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City of Sherwood Oregon

Willamette River Water Treatment Plant
MASTER PLAN UPDATE 2017

Project No. 1122

FINAL | March 2018

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City of Wilsonville
Willamette River Water Treatment Plant

2017 MASTER PLAN UPDATE

REGISTERED PROFESSIONAL ENGINEER
74678
OREGON
JUNE 30, 2013
JUDE D. GROUNDS
EXPIRES: 06/30/19

REGISTERED PROFESSIONAL ENGINEER
92982
OREGON
NOV. 14, 2017
MEGHANN F. CHELL
EXPIRES: 12/31/19

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Abbreviations

%	percent
#	number
@	at
2015 MPU	2015 WRWTP Master Plan Update
AACE	American Association of Cost Engineers
ACFM	actual cubic feet per minute Ag silver
Al	aluminum
ASCE	American Society of Civil Engineers
ASR	aquifer storage and recovery
B	boron
BRP	Blue Ribbon Panel
C	Celsius
$CaCO_3$	calcium carbonate
Caisson	Raw Water Intake Pump Station Caisson
CECs	contaminants of emerging concern
CF	cubic foot/feet
Cr+6	hexavalent chromium
CFD	computational fluid dynamic
CFM	cubic feet per minute
CIP	capital improvement plan
City	City of Wilsonville
COW	cost of work
CT	contact time
DCR	demand to capacity ratio
DBP	disinfection by-product
EBCT	empty bed contact time
EBMUD	East Bay Municipal Utility District
ENR	Engineering News Record
EPA	Environmental Protection Agency
ESA	Endangered Species Act
EWEB	Eugene Water and Electric Board
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FFA	future forced air cooled rating
fps	feet per second
ft	foot/feet GAC granular activated carbon

gpd	gallons per day
gpm	gallons per minute
gpm/sf	gallons per minute per square-foot
HAB	harmful algal bloom
HP	horse power
HR	hour(s)
HRT	hydraulic retention time
IBC	International Building Code
in	inches
IOC	inorganic contaminant
JWC	Joint Water Commission
KV	kilovolt
lb	pound(s)
LCR	Lead and Copper Rule
LOS	level of service
LOTWTP	Lake Oswego-Tigard Water Treatment Partnership
LOX	liquid oxygen
M.M.	Modified Mercalli Scale
MCC	motor control center
MCL	maximum contaminant level
MG	million gallon(s)
mg/L	milligrams per liter
mgd	million gallons per day
min	minute(s)
mL	milliliter
$MM	million dollars
mm	millimeter
Mn	manganese
MPN	most probable number
MPU	Master Plan Update
MS	main switchgear
MWh	megawatt hours
NAVD	North American Vertical Datum
NCOD	National Contaminant Occurrence Database
nm	nanometers
NMFS	National Marine Fisheries Service
NPV	net present value

NTU	Nephelometric turbidity units
OA	oil-cooled rating
OAR	Oregon Administrative Rule
ODFW	Oregon Department of Fish and Wildlife
OHA	Oregon Health Authority
ORP	Oregon Resilience Plan
ORS	Oregon Revised Statutes
OPCC	opinion-of-probable construction-cost
OSSAC	Oregon Seismic Safety Advisory Committee
OSSC	State of Oregon Structural Specialty and Fire and Life Safety Code
OWUC	Oregon Water Utility Council
PGE	Portland General Electric
PNW	Pacific Northwest
PPCPs	pharmaceuticals and personal care products
ppd	pounds per day
PRSE	post-regional seismic event
PWB	Portland Water Bureau
RM	Richter scale magnitude
RWF	Raw Water Facility
s^{-1}	per second
SCADA	supervisory control and data acquisition
SCM	streaming current monitor
SDC	system development charge
SDWA	Safe Drinking Water Act
SF	square feet
SOC	synthetic organic contaminant
TDH	total dynamic head
TDS	total dissolved solids
the Act	Oregon Drinking Water Quality Act
TOC	total organic carbon
TON	threshold odor number
TVWD	Tualatin Valley Water District
UBC	Uniform Building Code
UCM	Unregulated Contaminant Monitoring
UCMR	Unregulated Contaminant Monitoring Rule
USGS	United States Geological Survey
UV	ultraviolet

V	volt
V	vanadium
VFD	variable frequency drive
VOC	volatile organic compound
WRWTP	Willamette River Water Treatment Plant
WWSA	Willamette River Water Supply Agency
WWSP	Willamette Water Supply Program
Zn	zinc
µg/L	micrograms per liter
µm	micrometer

EXECUTIVE SUMMARY

ES.1 Introduction

The 2017 Willamette River Water Treatment Plant Master Plan Update (2017 MPU) for the Cities of Wilsonville and Sherwood defines the strategy to meet future demands, boost supply resiliency and reliability, and support responsible growth.

Commissioned in 2002, the Willamette River Water Treatment Plant (WRWTP) has a treatment capacity of 15 million gallons per day (mgd). Of this capacity, Wilsonville owns 10 mgd, and the Tualatin Valley Water District (TVWD) initially owned 5 mgd. The District invested in the plant's construction, oversizing many of its facilities to enable expansion for its own future water needs.

The existing property along the Willamette River in Wilsonville is irregularly shaped, creating two semi-contiguous parcels called the Lower Site and the Upper Site. During original design, the Lower Site, home to the existing treatment plant, would allow for an expansion of up to 60 mgd. The Upper Site was identified for future development in the *Willamette River Water Treatment Plant Master Plan* (MWH, 2006), which demonstrated enough space for at least 100 mgd additional capacity. Combined, both sites have a 160 mgd potential total capacity.

Since the 2006 Master Plan was published, several actions occurred that affect both construction and operational planning for expanding the WRWTP:

- In 2012, the TVWD sold its 5 mgd of plant capacity to the City of Sherwood.
- In 2013, the TVWD and the City of Hillsboro named the mid-Willamette supply alternative as their preferred supplemental supply, which laid the foundation for the Willamette Water Supply Program (WWSP).
- In 2014, the city of Wilsonville led a coalition of utilities that petitioned the Oregon Health Authority (OHA) for the right to recognize the disinfection benefits from intermediate ozonation.
- In 2015, the City and WWSP stakeholders updated the WRWTP Master Plan (MWH, 2006) in the 2015 MPU (Carollo, 2016) to outline how the existing plant could be expanded to meet future demand.
- As of 2017, the WRWTP is expected to supply Wilsonville and Sherwood exclusively. However, the oversized river intake and raw water pumping station will be expanded to supply raw water to both the WRWTP and the proposed WWSP treatment facilities.

The 2017 MPU updates the 2015 WRWTP MPU and addresses these changes. The 2017 MPU has the following key objectives.

1. To define the steps for expanding the existing WRWTP infrastructure to maximize the return on previous investments.
2. To optimize process selection and layout to meet capacity and water quality goals at the expanded WRWTP.
3. To strategize near- and long-term plant expansion for a 20-year planning horizon and cash-flow to guide future financial planning.
4. To ensure that WWSP-related facilities, including raw water pumping, surge protection, and standby power infrastructure, do not impact operation or prevent the Cities of Wilsonville and Sherwood from meeting their ultimate build-out demands for the existing WRWTP on the current site.

ES.2 Plant Expansion and Level of Service Goals

ES.2.1 Demand Projections

Two water agencies will continue using the expanded WRWTP as their primary source of drinking water supply: the City of Wilsonville and the City of Sherwood.

Figure 2.1 presents the two cities' respective projected annual peak daily demands through 2050 as well as the combined ultimate build-out demand projection for 2050. It also shows a phased expansion strategy, which is detailed in the following subsections. The demand projection was published in the Wilsonville Water Master System Plan, adopted September 2012, and is based on the following assumptions:

- Annual residential growth of 2.9%.
- Annual non-residential growth of 3.5%.
- Industrial demand of increase 0.25 mgd every five years to a total of 1 mgd by 2025.
- City of Sherwood demand to increase from 5 mgd to approximately 10 mgd by 2025.

Figure ES.1 presents the two cities' respective projected annual peak daily demands through 2050 as well as the combined ultimate build-out demand projection for 2050.

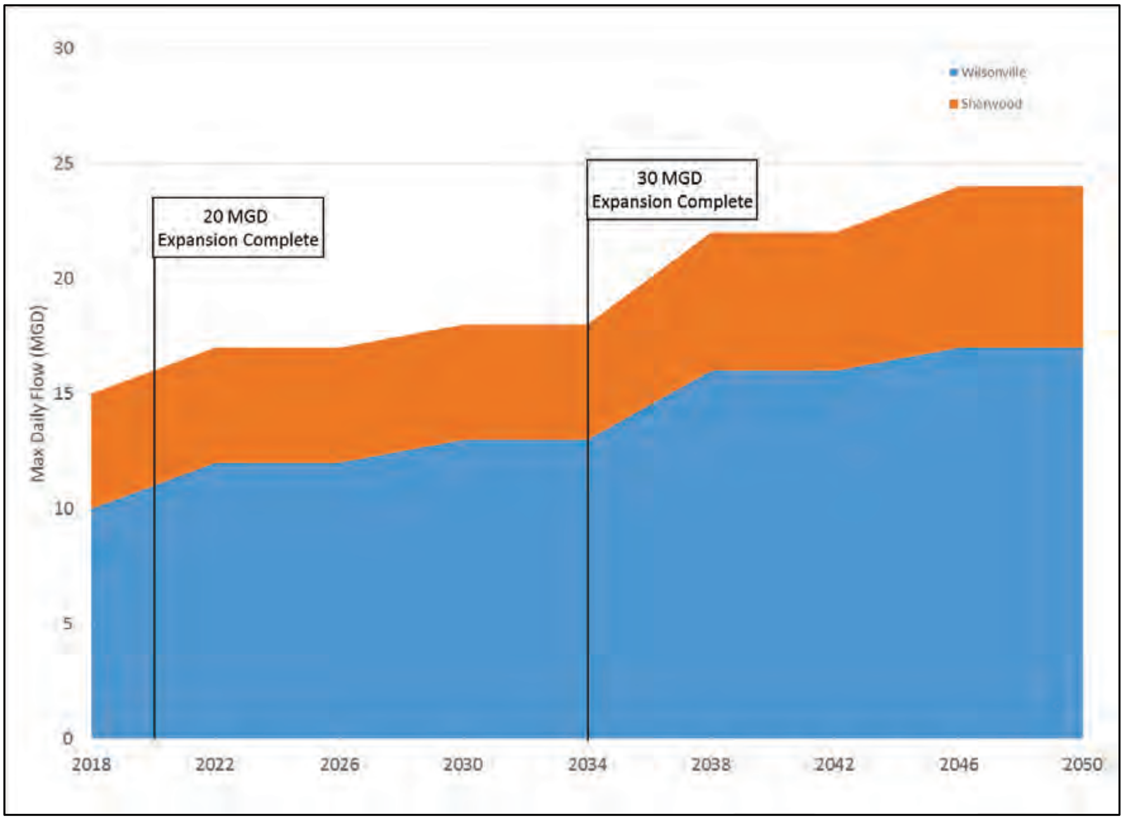

Figure ES.1 WRWTP Capacity Projections and Recommended Expansion Phasing

ES.2.2 Level of Service Goals

Level of service (LOS) goals were used to plan the preliminary site and estimate its construction and operations costs.

Municipal utilities in the United States and elsewhere commonly use LOS goals to evaluate systems and operations. LOS goals can be defined in terms of the customer's experience of utility service and/or technical standards based on professional expertise of utility staff.

LOS goals can guide investments in maintenance, repair, and replacement. For new assets, they can be used to set design criteria and prioritize needs. Using a structured decision-making process that incorporates LOS goals helps a utility reach desired service objectives and minimize life-cycle costs.

The LOS goals address only the facilities required to operate the expanded WRWTP and do not apply to City infrastructure outside of the WTP fence line. The goals were first developed with participants of the 2015 MPU during a project workshop and adopted by the participants' governing bodies. These LOS goals, which were revisited and re-confirmed during a 2017 MPU workshop, are shown in Table ES.1.

Table ES.1 Cities of Wilsonville and Sherwood Treatment LOS Goals

LOS Goal	Regional Event (Seismic)	Local Event (Non-Seismic)
"Following a W catastrophic event ...	2,500 year	Per occurrence
...within X days/weeks of the event...	48 hours	14 days
...deliver Y % of average day demand...	50% of nameplate capacity	100% of nameplate capacity
...with Z water quality."	Potable (at minimum regulatory requirement)	Potable (at plant's intended treatment processes and procedures)

As stated in Table ES.1, 48 hours after a 2,500-year regional (seismic) event, 50 percent of the nameplate treatment plant production capacity will be available, with potable water quality that meets minimum regulatory requirements. Within 14 days of a local (non-seismic) event, 100 percent of the nameplate production capacity will be available with potable water quality at the plant's intended treatment processes and procedures.

The costs for achieving these LOS goals were developed and confirmed to fall within the cities' affordability and risk tolerances. We recommend these LOS goals continue to guide the WRWTP planning efforts.

ES.2.3 Net Present Value

The 2015 MPU included a net present value (NPV) evaluation of three potential treatment alternatives for the WRWTP (which would also be design criteria for the WWSP treatment plant). The alternatives evaluated in Chapter 6 and Appendices I and J were the following:

- <u>Alternative A – Baseline Procedures</u>: The existing plant infrastructure would be maintained as-is, with additional capacity being gained by adding new concrete treatment basins and associated supporting mechanical equipment. This is the most conservative option but also had highest capital and operating costs.
- <u>Alternative B – OHA Modified Procedures</u>: Moderately increasing the treatment rate of select processes to realize available operational efficiencies and reduce the number or size of the process trains/basins compared to Alternative A. This the recommended option that utilized existing treatment steps with modified operational procedures to

achieve higher capacities in a smaller footprint while still meeting the existing WRWTP treated water quality goals.

- Alternative C – OHA Compliance: Aggressive increase in treatment rates compared to Alternative B and requires modifying the existing WRWTP treated water goals. This was the most aggressive with the lowest capital and operating costs. However, this alternative was not considered viable since it had the lowest potential to respond to future regulatory changes and would require changes to water treatment goals.

An NPV was developed as part of the 2015 MPU to determine the potential financial benefits of each alternative on a 36-year term with 4% interest rate. A version of the 2015 MPU NPV calculation (modified for 20-year and limited to the WRWTP expansions) is included in Appendix A. The relative cost differences for potential treatment alternatives are listed in Table ES.2. For a full list of the NPV criteria and assumptions, refer to Chapter 6 and Appendices I and J in the 2015 MPU.

Table ES.2 20-Year NPV for WRWTP Potential Treatment Alternatives

	Alternative A Baseline Procedures	Alternative B Modified Procedures	Alternative C OHA Compliance
NPV(1)	$88,400,000	$81,200,000	$76,700,000
Cost Comparison ($)			
Alternative A	--	$(7,200,000)	$(11,700,000)
Alternative B	$7,200,000	--	$(4,500,000)
Alternative C	$11,700,000	$4,500,000	--
Cost Comparison (%)			
Alternative A	--	-9%	-15%
Alternative B	8%	--	-6%
Alternative C	13%	6%	--

Notes:
(1) NPV amounts rounded up to the nearest $100,000.

ES.3 Existing Facilities and Operational Performance

When the 2006 WRWTP Master Plan was completed approximately four years after plant start-up, the City of Wilsonville was the only consumer of WRWTP finished water. In mid-2012, the City of Sherwood started using finished water from the WRWTP as its primary supply. To meet the demands of both cities, the plant went from operating on a daily start/stop basis for 8 to 16 hours per day depending on demand to operating 24 hours per day, year-round. Since the hours of operation impact plant operations and the expanded plant will continue to operate continuously, the plant performance data evaluated for this Master Plan Update was limited to 2012 through 2014, as included in the 2015 MPU. No additional plant performance data was analyzed as part of this 2017 MPU.

The 2015 MPU review of plant performance data demonstrates exceptional operational performance for turbidity removal, disinfection levels, total organic carbon (TOC) removal, and low disinfection by-product (DBP) formation. The extremely narrow range between the 5 and 95 percentile value for key water quality parameters such as turbidity, pH, and chlorine residual is a testament to the plant’s robust design and its operators’ attention to continuous optimal performance.

ES.4 Historical Raw and Finished Water Quality

Raw water quality data from May 2006 through 2014 was collected, reviewed, and compared to the data in the 2006 Master Plan and 2015 MPU. The trace-level contaminants detected in the raw water have not been detected in the finished water and were therefore assumed to be removed through the treatment processes.

The historical finished water quality data confirms that the plant consistently surpasses existing finished water regulatory requirements. The high-quality source water and robust treatment process result in excellent finished water quality delivered to customers. With only minor modifications, the current treatment processes are expected to continue to meet future regulatory requirements.

ES.5 Existing Infrastructure

The 2017 MPU offers additional electrical, seismic, and life-safety assessment for the WRWTP.

ES.5.1 Hydraulic Assessment

A hydraulic model of the WRWTP was developed in Carollo's Hydraulix® software to compare water surface elevations in the treatment train at 15 mgd and 20 mgd to determine the feasibility of an interim expansion using the existing WRWTP infrastructure. The model also includes 10 percent internal recycle flow through the Actiflo®, Ozonation, and filter systems. Results of the hydraulics assessment included:

- Increasing the maximum flow of each Actiflo® basin from 7.5 to 10 mgd raised the water level elevation by approximately 0.5 feet (ft), but head losses in the system will not increase substantially.
- Increasing the maximum flow rate of each ozone basin from 7.5 to 10 mgd resulted in head loss increase of less than 1 inch.
- Increasing the maximum filtration rate of each deep-bed filter from 7.5 gallons per minute per square-foot (gpm/sf) to 10 gpm/sf reduced the head available for solids collection by approximately 1.5 ft. This decrease in solids accumulation capacity is not expected to impact plant operations since the filter backwash is conducted based on schedule rather than solids accumulation.

ES.5.2 Equipment Assessment

An assessment of the existing plant facilities was included to determine how equipment replacement would be included in the 20-year planning horizon. This evaluation was used to identify likely equipment replacement periods in order to ensure continued successful operation. The equipment assessment was performed using Veolia's equipment database management system and operations staff input. This was then compared to the planned capacity expansions to identify when service life expiration would coincide with capacity increases requiring equipment upgrades. Equipment with a service life expiration that did not coincide with a capacity expansion were identified for replacement (either "in-kind" or upgraded) during an interim project.

ES.5.3 Electrical Supply and Distribution

To meet the 2020 site capacity of nominally 20 mgd, the plant's electrical supply and distribution system will need significant upgrades. Preliminary engineering for the capacity expansion will require detailed analysis of electrical supply alternatives, including backup power requirements.

Improving the "backbone" of electrical and standby power is recommended as part of the 20 mgd expansion project.

ES.5.4 Seismic Evaluation

The preliminary structural analysis identified both structural and non-structural vulnerabilities that may affect plant performance in a regional catastrophic seismic event. This 2017 MPU includes seismic retrofits as a CIP project to minimize infrastructure downtime and ensure plant performance after a catastrophic event.

ES.5.5 Life-Safety Evaluation

The preliminary life-safety analysis identified issues about building code compliance and structural improvements. This 2017 MPU includes life safety repairs as a CIP project to support continued safe plant operations.

ES.5.6 Transient Surge Analysis

A transient analysis was performed on the finished water pumping and delivery system to confirm the findings of *Hydraulic Transient Analysis – City of Wilsonville* (MWH, 2011). This analysis confirmed that a hydropneumatic tank is recommended when the demand approaches 15 mgd. A 1,500 cubic-foot (CF) surge tank is recommended for the current installation to enhance near-term surge protection and eliminate the need for additional construction during the 20 and 30 mgd capacity expansions. Note that the surge tank project is being pursued as a separate construction project outside of the 2017 MPU and therefore is not included in the CIP.

ES.6 WRWTP Expansion

Projected demand was submitted by the cities of Wilsonville and Sherwood based on each city's planning studies. To meet the cities' combined day demand of 30 mgd by 2036 as shown in Figure ES.1, this 2017 MPU recommends the following expansion and phasing:

- Preliminary design of the near-term expansion will likely begin in 2018 to bring WRWTP capacity from 15 mgd to 20 mgd by 2020.
- Total raw water intake capacity for both WRWTP and WWSP will be between 80 mgd and 84 mgd by 2026.
- Preliminary design of the 30 mgd expansion will likely begin in 2032 to bring the nameplate capacity of the WRWTP from 20 mgd to 30 mgd by 2034.
- Capacity expansion projects should be completed two years before the capacity is needed to allow flexibility. The 20 mgd capacity expansion will be completed in 2020 and the 30 mgd capacity expansion in 2034.

ES.6.1 20-MGD Expansion CIP

As outlined in the 2015 MPU, rather than constructing additional basins, the existing treatment processes will be uprated for the 20 mgd WRWTP expansion. For the primary treatment processes, the uprating will include the following.

- Increasing the Actiflo® flow rate from 7.5 mgd per basin to 10 mgd per basin.
- Increasing the ozonation basin flow rate from 7.5 mgd per basin to 10 mgd per basin. This will decrease the ozone contact time from 15 to 11 minutes, which still allows sufficient contact time for 1-log *Cryptosporidium* inactivation, provided increased levels of ozone can be dosed in the contactor.

- Increasing the filtration rate to a nominal rate of 5.7 gpm/sf and a maximum rate of 7.5 gpm/sf when one filter is off-line, and to a nominal rate of 7.5 gpm/sf and a maximum rate of 10 gpm/sf when one basin is offline. This increased filtration rate will require approval from OHA prior to increasing plant capacity. To support OHA approval, a full-scale pilot study should be conducted in which the filtration rate is gradually increased and water quality is closely monitored.
- Upgrade the existing electrical equipment to ensure that service is not interrupted by electrical fault. The following upgrades are recommended:
  - Replace switchgear with 15-KV metering switchgear and 5 KV transformer, which should be sufficient to power the WRWTP through 60 MGD.
  - Replace emergency generator with a 2-MW generator wired directly to the 15-KV metering switchgear. This will allow all plant equipment run on the emergency generator.
  - Rewire plant to connect all finished water pumps to the 5-V transformer/switchgear. This will leave sufficient capacity on the remaining transformers to power the rest of the plant.

Figure ES.2 depicts the site layout following completion of the 20-mgd capacity expansion.

ES.6.2 30-MGD Expansion CIP

The following two alternatives were considered for the 30 mgd expansion.

1. Install one additional process train: One Actiflo® basin, one ozone basin, and two filters.
2. Install two additional treatment process trains: Two Actiflo® basins, two ozone basins, and four filters.

Both alternatives would need to meet the LOS goal after a regional seismic event. However, Alternative 1 would have limited treatment rates during equipment maintenance. For example, during filter backwash, the maximum filtration rate of 12 gpm/sf would limit finished water production to 8 mgd. Conversely, the capital and operating costs required for Alternative 2 make it undesirable because it raises rates for Wilsonville and Sherwood residents. Therefore, we recommend that the WRWTP construct Alternative 1 and identify an additional water supply to meet the LOS goal after a regional seismic event.

Using Alternative 1, the 30 mgd expansion requires the following major construction projects:

- One Actiflo® basin.
- One ozonation basin.
- Two filters.
- One 35-foot diameter gravity thickener.

Figure ES.3 depicts the site layout for the 30-mgd capacity expansion. As recommended in the 2015 MPU, space dedicated for future AOP processes (such as UV treatment) improves the ability of the expanded WRWTP to treat constituents of emerging concern.

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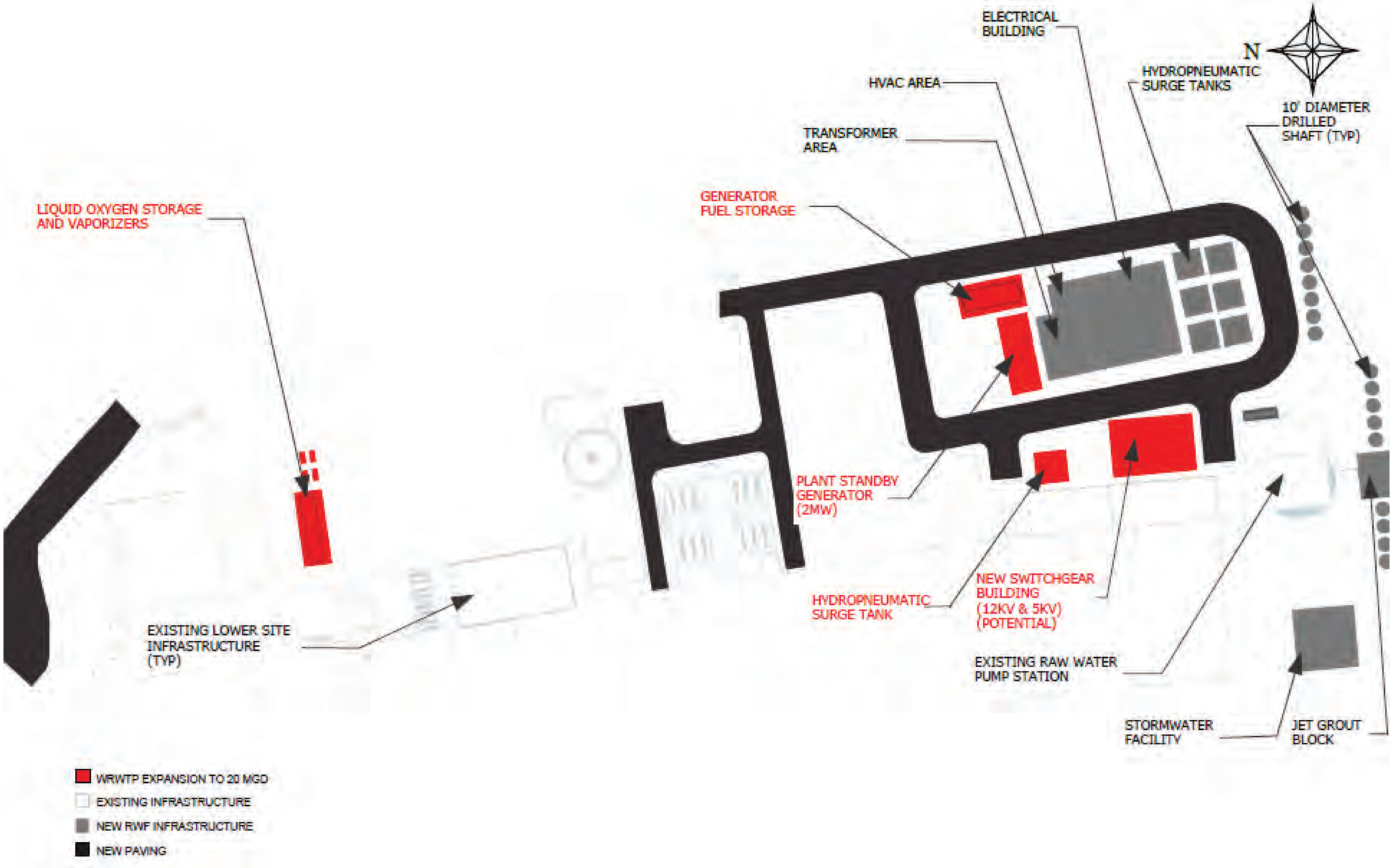

Figure ES.2 Site Plan – 20-MGD Capacity Expansion

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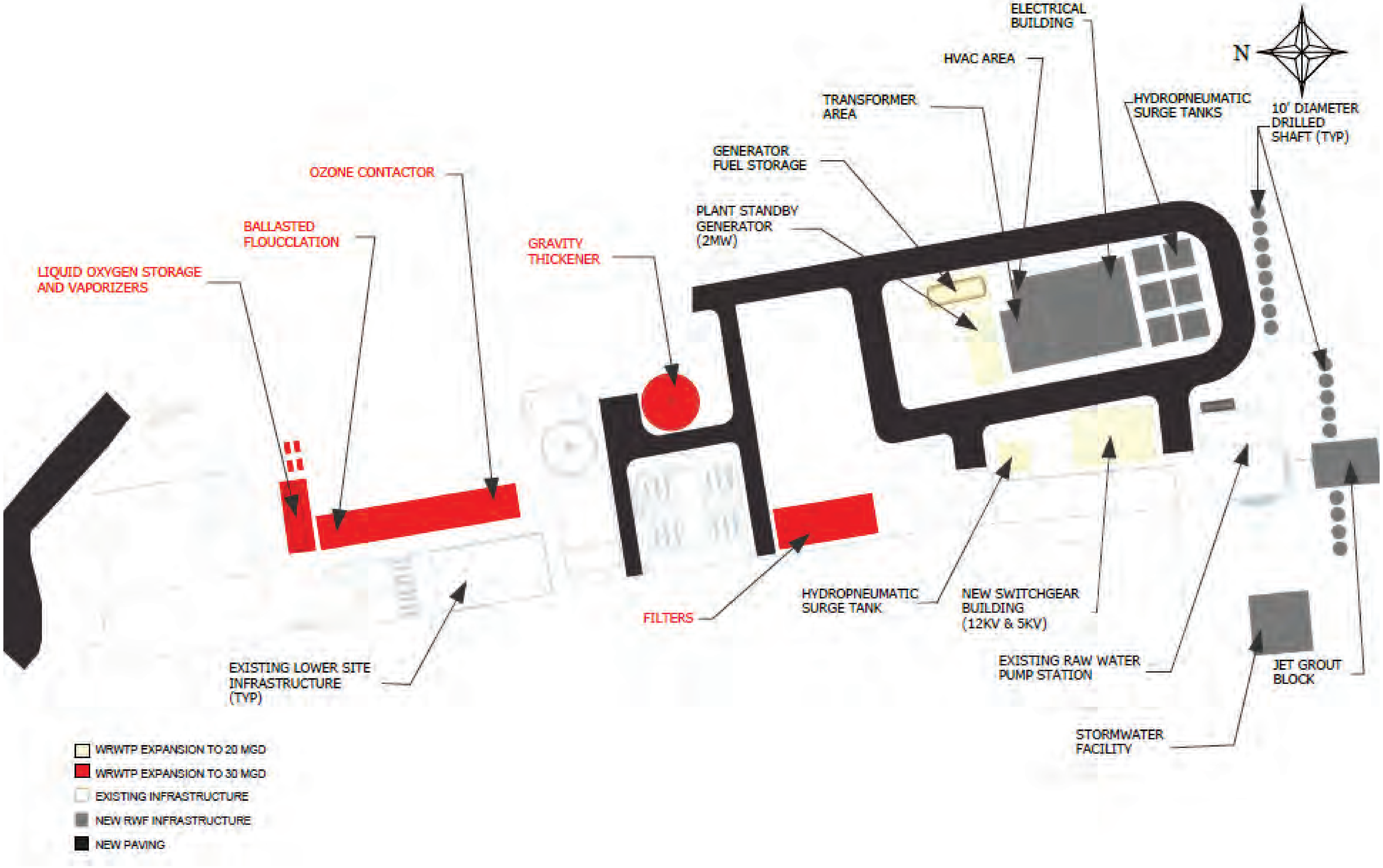

Figure ES.3 Site Plan – 30-MGD Capacity Expansion

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ES.6.3 Repair and Replacement CIP

In addition to the seismic and life-safety CIP, the WRWTP requires ongoing maintenance/repair and replacement (R&R) of its existing infrastructure to meet service goals. This 2017 MPU summarizes repair and replacement projects for the next 20 years.

ES.7 CIP Approach and Schedule

The existing WRWTP must be expanded to 20 mgd by 2020 and to 30 mgd by 2034.

Table ES.3 breaks down the capital costs for the two expansions and related repair and replace projects, electrical equipment upgrades, life safety repairs, and seismic retrofits necessary to maintain plant operation. Table ES.4 details repair and replace projects by year and dollar amount. Table ES.6 details the stakeholder financial responsibility and fee structure for each CIP project.

The CIP cost estimates are classified as American Association of Cost Engineers (AACE) Class 4 or Class 5 estimates. The Class 4 estimates have an expected level of accuracy of +50% to -30%. The Class 5 estimates have an expected level of accuracy of +100% to -50%. Figures ES.4 and ES.5 depict the near term and total CIP costs, respectively, as broken down by project.

Table ES.3 Estimated CIP Costs (2017 Dollars)

Project	Cost(1)	%City of Wilsonville	%City of Sherwood	% Water Operations	% SDCs
20 mgd Expansion	$15,730,000	66.7	33.3	37	63
30 mgd Expansion	$38,650,000	67.7	32.2	37	63
Life Safety Repairs	$630,000	66.7	33.3	100%	--
Seismic Retrofits	$1,170,000	66.7	33.3	100%	--
Operations - Repair and Replace	$17,740,000	66.7	33.3	100%	--

Notes:
(1) Includes 15% design fee and 10% administrative cost.
(2) All costs are rounded up to nearest $10,000.

Table ES.4 Operations – Repair and Replace Estimated CIP Cost (2017 Dollars)

Repair and Replace Year	Cost(1)	% Water Operations	% SDCs
2019	$1,360,000	100%	--
2020	$1,450,000	100%	--
2021	$20,000	100%	--
2022	$3,110,000	100%	--
2023	$20,000	100%	--
2024	$20,000	100%	--
2025	$20,000	100%	--
2026	$20,000	100%	--
2027	$4,740,000	100%	--
2028	$20,000	100%	--
2029	$20,000	100%	--
2030	$20,000	100%	--
2031	$20,000	100%	--
2032	$2,260,000	100%	--
2033	$20,000	100%	--
2034	$20,000	100%	--
2035	$20,000	100%	--
2036	$3,090,000	100%	--

Notes:
(1) Includes 10% administrative cost.

To meet growing water demand from Wilsonville and Sherwood, the existing WRWTP will first be expanded to a capacity of 20 mgd, followed by an expansion to 30 mgd near the end of this planning horizon. Table ES.5 summarizes a preliminary and final design and construction schedule.

Table ES.5 WRWTP Expansion Design and Construction Schedule

Project	Approx. Service Year	Duration (Months)			Start Date
		Design	Construction	Float	
20 MGD Capacity Expansion	2020	12	18	6	2018
Life Safety Repairs	2022	6	6	3	2020
Seismic Retrofits	2022	6	6	3	2020
30 MGD Capacity Expansion	2036	12	24	6	2033
Operations – Repair and Replace					
Year 1	2019	0	6	6	2018
Year 2	2020	0	6	6	2019
Year 3	2021	0	6	6	2020

Table ES.5 WRWTP Expansion Design and Construction Schedule (Continued)

Project	Approx. Service Year	Duration (Months)			Start Date
		Design	Construction	Float	
Year 4	2022	0	6	6	2021
Year 5	2023	0	6	6	2022
Year 6	2024	0	6	6	2023
Year 7	2025	0	6	6	2024
Year 8	2026	0	6	6	2025
Year 9	2027	0	6	6	2026
Year 10	2028	0	6	6	2027
Year 11	2029	0	6	6	2028
Year 12	2030	0	6	6	2029
Year 13	2031	0	6	6	2030
Year 14	2032	0	6	6	2031
Year 15	2033	0	6	6	2032
Year 16	2034	0	6	6	2033
Year 17	2035	0	6	6	2034
Year 18	2036	0	6	6	2035

Table ES.6 WRWTP 2017 MPU Stakeholder Responsibility

CIP Project	%City of Wilsonville	%City of Sherwood	%Water Operations	%SDCs
20 mgd Expansion	66.7	33.3	37	63
Life Safety Repairs	66.7	33.3	100	--
Seismic Retrofits	66.7	33.3	100	--
30 mgd Expansion	68	32	37	63
Operations – Repair and Replace	66.7	33.3	85	15

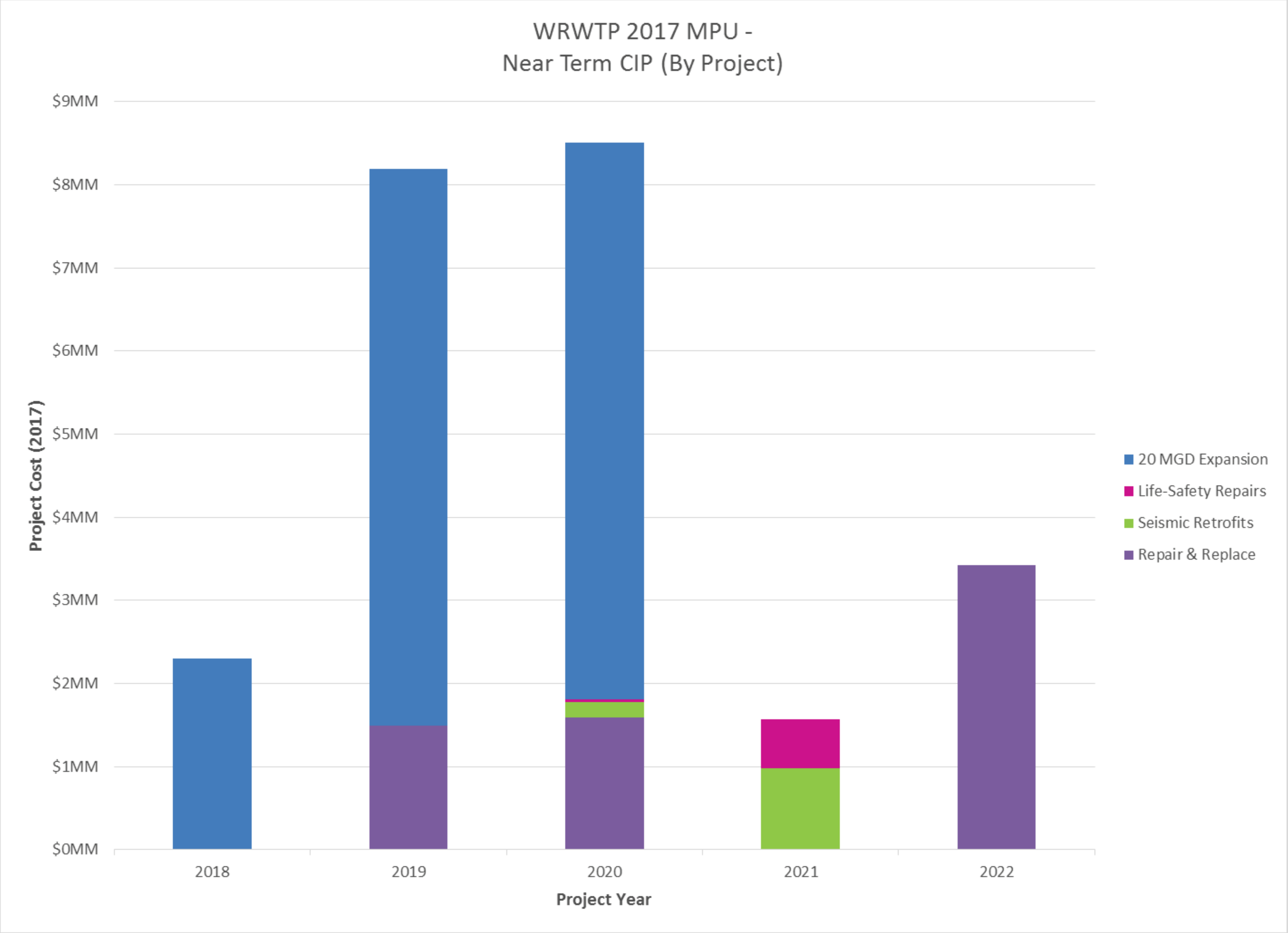

Figure ES.4 RWTP Near-Term CIP Costs by Project (2017 Dollars)

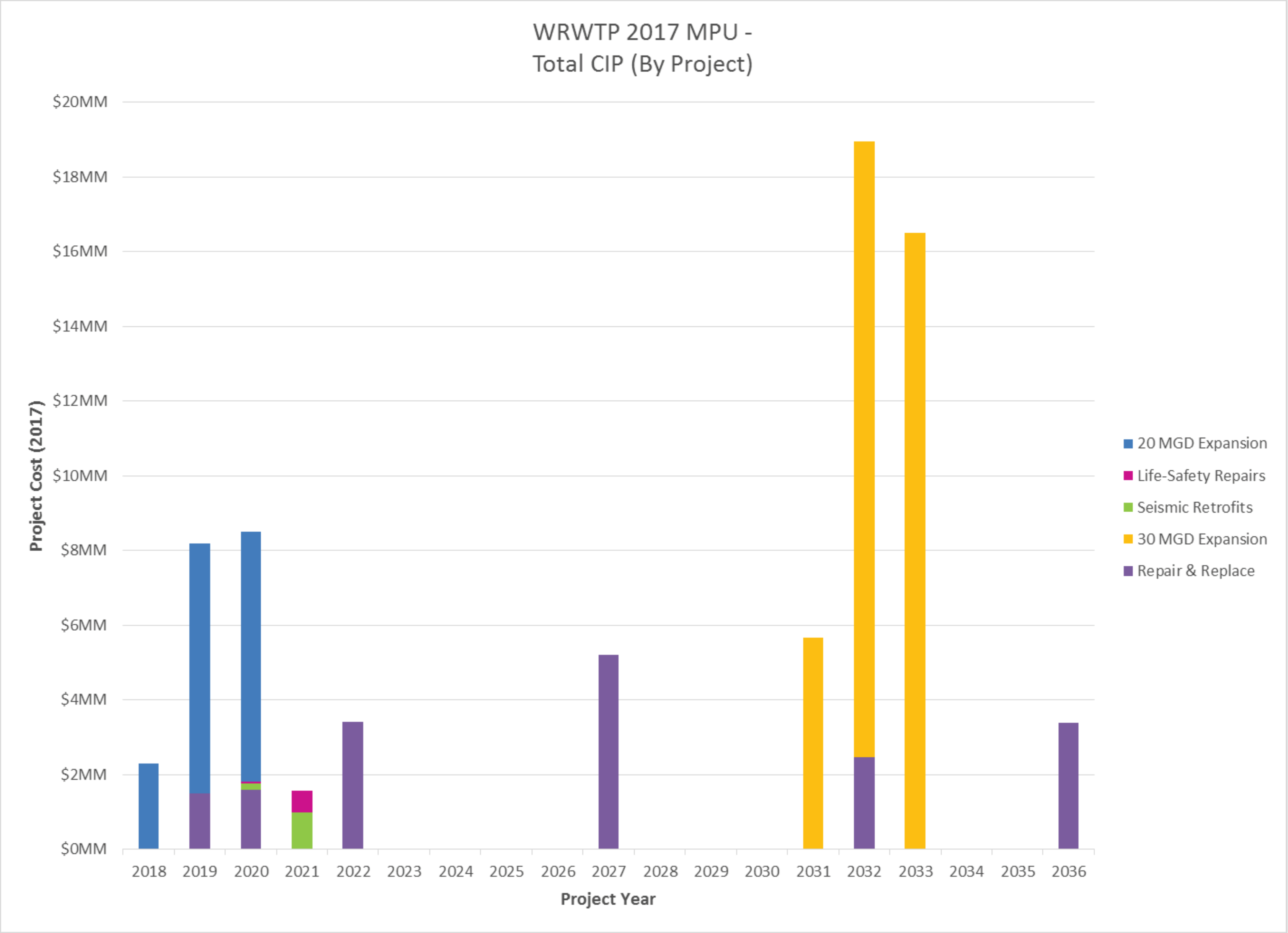

Figure ES.5 WRWTP Total CIP Costs by Project (2017 Dollars)

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Chapter 1

INTRODUCTION

The Willamette River is a source of high-quality and plentiful drinking water. In 1997, several Portland area agencies formed the Willamette River Water Supply Agency (WWSA) to assess the feasibility of using the Willamette River as a regional source. Extensive pilot testing and water quality sampling verified the supply's quality and treatability. The WWSA developed preliminary engineering plans for facilities, estimated associated costs, and identified potential governance and financing options to fund and manage the system. Members of the WWSA compared this information to other options for regional water supply and developed long-term strategic plans to best meet the region's needs.

At about the same time, the City of Wilsonville (City) placed a city-wide moratorium on new construction. The City’s groundwater supply was over-drafted and an additional drinking water supply was needed. Working with the Tualatin Valley Water District (TVWD), the City built a new drinking water treatment plant on the Willamette River.

The resulting Willamette River Water Treatment Plant (WRWTP), commissioned in 2002, has a treatment capacity of 15 mgd. The City contracted with Veolia to operate the plant. Of the 15 mgd original capacity, the City owns 10 mgd. TVWD owned 5 mgd of plant capacity. With an eye to accommodating future drinking water needs of its own, TVWD had invested in the plant's construction, oversizing many plant facilities to enable expansion. In 2012, TVWD sold its 5 mgd capacity to the City of Sherwood, but the agency retains an ownership interest at the WRWTP.

In 2017, the WRWTP users (the Cities of Wilsonville and Sherwood) collaborated to update the 2015 WRWTP Master Plan Update (2015 MPU). This 2017 Update describes the strategy for the following:

- Meeting future demands.
- Increasing supply resiliency and reliability.
- Coordinating with the upcoming requirement to pump raw water to the Willamette Water Supply Program (WWSP) treatment plant in Washington County.
- Facilitating responsible growth within existing urban growth boundaries.

1.1 WRWTP and Source Background

The original plant's key objectives were to:

1. Produce consistently high-quality drinking water using a multi-barrier treatment process.
2. Exceed 2002 regulatory treatment and water quality standards to enhance consumer confidence.
3. Minimize the plant footprint, thereby providing space for public amenities.
4. Incorporate flexibility for cost-effective future plant capacity expansions.
5. Operate quietly, respectfully, and without negative impact on the neighborhood.

6. Complete design and construction in less than three years to meet the City's 2002 startup target.
7. Meet "critical facility" seismic and structural criteria.

The plant employed four innovative and robust treatment technologies: 1) high-rate clarification (ballasted flocculation); 2) intermediate ozonation; 3) deep-bed granular activated carbon (GAC)/sand filtration, and; 4) mechanical dewatering (centrifuges). When it was commissioned in 2002, the WRWTP was the first plant in the Pacific Northwest to use all four advanced technologies for drinking water treatment.

The existing WRWTP property along the river is irregularly shaped, creating Lower and Upper Sites, depicted on Figure 1.1. Home to the existing treatment plant, the Lower Site was designed for future expansion of up to 60 mgd of total capacity. The Upper Site, owned by TVWD, was not master-planned until after the District-led WRWTP Master Plan (MWH, 2006) was completed. The 2006 Master Plan showed the Upper Site could accommodate at least 100 mgd in additional capacity. Therefore, the combined WRWTP production capacity that could be constructed on the Upper and Lower sites is as high as 160 mgd.

Since then, several events have unfolded that affect construction and operational decision-making for expanding the plant, requiring an update to the 2006 Master Plan:

- In 2012, the City of Sherwood began purchasing WRWTP finished water. The plant, which had historically been operated in "start/stop" mode to meet Wilsonville's daily demands alone, is now operated 24 hours per day, seven days a week.
- In 2013, TVWD and the City of Hillsboro identified the mid-Willamette Supply alternative as its preferred supplemental supply option, which laid the foundation for the WWSP.
- Because of the WRWTP Tracer Study (MWH, 2014), the City led a coalition of Oregon's current and potential ozone users to petition the Oregon Health Authority (OHA) to give disinfection credit for intermediate ozonation. This credit would eliminate the requirement for costly chlorine contact basins or ultraviolet (UV) treatment for WRWTP expansions, a possibility considered when plant expansion scenarios were developed. At the time of this publication, the OHA had not yet issued a decision.
- In 2015, the City and WWSP stakeholders updated the WRWTP Master Plan (MWH, 2006) to explore expanding the plant to meet future demands of all stakeholders. Although the WRWTP Master Plan 2015 Update (Carollo, 2016) succeeded in evaluating these possibilities, it was later decided that the WWSP treatment facilities would be optimized at an alternative location in Sherwood, several miles north of the WRWTP. The WRWTP is now expected to supply Wilsonville and Sherwood exclusively. However, the oversized river intake and raw water pumping station will be expanded to supply raw water to both the WRWTP and the proposed WWSP treatment facility.

The 2015 Master Plan Update (2015 MPU) documented future water needs, level of service (LOS) goals, regulatory requirements, reliability and resiliency of the distribution system, and preliminary seismic evaluation of shared WRWTP and WWSP facilities. The goal of the 2017 Master Plan Update (2017 MPU) is to supplement and expand on the parts of the 2015 MPU that apply to the WRWTP facilities. The resulting stand-alone document details how increased water demand in the Cities of Wilsonville and Sherwood can be accommodated in coordination with the future WWSP treatment facility.

1.2 Master Plan Update Objectives and Organization

This 2017 MPU describes the WRWTP expansion to meet long-term water supply needs of Wilsonville, Sherwood, and potential future partners. It gives options for expanding the facilities and recommends a treatment and implementation plan to meet Wilsonville's and Sherwood's planning objectives:

Objective #1:	Maintain water supply by completing the WRWTP 20 mgd and 30 mgd expansion projects by 2020 and 2034, respectively.
Objective #2:	Define process selection and layout to meet capacity and water quality goals at the expanded WRWTP.
Objective #3:	Chart the course for expanding existing WRWTP infrastructure to make the most of previous investments.

The primary purposes for this 2017 MPU are to:

- Develop treated water quality goals.
- Evaluate preliminary process requirements to meet water quality goals.
- Identify preliminary capacity requirements to meet long-term water supply needs.
- Verify space requirements at site facilities.
- Develop planning-level cost estimates.
- Develop preliminary implementation schedule.

The 2017 MPU is organized into the following chapters.

- Chapter 1 – Introduction
- Chapter 2 – Plant Expansion and Level of Service Goals
- Chapter 3 – Existing Facilities and Operational Performance
- Chapter 4 – Historical Water Quality and Regulatory Compliance
- Chapter 5 – Existing Infrastructure
- Chapter 6 – Expansion Alternatives Analysis
- Chapter 7 – CIP Approach and Schedule

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Chapter 2

PLANT EXPANSION AND LEVEL OF SERVICE GOALS

2.1 Introduction

This Chapter establishes the guiding principles for developing, evaluating, and comparing alternatives throughout the 2017 MPU and summarizes the current water supply demands and strategies for expansion phasing. This Chapter also reviews three alternative treatment procedures developed from workshops with the Participants for the 2015 MPU. With this review, the Chapter describes the methodology for evaluating the alternatives and summarizes the level of service (LOS) goals for the plant's expansion.

2.2 Water Demands and Expansion Strategy

Prepared in 1999, the Willamette River Water Supply System (WRWSS) Plan identified the potential need to withdraw up to 120 mgd from the existing Willamette River Water Treatment Plant (WRWTP) site based on combined projected demands from potential member agencies. The WRWSS Plan was updated in 2004, increasing the ultimate demand projection to 158 mgd. Following this, the 2006 WRWTP Master Plan bracketed the ultimate demand projection between 103 mgd and 156 mgd.

Under the original project, Wilsonville partnered with the Tualatin Valley Water District (TVWD) to fund oversized infrastructure that would better accommodate future WRWTP plant expansion(s) and meet the needs of the combined communities. In 2015, Wilsonville, along with other stakeholders, updated the WRWTP Master Plan (MWH, 2006) to determine how the existing plant could be expanded to meet future demands of the emerging Willamette Water Supply Program (WWSP); this effort culminated in the WRWTP 2015 Master Plan Update (2015 MPU) (Carollo, 2016).

However, after completing the 2015 MPU, the decision was made to construct the WWSP treatment facilities at an alternate site located several miles north of the existing WRWTP in unincorporated Washington County. The raw water intake and pump station for this alternate WWSS WTP will be co-located/shared with the existing WRWTP, which requires careful coordination between both sites.

Adjustments to the 2015 MPU's projected demand/capacity requirements and the timing of the capacity needs affect the planning of the expanded WRWTP site. This 2017 MPU summarizes these efforts in subsequent subsections.

2.2.1 Demand Projections and Hydraulic Requirements

Two water agencies will continue using the expanded WRWTP as their primary source of drinking water supply: the City of Wilsonville and the City of Sherwood.

Figure 2.1 presents the two cities' respective projected annual peak daily demands through 2050 as well as the combined ultimate build-out demand projection for 2050. It also shows a phased expansion strategy, which is detailed in the following subsections. The demand projection was published in the Wilsonville Water Master System Plan, adopted September 2012, and is based on the following assumptions:

- Annual residential growth of 2.9%.
- Annual non-residential growth of 3.5%.
- Industrial demand of increase 0.25 mgd every five years to a total of 1 mgd by 2025.
- City of Sherwood demand to increase from 5 mgd to approximately 10 mgd by 2025.

Figure 2.2 presents the projected annual peak demand for the WRWTP and the proposed WWSP treatment facility. Projected WWSP demands were developed based on the agency's planning project and are separate from this 2017 MPU. However, as described in subsequent sections, the demands are relevant to upgrading some shared WRWTP facilities.

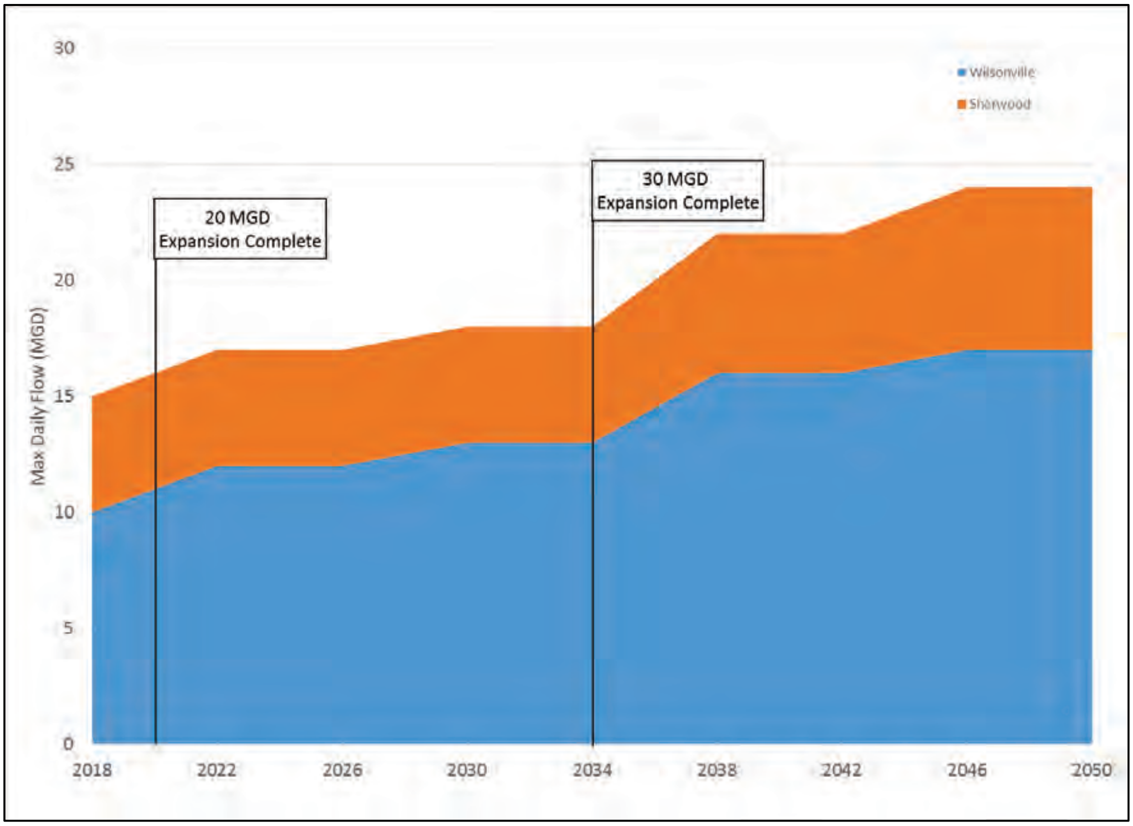

Figure 2.1 WRWTP Capacity Projections and Recommended Expansion Phasing

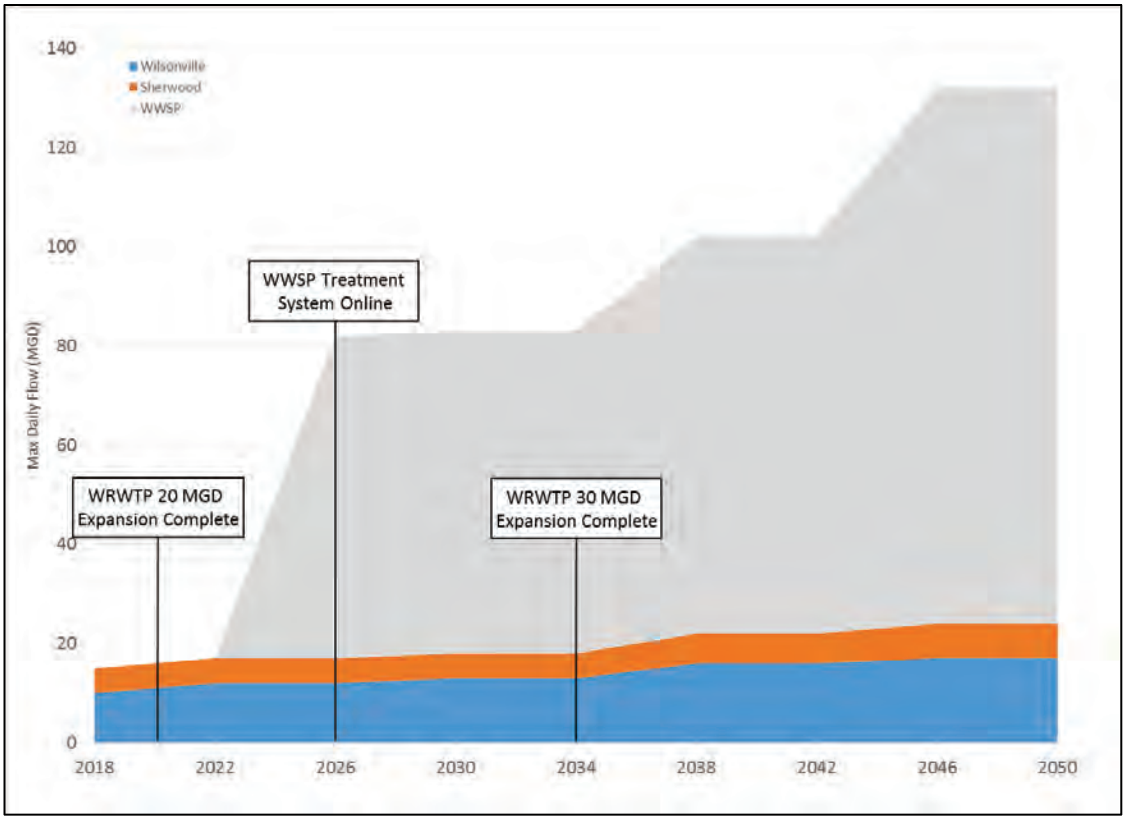

Figure 2.2 WRWTP and WWSP Water Demand Projections

Table 2.1 summarizes the anticipated demands and the hydraulic elevation that each City will likely require to serve its respective system.

Table 2.1 Hydraulic and Capacity Requirements of the WRWTP Participants

Participant	Hydraulic Elevation (ft)	2026 Max Day Demand (mgd)	2036 Max Day Demand (mgd)	2046 Max Day Demand (mgd)	Future Max Day Demand (mgd)
Wilsonville	400	12	14	17	30
Sherwood	380	5	6	7	13
Total		**17**	**20**	**24**	**43**

Notes:
(1) Projected demands obtained from independent City planning exercises.

2.2.2 Capacity Expansion and Phasing Strategy

Figures 2.1 and 2.2 present the projected WRWTP plant production capacity and total raw water withdrawals, respectively. Highlights of these projections are as follows:

- An initial expansion of the existing WRWTP required to meet combined demands for the Cities of Wilsonville and Sherwood: this expansion will increase WRWTP capacity to 20 mgd in 2020, two years before the capacity is required in 2022.

- Construction to support the WWSP Raw Water Facility (RWF) connection to the WRWTP intake structure and Raw Water Pump Station: this modification is expected to be completed by 2024, two years before the capacity is required in 2026.
- A subsequent expansion of the existing WRWTP to meet combined demands from the Cities of Wilsonville and Sherwood: this expansion will increase WRWTP capacity to 30 mgd in 2034, two years before the capacity is required in 2036.
- Capacity expansion projects: these projects are expected to be completed two years before the capacity is required, allowing flexibility for future unknowns.
- Ongoing repair and replacement projects: These R&R projects address aging infrastructure that has exceeded its service life or has become unreliable, but remain crucial to operations and must be integrated into the overall expansion plan.
- Seismic retrofits: These additions reflect changes in the seismic design criteria since the WRWTP was constructed in 2002. Given the changes in the USGS data between 2002 and 2008, projected ground accelerations in the region have increased up to 28 percent, significantly adding to the structural design requirements.
- Life safety upgrades: These improvements are necessary to protect the operations staff and maintain compliance with safety and building code requirements.

Based on capital, operational, and technical evaluations performed during the 2015 MPU, the WRWTP 20 mgd capacity expansion will be achieved by uprating major process trains and by providing installed redundancy wherever feasible. No additional basins will be constructed under this expansion. The details of this evaluation are summarized in Chapters 2 and 6 of the 2015 MPU.

Furthermore, evaluations of the 30 mgd capacity expansion include a discussion of pre- and post-regional seismic event resiliency to determine the scope of the expansion. Chapter 6 of this 2017 MPU describes the WRWTP expansions falling within the 20-year planning horizon and summarizes an evaluation of them.

2.2.3 Net Present Value

The 2015 MPU included a net present value (NPV) evaluation of three potential treatment alternatives for the WRWTP (which would also be design criteria for the WWSP treatment plant). The alternatives evaluated in Chapter 6 and Appendices I and J were the following:

- Alternative A – Baseline Procedures: The existing plant infrastructure would be maintained as-is, with additional capacity being gained by adding new concrete treatment basins and associated supporting mechanical equipment.
- Alternative B – OHA Modified Procedures: Moderately increasing the treatment rate of select processes to realize available operational efficiencies and reduce the number or size of the process trains/basins compared to Alternative A. Alternative B will use existing treatment steps but would modify operational procedures to achieve higher capacities in a smaller footprint while still meeting the existing WRWTP treated water quality goals
- Alternative C – OHA Compliance: Aggressive increase in treatment rates compared to Alternative B and requires modifying the existing WRWTP treated water goals

Of these three options, Alternative A was the most conservative but also had the highest capital and operating costs. Alternative C was the most aggressive and had the lowest capital and operating costs, but was also determined to have the lowest potential to respond to future regulatory changes and would require changes to water treatment goals. Alternative B was a balanced approach, as it reduced capital and operating costs but maintained the same water quality goals. Therefore only Alternatives A and B were viable options to maintain the same water treatment goals.

An NPV was developed as part of the 2015 MPU to determine the potential financial benefits of each alternative on a 36-year term with 4% interest rate. Though the NPV evaluation was not performed for the 20 mgd expansion individually, the scale of the results are representative of the interim expansion costs for each alternative. The 2015 MPU recommended adopting Alternative B as the preferred alternative that provides a balanced approach where water quality goals expected by the community are maintained while allowing operational efficiencies that will limit the cost impacts of the interim and future expansions.

A version of the 2015 MPU NPV calculation (modified for 20-year and limited to the WRWTP expansions) is included in Appendix A. The relative cost differences for potential treatment alternatives are listed in Table 2.2. For a full list of the NPV criteria and assumptions, refer to Chapter 6 and Appendices I and J in the 2015 MPU.

Table 2.2 20-Year NPV for WRWTP Potential Treatment Alternatives

	Alternative A Baseline Procedures	Alternative B Modified Procedures	Alternative C OHA Compliance
NPV(1)	$88,400,000	$81,200,000	$76,700,000
Cost Comparison ($)			
Alternative A	--	$(7,200,000)	$(11,700,000)
Alternative B	$7,200,000	--	$(4,500,000)
Alternative C	$11,700,000	$4,500,000	--
Cost Comparison (%)			
Alternative A	--	-9%	-15%
Alternative B	8%	--	-6%
Alternative C	13%	6%	--

Notes:

(1) NPV amounts rounded up to the nearest $100,000.

2.3 Hazard Analysis and Associated Level of Service Goals

This section describes the methodology used to identify hazards and to develop corresponding LOS goal recommendations for the WRWTP expansion. For the 2015 MPU planning process, preliminary LOS goals were used to establish the preliminary site plans and associated construction and operations cost estimates. After confirming that these preliminary results were consistent with those of the Cities of Wilsonville and Sherwood, this 2017 MPU adopts these LOS goals.

LOS goals address only the facilities required to operate the WRWTP and do not apply to facilities outside of the WTP fence line, such as the piping for the transmission and distribution systems. The goals herein were developed during the 2015 MPU and confirmed with the Cities during a 2017 MPU project workshop.

2.3.1 LOS Goal Objective

LOS goals are typically stated as follows:

"Following a W catastrophic event, within X days/weeks of the event, the WTP will deliver Y percent of average day demand with Z water quality."

This policy-level statement addresses how facilities will be recovered after a catastrophic event, in terms of water quality, quantity, and recovery time. Thus, the goal of this section is to first identify the various types of catastrophic events that may occur and then develop LOS goals that correspond to each event.

2.3.2 Catastrophic Event

To guide the selection of LOS goals after a catastrophic event, the Clackamas County Natural Hazards Mitigation Plan (December 2012) was reviewed for hazards of concern to the County. Additional hazards were also identified based on similar work performed by Ballantyne Consulting LLC. Potential WTP impacts were also considered for the 2015 MPU, although they may differ from those that could affect the County overall. Table 2.3 presents the identified hazards and the potential impacts on the Lower Site, which includes the WRWTP and WWSP raw water intake and pumping facilities.

Table 2.3 Catastrophic Hazards Events and Potential Impact on the WRWTP Lower Site

Hazard	Potential WTP Impacts
Seismic – Geotechnical	• Liquefaction at site causes differential settlement that compromises facilities. • Lateral spreading/landslide at river bank compromises slope stability and RW Intake.
Seismic – Structural	• Causes raw Water Pump Station structural damage. • Leads to High Service Pump Station / Clearwell structural damage. • Compromises connections of process piping and electrical duct banks at process facilities due to shearing.
Flood	• Erodes river bank. • Plugs or damages raw water intake.
Volcano	• Ash fall or water-transported debris compromises ability of plant to treat water.
Spills/Contaminants in River	• Raw sewage discharge from upstream communities compromises ability of plant to treat water. • Oil spill compromises ability of plant to treat water. • Other chemical spill compromises ability of plant to treat water.
Wild Fire	• Decreases water quality of Willamette River watershed. • Impact on river bank compromises raw water pump station.
Wind, Ice, Snow	• Local or regional power outage compromises plants' abilities to treat water. • Reduces staff availability.
Terrorism/Cyber Attack	• Reduces IT security and operational control. • Compromises control over finished-water quality.

Of these hazards, seismic hazards (geotechnical and structural) are expected to also affect other water supply facilities serving the region. The remaining hazards are expected to affect only the WRWTP, with exception of two possibly far-reaching hazards: volcanic ash and regional power disruption.

Volcanic ash fall could affect the City of Portland, City of Lake Oswego/Tigard, and Joint Water Commission (JWC) surface water supplies, depending on which volcano erupts and the wind direction at the time surrounding the eruption(s). Table 24 shows the relative likelihood of volcanic ash from an eruption of Three Sisters, Mount Hood, or Mount St. Helens, which would affect the surrounding four regional supply watersheds with the predominant southwest prevailing wind. As Table 2.4 shows, a volcanic event would likely not affect all four regional supplies.

Table 2.4 Likelihood of Volcanic Ash Having Substantial Impact on Watersheds with a Southwest Wind

River/Volcano	Three Sisters	Mount Hood	Mount St. Helens
Willamette River	High	Low	Low
Clackamas River	Moderate	High	Moderate
Bull Run River	Moderate	High	Moderate
Tualatin River	Low	Low	Low

A wind or ice storm could affect the regional power supply if it downs multiple high-voltage circuits crossing the Cascades. This hazard would be categorized as similar to seismic hazards. Based on this understanding, seismic hazards affecting all the regional water supply facilities shall be addressed separately from local hazards that would only affect the WRWTP Lower Site.

2.3.2.1 Hazards Affecting All Regional Facilities

A seismic hazard is typically discussed in terms of its likelihood of occurring in a 50-year period as well as its associated return period. This timeframe is used because it represents a building's typical life expectancy. Equipment has a life expectancy of approximately 20 years, and buried pipelines have a life expectancy of 100 years. For example, an earthquake with a 10 percent chance of occurring in 50 years has an approximately 500-year return period; one with a 5 percent chance has an approximately 1,000-year return period; and one with a 2 percent chance has an approximately 2,500-year return period.

On average, the Cascadia Subduction Zone earthquake occurs every 500 years. However, other earthquake sources also contribute to and heighten the probability of 500-year-return ground motions.

The Minimum Design Loads for Buildings and Other Structures (ASCE, 2010), which is a consensus-based standard, is used in conjunction with the International Building Code (IBC) to guide structural designs. Both start with a 2,500-year probabilistic ground motion, which are then multiplied by two-thirds. The resulting ground motion estimate is used to design most facilities and to achieve life safety for Category II facilities, such as residential and commercial structures.

ASCE 2010 assigns a risk category to various types of structures ranging from I to IV. Specifically, Risk Category II has an Importance Factor of 1.0, Risk Category III has an Importance Factor of 1.25, and Risk Category IV has an Importance Factor of 1.5. These factors are applied to the ground motion. With the Importance Factor applied, the IBC ensures that structures designed to Risk Categories III and IV will only require minor repairs before returning to operation (Category III) or remain operational after a 500-year return event. The IBC requires "qualifying" equipment used in Category IV to demonstrate their ability to remain operable after an earthquake.

The Importance Factors are based on building observations and engineering judgment. Water facilities, particularly water treatment plants, are complicated systems made up of many geotechnical considerations, structural and non-structural components, and systems that may be vulnerable to earthquakes. Applying an Importance Factor of 1.5 does not necessarily address all of these various elements and does not guarantee post-earthquake operation after a 500-year return earthquake. To increase the likelihood of post-earthquake operation, a detailed facility system seismic vulnerability analysis is recommended. At a minimum, it is recommended that this vulnerability analysis include unit processes, communications, staffing, supply logistics, inventory maintenance, and staff accommodations. This analysis should be relevant to all facilities on the WRWTP Lower Site and will need to include coordination with the WWSP.

To be more conservative, the owner may request to design for 2,500-year return ground motions. These are 1.5 times the ground motions used for most structures, the same as the Category IV 1.5 Importance Factor. Applying the same methodology as used for a base-level earthquake, 2,500-year ground motions should be used in conjunction with an Importance Factor of 1.5. Adding these factors of safety would result in a ground motion design of 1 + 0.5 + 0.5 = 2.0 multiplied by the base ground motion.

Because it only addresses the facilities' structural elements, this increase may not be enough to achieve post-earthquake facility functionality. To return to operations within days of a 2,500-year return event, a detailed facility system seismic vulnerability assessment is recommended. Furthermore, applying one 0.5 factor of safety (Importance Factor = 1.5), instead of applying both 0.5 factors of safety (Importance Factor = 2.0), is recommended.

The ground motion design, Importance Factor, and Facility System Seismic Analysis drive the Recovery Level, which represents the time it takes to get back in operation. The Recovery Level is the key parameter in determining a catastrophe's impact on a community. Table 2.5 shows the expected recovery level for combinations of ground motion design level, the Importance Factor, and a Facility System Seismic Analysis.

Table 2.5 Water Treatment Facility Recovery Levels for Various Earthquake Hazard Levels as Implied by Current Codes and Standards for New Construction

	Ground Motion Design Level					
	500-year	500-year	500-year	2,500-year	2,500-year	2,500-year
Importance Factor	1	1.5	1.5	1	1.5	1.5
Facility System Seismic Analysis	No	No	Yes	No	No	Yes
Subjected to:	**Resume Service in:**					
500-Year Return Period Earthquake	Months to Years	Days to Weeks	Days	Days to Weeks	Days	Days
2,500-Year Return Period Earthquake	Years	Months to Years	Months to Years	Months to Years	Days to Weeks	Days

In terms of the overall cost for the project, the difference of building new structures for Risk Category IV versus Risk Category III is nominal (estimated at 2 to 3 percent of total project cost to achieve Category IV for just the structures). The cost to conduct a detailed facility seismic vulnerability analysis is less than $100,000, plus mitigation of identified deficiencies. As a result, this 2017 MPU recommend designing the future expanded WRWTP facilities to Category IV seismic design loading for a 500-year return event with no additional increase for 2,500-year ground motions. Chapter 5 of this 2017 MPU provides a detailed facility seismic vulnerability analysis of the existing facilities and summarizes Oregon's seismic requirements and standards put in place while the WRWTP was constructed.

As mentioned earlier, the IBC requires "qualifying" equipment in facilities designed to Risk Category IV. This means that the equipment used must be tested to ensure that it remains functional after the prescribed earthquake loading. Some standard WTP equipment and systems, such as motor control centers, were previously qualified. This equipment must be identified and located in the facilities.

In case of earthquakes and potential wind and ice events, loss of regional power is expected to affect all the regional supplies. Although some of the other regional supply facilities have backup power, these may be damaged in an earthquake. Therefore, the existing backup power facilities at the WRWTP must be expanded to meet the desired LOS goals.

2.3.2.2 Hazards Only Affecting the WRWTP

As discussed briefly in 2.3.2, flood, volcanic debris flow, water quality events, wild fire, wind/ice/snow storms (excluding regional power outage), and terrorism/cyber-attacks are expected to affect only the WRWTP. These local hazards have the largest impact on the intake (raw water quality) and finished water quality.

Unlike seismic events, where the shaking intensity increases for an event with a longer return period (lower probability), local hazards such as chemical spills or terrorist attacks do not have different intensities depending on different return periods. Therefore, we recommend not attaching a return period to this group of hazards. These events do, however, have a reasonable likelihood of occurring during the life of the WRWTP.

2.3.3 Regional Precedents

This section reviews the regional precedence for large regional water supply systems, which guides the selection of seismic LOS goals.

2.3.3.1 East Bay Municipal Utility District (Oakland, California)

A thought leader in seismic reliability, the East Bay Municipal Utility District (EBMUD) in Oakland, California, established LOS goals for a probable and maximum earthquake event. These goals apply to an existing system that includes supply, treatment, and distribution. Table 2.6 presents these LOS goals.

Table 2.6 East Bay Municipal Utility District Level of Service Goals

Category	Probable Earthquake	Maximum Earthquake
General	• All water introduced into the distribution system are fully treated, but minimally disinfected.	• All water introduced into the distribution system are fully treated, but minimally disinfected.
Fire Service	• Service to all hydrants within 20 days.	• Service to all hydrants within 100 days.
Hospitals and Disaster Collection Centers	• Minimum service to affected area within 1 day (water available via backbone distribution system near each facility).	• Minimum service via distribution system or truck within 3 days.
Domestic Users	• Potable water via distribution system or truck within 1 day.	• Impaired service within 30 days (water available via distribution system to each facility, possibly at reduced pressures).
Commercial, Industrial, and Other Users	• Impaired service to affected area within 3 days (water available via distribution system to each commercial or industrial user, possibly at reduced pressures).	• Potable water at central locations for pick up within 1 week. • Minimum service to 70% of customers within 10 days. • Impaired service to 90% of customers within 30 days.

2.3.3.2 Oregon Resiliency Plan

The Oregon Seismic Safety Advisory Committee (OSSAC) developed the Oregon Resilience Plan (ORP) per the Oregon State Legislature's request. The ORP includes goals for specific functions of water systems, as shown in Table 2. 7. For WTPs, the ORP recommends that 20 to 30 percent of the potable supply be available within 24 hours of the event and be at near-full restoration within 1 to 2 weeks.

Table 2.7 Oregon Resilience Plan Recommended LOS Goals for Water Systems

System Function	Event Occurs							
	0-24 hours	1-3 days	3-7 days	1-2 weeks	2-4 weeks	1-3 months	3-6 months	6-12 months
Potable water available at supply source	🔺	🟡		🟩			✖	
Main transmission facilities, pipes, pump stations, and reservoirs operational	🟩					✖		
Water supply to critical facilities available	🟡	🟩				✖		
Water for fire suppression at key supply points	🟩		✖					
Water for fire suppression at fire hydrants			🔺	🟡	🟩			✖
Water available at community distribution centers/points		🟡	🟩	✖				
Distribution system operational		🔺	🟡	🟩				✖

Notes:

(1) 🟩 Desired time to restore component to 80-90% operational.

(2) 🟡 Desired time to restore component to 50-60% operational.

(3) 🔺 Desired time to restore component to 20-30% operational.

(4) ✖ Current state (90% operational).

2.3.3.3 Joint Water Commission (JWC) (Hillsboro, Oregon)

The JWC developed LOS goals for its existing WTP (originally constructed in 1976) for three earthquake return periods (72, 475, and 2,475 years) with goals for immediate and short-term capacity, as well as short-term restoration. In all cases, the water quality produced was intended to be potable. For the JWC WTP, the expected performance of various unit processes during a seismic event governed the capacities. Table 2.8 shows the JWC's LOS goals.

Table 2.8 Joint Water Commission WTP LOS Goals

Seismic Events	Immediate Capacity mgd	Short-Term Capacity mgd	Short-Term Restoration Time days	Water Quality
72 Year Event	42(1)	42(1)	0	Potable
475 Year Event	0	24	1	Potable
2,475 Year Event	0	12	3	Potable
		28(2)	7 to 14	
		42(1)	60 to 90	

Notes:

(1) Average Day Demand is 42 mgd.

(2) Average Winter Demand is 28 mgd.

2.3.4 Recommended Preliminary LOS Goals for WRWTP Expansion

Two categories of preliminary LOS goals are recommended for the expanded WRWTP: 1) a regional seismic event that potentially affects all regional supplies where Participants rely on the WRWTP and 2) local events that affect only the WRWTP supply (i.e., other regional supplies remain on-line) and allow Participants to rely on other regional supplies.

Recommended LOS goals in this section were developed in a workshop setting that included the technical advisory committee (TAC). Because the expansion is for a regional facility, LOS goals must be verified with each agency during the design phase for compatibility with their own distribution and storage LOS goals. LOS goals developed as part of the 2015 MPU were adopted by the governing bodies of both Wilsonville and Sherwood.

Note that the WRWTP was designed and constructed in 2002, prior to Oregon's adoption of International Building Code (IBC) in 2004. Because of this, the WRWTP was built to withstand a reduced earthquake threshold (i.e., 500-year return period rather than 2,500-year return period specified in the IBC). For this reason, the WRWTP will not be able to meet their LOS goals until they construct additional infrastructure at the increased seismic requirement.

2.3.4.1 Hazard Return Period

To prepare for a regional event, new facilities should be designed and upgraded for 2,500-year return period ground motions, in accordance with the IBC Risk Category IV. When available, pre-qualified equipment should also be specified.

To prepare for local hazard events, no return periods should be attached to them, but scenarios for each event type should be considered.

2.3.4.2 WTP Outage Time

For the regional event, the region will depend on the WRWTP. The plant should be operable within 48 hours after the event.

For local hazard events, the Cities of Wilsonville and Sherwood will rely on their existing groundwater supplies for short-term use, while potential interties with other regional water purveyors will be considered for long-term use. The WRWTP should be returned to operation within 14 days of the event.

2.3.4.3 Delivery Capacity Percentage

For a regional event, the WTP should be able to deliver 50 percent of its full capacity. This number controls the amount of backup power required and the size of chemical storage facilities.

For a local hazard event, the WTP should be at full capacity when service resumes.

2.3.4.4 Water Quality

Whenever operational, the WTP should produce potable water for both the regional and local hazard events.

Table 2.9 summarizes the final LOS goals recommended for the expanded WRWTP facilities.

Table 2.9 Adopted LOS Goals for the WRWTP

LOS Goal	Regional Event (Seismic)	Local Event (Non-Seismic)
"Following a W catastrophic event ...	2,500 year	Per occurrence
...within X days/weeks of the event...	48 hours	14 days
...deliver Y % of average day demand...	50% of nameplate	100% of nameplate
...with Z water quality."	Potable (at minimum regulatory requirement)	Potable (at plant treatment processes and procedures)

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Chapter 3

EXISTING FACILITIES AND OPERATIONAL PERFORMANCE

3.1 Introduction

The 2006 Willamette River Water Treatment Plant (WRWTP) Master Plan was completed approximately four years after initial plant start-up in 2002. At that time, the City of Wilsonville was the only consumer of WRWTP water.

In mid-2012, the City of Sherwood purchased 5 mgd of capacity from the Tualatin Valley Water District (TVWD) and started using water from the WRWTP as its primary supply. With this additional demand, the WRWTP moved from operating on a daily start/stop basis for 8 to 16 hours per day, depending on demand, to operating 24 hours per day.

This Chapter describes each major plant component and summarizes the existing WRWTP treatment facilities, previous studies, and historical operating performance. Because hours of operation affect plant operations and the expanded plant will operate continuously, the plant performance data considered for the 2015 MPU was limited to 2012 through 2014; no additional water quality data was analyzed as part of this 2017 MPU. Discussion on the existing facility infrastructure, including seismic and life-safety analysis, is presented in Chapter 5.

3.2 Summary of Previous Studies

WRWTP planning began in the early 1990s with preliminary raw water quality sampling. About ten years later, between 2000 and 2002, the existing 15-mgd WRWTP facility was constructed. The studies reviewed for the 2015 MPU are as follows:

- WWSA – Raw Water Quality Monitoring Program (WRWSA/MWH, 1994-2002).
- Willamette River Pilot Plant Study (MWH, 1994) – Summarizes bench- and pilot-scale studies verifying the treatability of the Willamette River.
- Willamette River Water Supply System, Preliminary Engineering Report (MSA/MWH, 1998) – Summarizes and consolidates several planning-level documents for the WRWTP, including water user permits and intergovernmental agreements, intake and river hydraulics, alternative RWPS layouts, preliminary geotechnical work, and water treatment plant schematic designs. Evaluates the treatment needs, treatment processes and procedures, and project and O&M costs for an initial 35 mgd WTP, ultimately expanding to 120 mgd. Findings enabled the project participants to determine how to meet future drinking water needs.
- Actiflo® Pilot Study Report (MWH, April 2000) - To evaluate performance of the combined Actiflo® and filtration treatment trains on the Willamette River, Actiflo® was piloted from February 24 through March 10, 2000, at the WRWTP site, in conjunction with a filter column modeling the proposed full-scale filter beds.

- *Source Water Assessment Report of Surface Water Supply* (MWH, September 2002) – Assesses the surface water source area upstream of the proposed WTP intake. Primary objectives are to delineate sensitive areas requiring special consideration to protect water quality, record potential contaminant sources, and assess the susceptibility of the supply to contamination.
- *Wilsonville Water Treatment Plant, Geotechnical Analysis* (Squire Associates, 2000) – Presents the results of a third-party geotechnical analysis and recommendations to support the WRWTP 30 percent level design-build documents.
- *Water Treatment Plant 3rd Party Peer Review* (Degenkolb, 2000) – Presents the findings and records the resulting design changes of a third-party peer review of the structural design.
- *WRWTP Record Drawings and O&M Manual* (MWH, 2002) – Offers the final record drawings and Operations and Maintenance Manual from the design-build contractor after start-up and commissioning of the original plant facilities.
- *WRWTP Tracer Study* (CH2MHill, 2002) – Summarizes the results of the original tracer study of the WRWTP clearwell to obtain OHA approval for finished water flows up to 10 mgd.
- *WRWTP Master Plan* (MWH, 2006) – Planning-level document to help the District select long-term water supply needs. The report recommends treatment technologies, provides treatment procedures, construction and O&M cost estimates, and offers an implementation plan for expanding the WRWTP.
- *WRWTP Surge Analysis* (MWH, 2009) – Shows the results of preliminary hydraulic calculations to determine the WRWTP finished water flow rates that would trigger the need for surge protection at the plant.
- *Water Treatment Plant CT Model* (MWH, 2011) - A disinfection calculation tool for performing real-time CT calculations at the WRWTP.
- *Willamette River WTP Disinfection (CT) Analysis* (MWH, 2011) - Updates and further defines the CT capacity of the existing WRWTP.
- *Hydraulic Transient Analysis (MWH, 2011)* - Updated modeling efforts focused on surge analysis at the existing WRWTP.
- *City of Wilsonville Water Master Plan* (Keller & Associates, 2012) – In part, this report summarizes finished water quality and disinfection strategies for the WRWTP, Wilsonville's primary water supply. This document focuses on the distribution system, but also summarizes WQ issues.
- *WRWTP Tracer Study* (MWH, 2014) – Summarizes the results of the second tracer study of the WRWTP clearwell, which was used to obtain OHA approval for finished water flows up to 15 mgd.
- *WRWTP 2015 Master Plan Update (Carollo, 2016)* – Summarizes the planning efforts for incorporating the WWSP WTP at the existing site of the WRWTP: develop LOS goals for the plant, update raw water and finished water quality and plant performance, select structural and life-safety analysis, and complete an implementation plan/schedule.

3.3 Major Plant Components

3.3.1 General

The WRWTP site on the Willamette River in Wilsonville at approximately River Mile 39 is irregularly shaped and includes a narrow bottleneck separating the site into Upper and Lower Sites (see Site Plan presented in Figure 1-1). The existing treatment plant and Willamette River Water Treatment Plant Park are on the Lower Site.

When the plant was designed in 1999-2000, the WRWTP was master-planned for an ultimate capacity of 60 mgd, with features and infrastructure in the plant design and construction to facilitate expansion. The intake pipeline, which was tunneled from the raw water caisson to the river, and the 81-foot-deep circular caisson were designed and sized to accommodate approximately 100 mgd, estimated to be the ultimate capacity of the WWSP treatment plant at build-out.

Primary water treatment processes for the WRWTP effectively treat the raw Willamette River water and comply with existing and anticipated future drinking water regulations. A multi-barrier approach currently addresses these key "contaminants of concern":

- Turbidity.
- Pathogenic microorganisms.
- T&O.
- Trace organics.

The WRWTP intake has two cylindrical tee-shaped screens, a raw water intake pipe and caisson, a raw water pump station and flow metering, flash mixing, a ballasted flocculation (Actiflo®) system, ozonation, filtration using deep-bed GAC/sand media, a 2.9-million-gallon (MG) clearwell, a high-service pump station and flow metering, backwash equalization, solids thickening, and a centrifuge solids dewatering facility. Table 3.1 summarizes plant treatment processes and procedures. Figures 3.1 through 3.3 give an overview of existing facilities.

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures

Description	Units	Value
Plant Design Flow	mgd	15
Willamette River		
Minimum River Level	FT	52.5
100 Year Flood Elevation	FT	91.1
500 Year Flood Elevation	FT	102.3
Intake Screens		
Type: Horizontal Cylindrical		
Number	#	2
Capacity, total	mgd	70
Diameter	IN	66

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures (Continued)

Description	Units	Value
Screen Opening Size	mm	1.75
Maximum Face Velocity	FPS	0.4
Top of Screen Elevation	FT	42.75
Screen Cleaning		
Cleaning Method: Air Burst		
Number of Compressors	#	2
Compressor Capacity	CFM	200
Air Receiver Volume	CF	2,200
Motor Size per Compressor	HP	50
Raw Water Pumps		
Type: Vertical Turbine, Single-Stage		
Number	#	4
Total Capacity with Standby	mgd	26.5
Capacity (each)		
1 VFD-Driven Pump (on backup power)	mgd	4
2 VFD-Driven Pumps	mgd	7.5
1 Constant-Speed Pump	mgd	7.5
Total Dynamic Head (15 mgd)	FT	107
Total Motor Horsepower	HP	1@100, 3@200
Initial Flash Mix		
Type: Pumped		
Number (Installed)	#	1
Mixing Energy	s^{-1}	1,000
Pump Capacity	gpm	1,000
Total Dynamic Head	FT	16
Total Motor Horsepower	HP	7.5
Clarification Process		
Type: Ballasted Flocculation (Actiflo®)		
Number of Basins	#	2
Design Flow (per basin)	mgd	7.5
Maximum Process Hydraulic Flow (per basin)	mgd	15
Mixing/Flocculation		
Coagulation Chamber Volume	CF	2,000

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures (Continued)

Description	Units	Value
Coagulation Chamber HRT	MIN	2.9
Injection Chamber Volume	CF	2,165
Injection Chamber HRT	MIN	3.1
Maturation Chamber Volume	CF	6,330
Maturation Chamber HRT	MIN	9.1
Clarification		
Settling Chamber Volume	CF	7,570
Settling Chamber HRT	MIN	9.6
Lamella Tube Settlers, surface area	SF	520
Design Surface Loading Rate	GPM/SF	20
Maximum Surface Loading Rate	GPM/SF	40
Sand Slurry Recirculation System		
Number of Sludge Recirculation Pumps per Basin	#	2
Sludge Recirculation Rate	%	3
Capacity per Pump	GPM	165
Total Design Head	FT	75
Pump Horsepower	HP	10
Number of Sand Hydrocyclones (per basin)	#	2
Manufacturer's Maximum Anticipated Sand Loss	LB/MG	25
Ozone Contact Basins		
Type: 8-Stage Counter-Co-Counter with Fine-Bubble Diffusers		
Number of Basins	#	2
Detention Time at 15 mgd with Both Basins in Service	MIN	14.9
Average Water Depth	FT	21
Inside Dimensions (each basin)	FT x FT	6 x 10
Volume (total)	CF	20,800
Ozone Generators		
Number	#	2
Feed Gas Vaporized From LOX	-	GOX
Capacity (each)	ppd	300
% Ozone by Weight (maximum)	%	10
Design Ozone Dose at 15 mgd	mg/L	2.5
Filters		
Type: Deep Bed, Dual Granular Media		
with Influent Flow Splitting		

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures (Continued)

Description	Units	Value
Number of Filters	#	4
Number of Bays/Filter	#	1
Filter Bay Dimensions	FT x FT	20 x 23
Filter Area (each filter)	SF	460
Total Filter Area	SF	1,840
Maximum Filtration Rate (Q/A)		
All Filters On-Line at 15 mgd	GPM/SF	5.7
One Filter Off-Line at 15 mgd	GPM/SF	7.5
Hydraulic Maximum	GPM/SF	12
Filter Media		
GAC		
Depth	IN	72
Effective Size	MM	1.4
Uniformity Coefficient		<1.4
Depth: Diameter (L:D)		1,306
Minimum Empty Bed Contact Time (EBCT)		
All Filters On-Line at 15 mgd	MIN	7.9
One Filter Off-Line at 15 mgd	MIN	5.9
Sand		
Depth	IN	12
Effective Size	MM	0.45
Uniformity Coefficient		<1.4
Depth: Diameter (L:D)	MM:MM	677
Total Media		
Depth (maximum)	IN	84
Depth: Diameter (L:D)	MM:MM	1,984
Filter Wash System		
Air Scour Blowers		
Number	#	2
Air Scour Rate	CFM/SF	3.2
Blower Capacity (each)	SCFM	2,000
Blower Horsepower (each)	HP	100
Backwash Pumps		
Number	#	2
Maximum Backwash Rate	GPM/SF	20

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures (Continued)

Description	Units	Value
Pump Capacity (each)	GPM	9,200
Pump Horsepower (each) – constant speed	HP	150
Clearwell		
Type: Buried, Reinforced Concrete		
Active Volume	MG	2.9
Max Operating Side Water Depth	FT	21.5
Dimensions	FT x FT	135 x 135
Detention Time (HRT) at 15 mgd When Full	HOURS.	4.6
Hydraulic Efficiency up to 9.6 mgd	T10:HRT	0.16
Hydraulic Efficiency 9.6-15.0 mgd	T10:HRT	0.11
Treated Water Pumps		
Type: Vertical Turbine, Two-Stage		
Number	#	4
Total Capacity with Standby	mgd	26.5
Capacity (each)		
1 VFD-Driven Pump (on backup power)	mgd	4
2 VFD-Driven Pumps	mgd	7.5
1 Constant-Speed Pump	mgd	7.5
Total Dynamic Head	FT	312
Motor Size	HP	3@500, 1@300
Waste Washwater Equalization and Pump Station		
Equalization Basins		
Type: Concrete		
Number of Basins	#	1
Volume/# of Backwashes	GAL/#	244,000/2
Washwater Recycle Pumps		
Type: Vertical Turbine		
Number	#	3
Total Capacity with Standby	GPM	1,500
Capacity (each)		
2 VFD-Driven Pumps	GPM	500
1 Constant-Speed Pump	GPM	500
Total Dynamic Head	FT	25
Motor Horsepower	HP	3 @ 5

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures (Continued)

Description	Units	Value
Solids Treatment		
Type: Gravity Thickener and Centrifuges		
Estimated Maximum Solids Production (dry) at 15 mgd	LB/DAY	2,000
Gravity Thickener (circular)		
Number of Units	#	1
Side Water Depth	FT	12
Diameter	FT	35
Maximum Solids Loading Rate	PPD/SF	8
Maximum Hydraulic Loading Rate	GPM/SF	1
Solids Mixing		
Type: Vertical Non-Clog		
Number of Pumps	#	1
Pumping Capacity	GPM	600
Pump Horsepower	HP	5
Total Dynamic Head	FT	12
Solids Pump Station		
Type: Progressive Cavity		
Number of Pumps	#	2
Pumping Capacity (each)	GPM	60
Motor Size (each)	HP	5
Total Dynamic Head	FT	60
Centrifuges		
Type	-	Horz. Scroll
Number of Units	#	2
Minimum Solids Cake Concentration	%	18
Capacity (each)	GPM	60
Maximum Solids Loading (each)	LB/HR	750
Motor Horsepower-Scroll (each)	HP	40
Motor Horsepower-Back Drive (each)	HP	15
Chemical Storage		
Primary Coagulant (49% alum solution)		
Number of Tanks	#	2
Storage Capacity, total	GAL	13,000
Storage (average dose x maximum flow)	DAYS	40
Average Dosage	mg/L	15

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures (Continued)

Description	Units	Value
Solution Strength (alum)	LB/GAL	5.4
Cationic Polymer (dry polymer)		
Type	-	Dry Feeder
Feed Capacity	LB/HR	17.6
% solution	%	1
Mixing Time	min	30
Sodium Hypochlorite (12.5% NaOCl solution)		
Number of Tanks	#	2
Storage Capacity, total	GAL	10,000
Storage (average dose x maximum flow)	DAYS	80
Average Dosage	mg/L	10
Solution Strength	LB/GAL	1.0
Caustic Soda (25% NaOH solution)		
Number of Tanks	#	1
Storage Capacity, total	GAL	6,500
Storage (average dose x maximum flow)	DAYS	20
Average Dosage	mg/L	5
Solution Strength	LB/GAL	2.65
Liquid Oxygen (100% LOX)		
Number of Tanks (with vaporizers)	#	1
Storage Capacity, total	GAL	6,000
Storage (average dose x maximum flow)	DAYS	17
Average Dosage	mg/L	26
Aqueous Ammonia (19% NH_4OH solution) NOT USED		
Number of Tanks	#	1
Storage Capacity, total	GAL	1,400
Anionic Polymer		
Number of Drums	#	1
Storage Capacity, total	GAL	55
Storage (average dose x maximum flow)	DAYS	> 1 year
Average Dosage	mg/L	0.4
Non-Ionic Polymer		
Number of Drums	#	1
Storage Capacity, total	GAL	55
Storage (average dose x maximum flow)	DAYS	> 1 year
Average Dosage	mg/L	-

Table 3.1 WRWTP Existing Facilities Treatment Processes and Procedures (Continued)

Description	Units	Value
Calcium Thiosulfate		
Number of Totes	#	2
Storage Capacity, total	GAL	440
Storage (average dose x maximum flow)	DAYS	20
Average Dosage	mg/L	0.6
Solution Strength	LB/GAL	3.6

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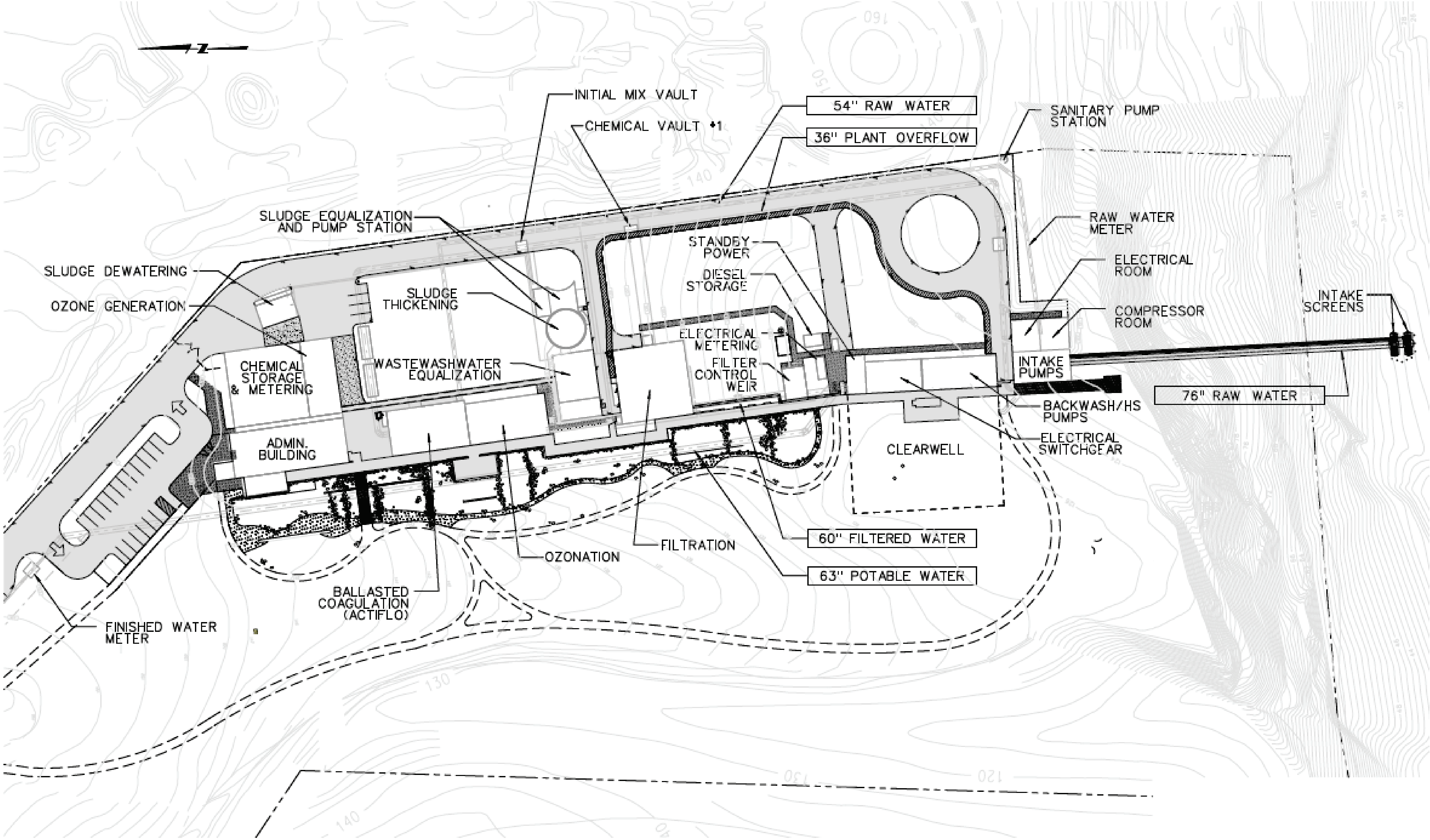

Figure 3.1 WRWTP Existing Site Plan

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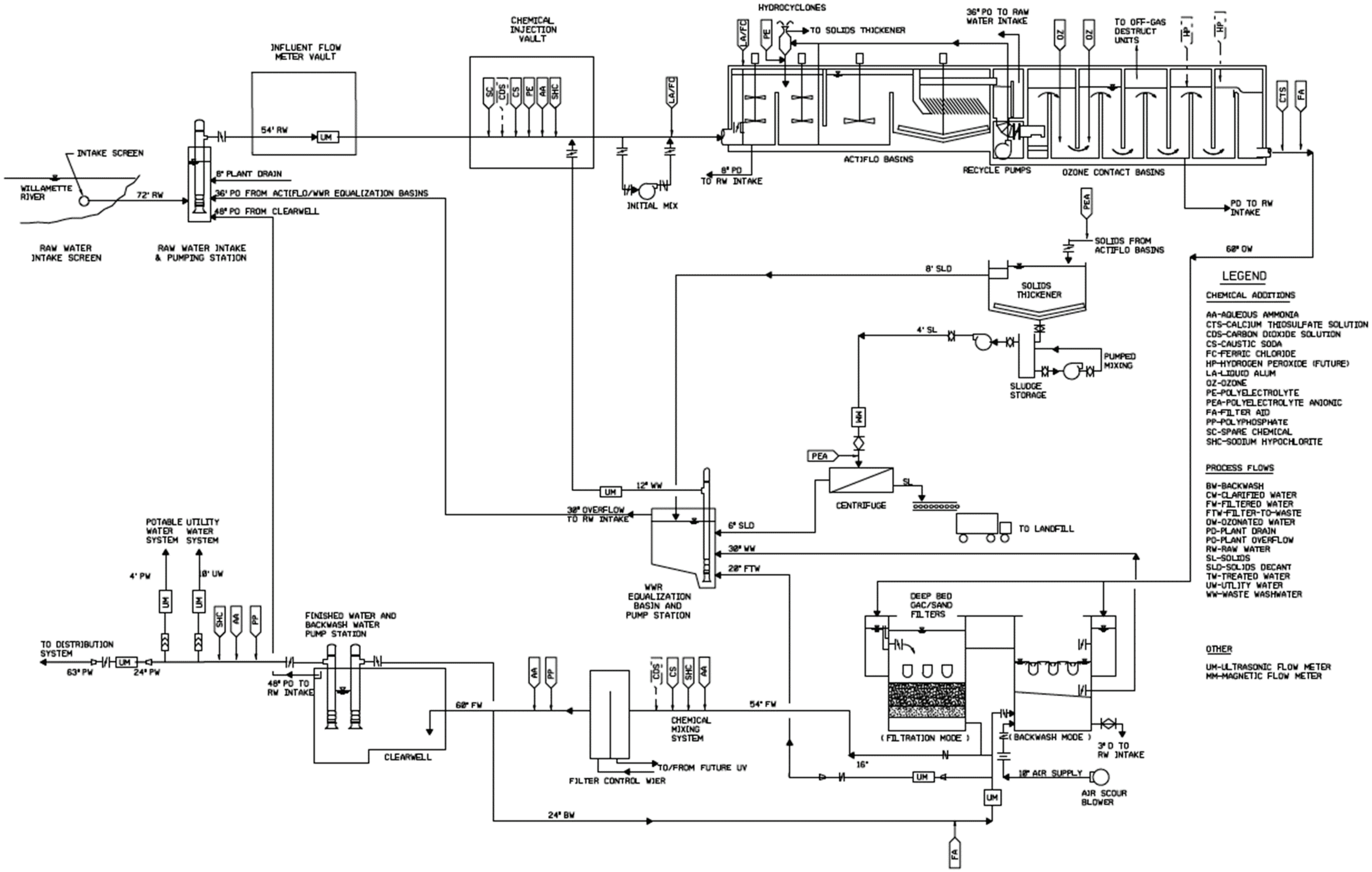

Figure 3.2 WRWTP Process Flow Diagram

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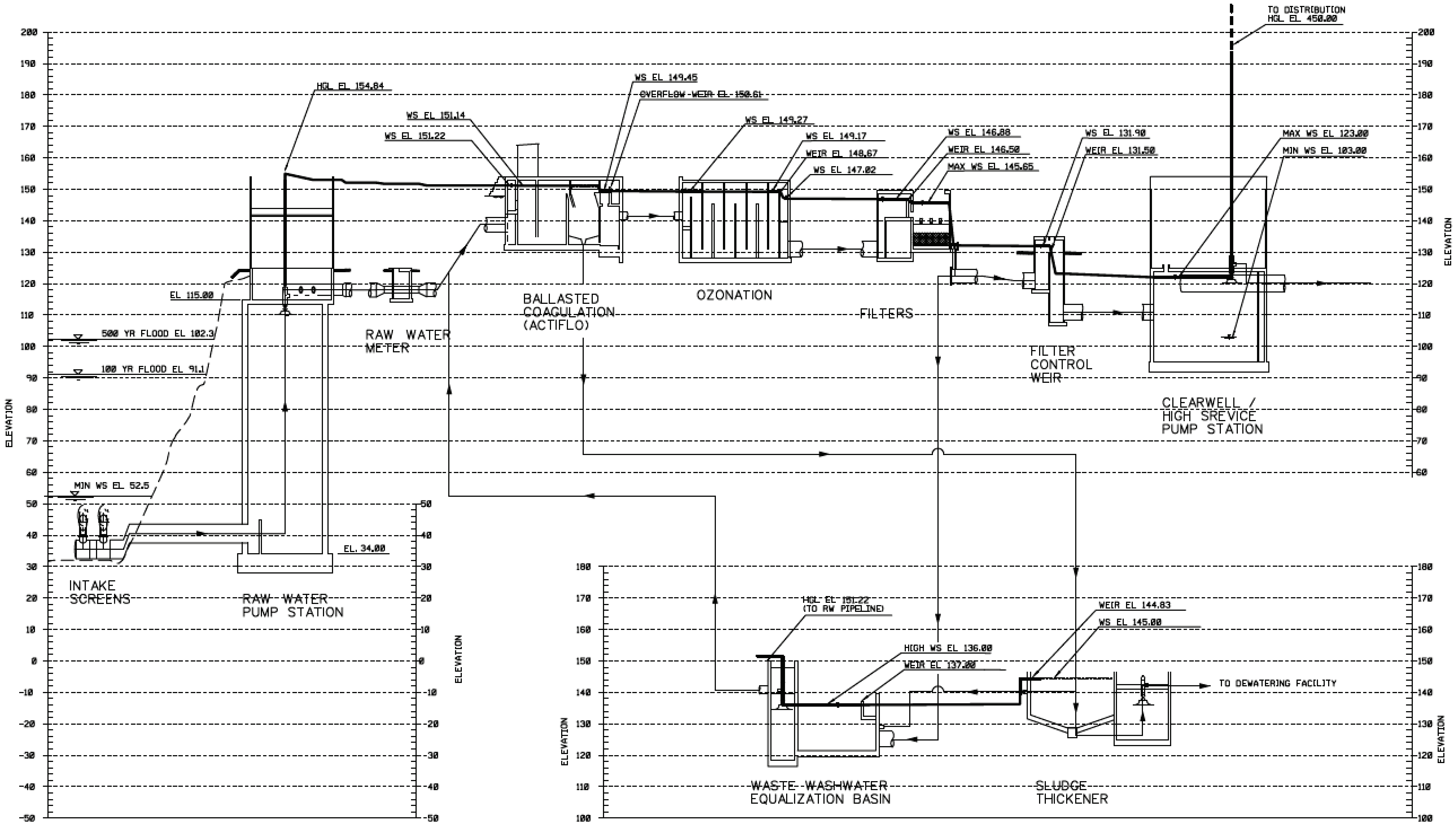

Figure 3.3 WRWTP Hydraulic Profile

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3.3.2 Raw Water Facilities

At the river end of the intake pipeline, cylindrical tee-shaped screens prevent debris and aquatic species from being drawn into the treatment plant. The screen system protects anadromous juvenile fish in flows up to 70 mgd, using Oregon Department of Fish and Wildlife (ODFW) and National Marine and Fisheries Service (NMFS) standards to meet Endangered Species Act (ESA) requirements.

The screens are cleaned with an airburst system, which releases pressurized air into the screen interior. Two compressors and an air receiver tank in the raw water pump station deliver air to the screens via two 12-inch air pipelines. Plant staff determines the frequency of screen cleaning according to intake flow, debris in the river, and the season of the year.

The raw water pump station consists of an 85-foot-deep circular caisson wet well below a pump station superstructure. All raw water pumps are vertical turbines. Pump columns extend to within a few feet of the bottom of the caisson.

The wet well and pump station were designed for an ultimate flow of approximately 120 mgd; the initial installed firm capacity was 19 mgd (with the largest pump out of service); and the total raw water pumping capacity is 26.5 mgd. Three of the pumps have variable frequency drives (VFDs), allowing for a wide range of pumping rates. The backup power generator can serve one 4-mgd pump.

To recycle flows within the plant and avoid surface discharge, an 8-inch plant drain pipe to empty water-retaining process basins, a 36-inch plant overflow pipe, and a 48-inch clearwell overflow pipe penetrate the raw water caisson.

The raw water pumps discharge to two separate manifolds that connect to the main 54-inch raw water pipeline to the treatment facility. The 54-inch pipeline is sized to deliver 70 mgd. A 24-inch magnetic flowmeter measures raw water flow rate, and the flow signal is transmitted to the Supervisory Control and Data Acquisition (SCADA) system to control downstream plant operations.

A sample tap on the raw water pipeline discharge header monitors raw water continuously at the raw water pump station. Turbidity, particle counts, pH, temperature, and hydrocarbon concentrations are monitored with on-line analyzers, and results are transmitted to SCADA.

3.3.3 Chemical Injection Vault and Initial Mixing Facility

A chemical injection vault upstream of the ballasted flocculation system is a point for adding the following chemicals:

- Alum or ferric chloride (not used) for primary coagulant.
- Sodium hydroxide for pH adjustment, if needed for optimized coagulation.
- Cationic polymer for the Actiflo® process.
- Sodium hypochlorite (for disinfection residual).

In addition, while not used currently, the chemical injection vault can add the following in the future:

- Aqueous ammonia if chloramines are used in lieu of free chlorine.
- Carbon dioxide for pH adjustment, if needed for optimized coagulation.

Alum, the primary coagulant, is added at the initial mixing vault upstream of the Actiflo® process. In the vault, raw water is suctioned from the raw water pipeline upstream of chemical injection and pumped back to the pipeline through a 90-degree spray nozzle. Primary coagulant is added at the "eye" of the spray cone to instantly mix coagulant into the raw water flow stream.

As a backup, primary coagulant can also be added at the coagulation chamber of the Actiflo® basin where the 36-inch raw water pipeline penetrates the structure. Coagulant addition is flow-paced using data from the raw water flowmeter. It can also be paced based on a signal from the Streaming Current Monitor (SCM), located in the Sludge Thickener Building.

Sampling for the SCM from the raw water pipeline occurs just downstream of the Initial Mix Vault, with alum being the only chemical typically added. The other chemical injection points in the injection vault are used seasonally.

3.3.4 Ballasted Flocculation (Actiflo®) System

Coagulated water flows into the Actiflo® inlet channel and is distributed to the two Actiflo® basins via 36-inch diameter inlet isolation valves. Designed for 7.5 mgd (at 20 gm/sf surface loading rate), each Actiflo® basin consists of four separate chambers: coagulation, injection, maturation, and settling.

The first three chambers contain vertical shaft mechanical mixers. The coagulation chamber provides intense mixing and is an alternate feed point for primary coagulant addition (as described in Section 3.3.3). The injection chamber also provides intense mixing for adding coagulant-aid polymer and microsand, which is critical to ensure that the floc and microsand adhere to each other.

Microsand added to the injection chamber is separated from the sludge via the hydrocyclones in a building above the injection chamber. The maturation chamber allows for slower mixing of the coagulated water for floc formation and attachment of the microsand to the floc. Enmeshment of the microsand in the floc creates a high-density material known as "ballasted floc".

The ballasted, or weighted, floc is then settled out in the settling chamber, which contains plastic lamella tube settlers to enhance settling and a rotating scraper arm to collect settled sludge. The sludge/microsand mixture collected in the settling chamber is pumped back to the head of the process where the microsand is separated in the hydrocyclones and returned to the injection chamber. The separated sludge is discharged to the gravity thickener. The hydrocyclones are housed inside of the Sand Storage Building on top of the Actiflo® coagulation and injection chambers.

Settled water from the Actiflo® process collects in rectangular weir troughs and flows into an effluent channel. The channel has a slide gate to isolate the effluent of each of the Actiflo® basins. Flow from the effluent channel is diverted to the ozone contact basins via a 30-inch diameter pipeline with an isolation butterfly valve.

Sample taps are located on each of the effluent pipelines, which route water through a turbidimeter and a pH/temperature probe. A settled water sample is also pumped to the laboratory sample sink.

The slide gate and isolation valves allow for operational flexibility. If one of the two ozone contact basins is out of service, settled water from both Actiflo® basins can flow to either ozone contact basin. If an Actiflo® basin is out of service, settled water can flow from one Actiflo® basin to both ozone contact basins. The slide gate also allows the operator to bring one basin on-line and to overflow to waste while the other is in operation.

The Actiflo® process also contains an overflow weir and channel, which can divert flow back to the raw water caisson during initial start-up of the Actiflo® process or if the quality of the clarified water exceeds an operator setpoint. To dewater the basins, mud valves are located in each coagulation and maturation chamber to drain the basins while the recirculation pumps deliver flow back to the injection chamber.

3.3.5 Ozonation System

Ozonation following clarification (termed "intermediate ozonation") disinfects and inactivates *Giardia*, viruses, and *Cryptosporidium* (though not currently recognized by the State of Oregon from a regulatory compliance perspective). Ozonation also oxidizes the mild T&O compounds that occur nearly year-round in Willamette River water and oxidizes trace organic compounds that may occasionally be present. Ozone also improves the downstream filtration process by altering the surface charge of particles and making them more filterable. While not required by OHA, Wilsonville has operated the ozonation system since the plant's start-up in 2002 to achieve a minimum of 1.0-log of *Cryptosporidium* inactivation based on the United States Environmental Protection Agency (EPA) CT (product of concentration [C] and contact time [T]) tables.

Clarified water is conveyed from the Actiflo® process to the two ozone contact basins through individual pipes from the Actiflo® effluent channel. The individual pipes have motorized valves that can isolate each ozone contact basin if necessary. The ozonation system operates with both basins in service for a total treatment capacity of 15 mgd, or 7.5 mgd per basin. The nominal ozone contact time is 15 minutes at 15 mgd.

Multiple sample ports connected to on-line ozone residual monitors detect the dissolved ozone concentration throughout the contact basin. Each of the three residual ozone monitors connects to two to four sample locations. The ozone contactor gallery contains ambient air/oxygen and ozone monitors to detect any gas release into the gallery area.

In addition to local visual and audio alarms, each unit is alarmed to the SCADA system to notify operators. Ozone off-gas in the contactor headspace is conveyed to one of two ozone destruct units in the Ozone Contactor Gallery. There, the ozone is destroyed prior to venting to the atmosphere.

At the ozone effluent channel, calcium thiosulfate is added to the process stream to reduce any dissolved ozone residual in the settled water prior to entering the filters. This prevents ozone off-gassing at the filters and protects the piping, valves, and GAC filter media from ozone's potentially degrading effects. A sample line connected to an ozone residual monitor in the filter influent channel to detect any residual ozone in the filter influent water.

Non-ionic filter aid polymer can also be added to the ozone effluent to reduce filter-to-waste durations and improve filtration/solids capture. Filter aid polymer is not currently used, since the filtration process has historically performed well without it.

The Ozone Generation Room in the Administration Building complex contains two ozone generators, each rated at 300 pounds per day (ppd) with sufficient capacity to treat 15 mgd. The ozone generators are cooled using utility water from the treatment plant. Also in this room are the nitrogen boost system, ambient air oxygen and ozone monitors that detect any release of gas into the area, and heating and ventilation equipment. Each monitor is alarmed to the SCADA system for operator notification and to local visual and audio alarms. A 6,000-gallon liquid oxygen (LOX) tank is located outdoors just south of this room.

3.3.6 Filtration System

The filters are located downstream of the Ozone Contact Basins. Filtration through a deep-bed dual media (GAC over sand) removes any material carried over from the Actiflo® basin and allows time for adsorbing dissolved organic material, such as SOCs, onto the GAC.

The GAC media is an optimal surface for growing bio-organisms for biofiltration, which also removes trace organic compounds. An inlet weir at each filter allows uniform distribution of flow to each of the four filter cells. At the current 15-mgd plant capacity, the filters are rated at 7.5 gpm/sf with one filter out of service for backwashing, and a nominal filtration rate of 5.7 gpm/sf when all four filters are in service.

The GAC filter media depth provides an EBCT of 7.5 minutes when all filters are on-line and 5.6 minutes with one filter out of service. The GAC filters adsorb trace organic compounds, which may occur infrequently at trace concentrations in the raw water supply, and act as another barrier against T&O. To maintain optimal adsorption capacity, the GAC and sand media are replaced approximately every four years; media change-outs are performed on two filters at a time, resulting in change-outs every two years.

The treated water exits the filters through the underdrain system and ultimately flows into a common filter effluent pipeline under the filter gallery slab. Filter-to-waste is provided by diverting filtered water back through the backwash header and over to the washwater equalization basin. A filter control weir structure is located between the filters and the clearwell to control the downstream hydraulic gradeline of the filters.

At the combined filter effluent pipeline, sodium hypochlorite is added to provide free chlorine residual for disinfection. Sodium hydroxide is also added to adjust the pH for corrosion control.

Space and hydraulic head were allocated in the original 1999-2000 designs and 2002 construction between the filters and clearwell to accommodate a potential future UV disinfection system.

Filters are backwashed based on an operator set time, effluent turbidity, or maximum head loss, as measured by filter differential pressure. Analytical instruments monitor the filtered water turbidity and particle counts on each filter effluent and a turbidity of the combined filtered effluent.

The cleaning cycle for each filter includes air scour and water backwash. When a wash cycle starts, the water level is drained to a few inches above the media, and air scour begins. After an operator-adjustable time, the backwash pump is activated at a low flow for concurrent air scour and wash water. When the water level rises to an operator-set level below the lip of the washwater troughs, the air scour is terminated, and the backwash rate is increased to an operator-adjustable high rate level.

3.3.7 Liquid Chemical Storage and Feed Facilities

The treatment plant has bulk storage space allocated for the following liquid treatment chemicals. The Chemical Storage Room in the Administration Building complex contains the following chemical storage facilities:

- Two 6,500-gallon tanks for liquid alum (or ferric chloride).
- One 4,400-gallon tank and one 3,900-gallon tank for liquid sodium hypochlorite.
- One 6,500-gallon tank for sodium hydroxide.
- One 1,400-gallon tank for aqueous ammonia (not used).
- Two 55-gallon drums for sludge conditioning polymer.
- Two 220-gallon totes for calcium thiosulfate.
- Two 55-gallon drums for filter aid polymer.
- One dry feeder and mixing tank for Actiflo® polymer.

Primary coagulant (alum) is used to coagulate the suspended solids and dissolved organic carbon in the raw water. The coagulant is added at the initial mix vault for efficient contact with the raw water. A secondary addition point in the Actiflo® basin's coagulation chamber is typically not used but is available as a back-up for the initial mix vault.

Liquid alum is stored as a 49 percent solution. The tanks are piped to the diaphragm metering pumps, which transfer the alum solution to the dosing location. The metering pumps have manual stroke adjustments and automatic speed control for flow-pacing based on the raw water flowmeter signal. All chemical systems share this common feature for chemical feed rate control.

A coagulant aid polymer used in the coagulation process is vital to the proper function of the Actiflo® process because it creates a floc that adheres to the microsand. High-molecular-weight cationic polymer is added at both the Hydrocyclone Collection Box and the effluent of the injection chamber. In case of a mechanical failure, another application point for temporary use is located upstream of the Actiflo® process at the chemical vault. Dry polymer is automatically batched into a dilute solution using the dry chemical feed system, which includes a dry hopper, mixing tank, and aging tank. The resulting solution is pumped to the appropriate location with chemical metering pumps. Each Actiflo® basin has a separate feed point.

Sodium hypochlorite, delivered in bulk as a 12.5 percent liquid solution, is provided for free chlorine disinfection following filtration and for residual disinfection in the distribution system. It can also be added for intermittent chlorination at other locations in the plant to keep various basins clean. The storage tanks are piped to the metering pumps, which transfer the solution to the dosing location. The primary application point is at the filter effluent, while additional "booster" chlorine can be added to the finished water.

Sodium hydroxide, delivered and stored as a 25 percent liquid solution, is used for pH adjustment and is delivered to the application location by metering pumps. The water's pH can be adjusted at three locations in the plant: raw water (chemical vault), filter influent, and filter effluent. The typical chemical feed point is at the filter effluent. Seasonally, sodium hydroxide is added to the raw water to optimize coagulation.

Although not currently used at the plant, nonionic polymer can be used as a filter aid. The primary point of chemical addition is at the Ozone Contact Basin effluent channel. The polymer can also be added to the backwash water based on a flow signal from the backwash water flowmeter.

Calcium thiosulfate is used to quench any ozone residual in the ozonation system effluent prior to filtration. Liquid calcium thiosulfate is stored in 220-gallon totes. The active tote is connected to metering pumps that deliver the chemical to the ozone effluent channel. An ozone residual monitor in the filter gallery detects any ozone residual in the filter inlet channel.

Space in the Chemical Storage Room is allotted for storage and metering of polyphosphate, a corrosion inhibitor. However, this chemical has never been used at the WRWTP.

Space, chemical storage, and feed facilities were provided for aqueous ammonia. Aqueous ammonia reacts with sodium hypochlorite to form chloramines for residual disinfection of treated water. The chemical can be added downstream of the Filter Control Weir or at the High Service Pump Station. This system was added in case additional DBP control is needed to meet more stringent future regulations, or if the plant water were to be blended with another chloraminated water supply in the region, such as the Portland Water Bureau (PWB). To date, this chemical has not been used at the WRWTP

Anionic polymer can be added to the thickener influent or the centrifuge inlet for sludge processing. It is stored as a liquid (emulsion) in 55-gallon drums housed in the Chemical Building. Polymer is pumped to the point of addition with PolyBlend® units, which combine polymer mixing with utility water and chemical delivery to the application points.

A truck fill station is located at the southeast corner of the Chemical Storage Room for bulk delivery of chemicals stored in tanks. At the fill station, the operator must select the chemical tank to fill on a local control panel, which displays the level in the tank to verify that it requires filling. When the operator selects start, the inlet valve will open and the delivery driver can connect the hose to the proper fill station and open the manual isolation valve. An alarm will sound at the station's tank HIGH level to warn that the tank has been filled.

3.3.8 Washwater Equalization Basin

The washwater equalization basin provides equalization for recycling the filter backwash water, filter-to-waste water, sludge thickener decant water, and the dewatering facility centrate water. The basin is sized to store approximately two backwash volumes, including filter-to-waste. Flow collected in the basin is pumped back to the raw water pipeline just downstream of the chemical injection vault.

The recycle pump station contains three variable-speed vertical turbine pumps, each rated at 500 gpm, which are controlled according to the desired recycle rate. The basin contains an overflow weir box and pipe to divert overflows back to the raw water pump station caisson.

3.3.9 Gravity Thickener

Sludge, containing suspended solids and chemical floc, is physically removed from the treatment plant in the settling basins of the Actiflo® process. The solids are separated from the microsand at the hydrocyclones and conveyed by gravity to the gravity thickener. While the Actiflo® process is operating, sludge flow to the thickener is continuous. Sludge is thickened from approximately 0.05 percent to 0.5 percent solids (in the Actiflo® waste stream) to 2.5 percent average solids concentration in the thickener.

Thickened sludge flows by gravity from the thickener to the sludge equalization and mixing tank, where sludge quality and quantity are equalized prior to pumping to the centrifuges. The pipeline between the thickener and mixing tank contains a motorized valve that controls sludge transfer based on an operator-set timer. The mixing tank contents are mixed with a constant-speed solids mixing pump.

A PVC standpipe is located adjacent to the mixing tank. In an emergency, the standpipe can be used to divert sludge from the mixing tank to the Irrigation Waste Pump Station. The pump station discharges to the sewer system. While this system has not been needed to date, it can be used for short-term removal of solids from the treatment plant.

Thickened sludge transfer pumps, monitored by a magnetic flowmeter, convey contents of the sludge mixing tank to the centrifuges for dewatering in conjunction with the centrifuges. Polymer is added to the thickened sludge before the centrifuges to help with dewatering.

The centrifuges are located in the two-story Solids Handling Building. The upper floor contains the mechanical equipment, and the lower floor is a pass-through for the sludge-hauling trucks. A diverter gate is located on the solids discharge chute of the centrifuges. Once the solids have reached a specified percent solid concentration, or an operator set time has elapsed, the diverter gate opens and dewatered sludge drops down into a screw conveyor trough on the underside of the upper story floor slab. The conveyor must be operating when the centrifuge is in operation to collect sludge and divert it to the conveyor chutes and into sludge collection bins (or a hauling truck in the future). Liquid recovered from the centrifuge operation (called "centrate") is conveyed by gravity to the washwater equalization basin.

3.4 Historical Plant Performance

In March 2015, plant staff provided historical operating and plant performance data. Figure 3.4 summarizes key operational and water quality performance parameters as a process flow diagram of the overall plant.

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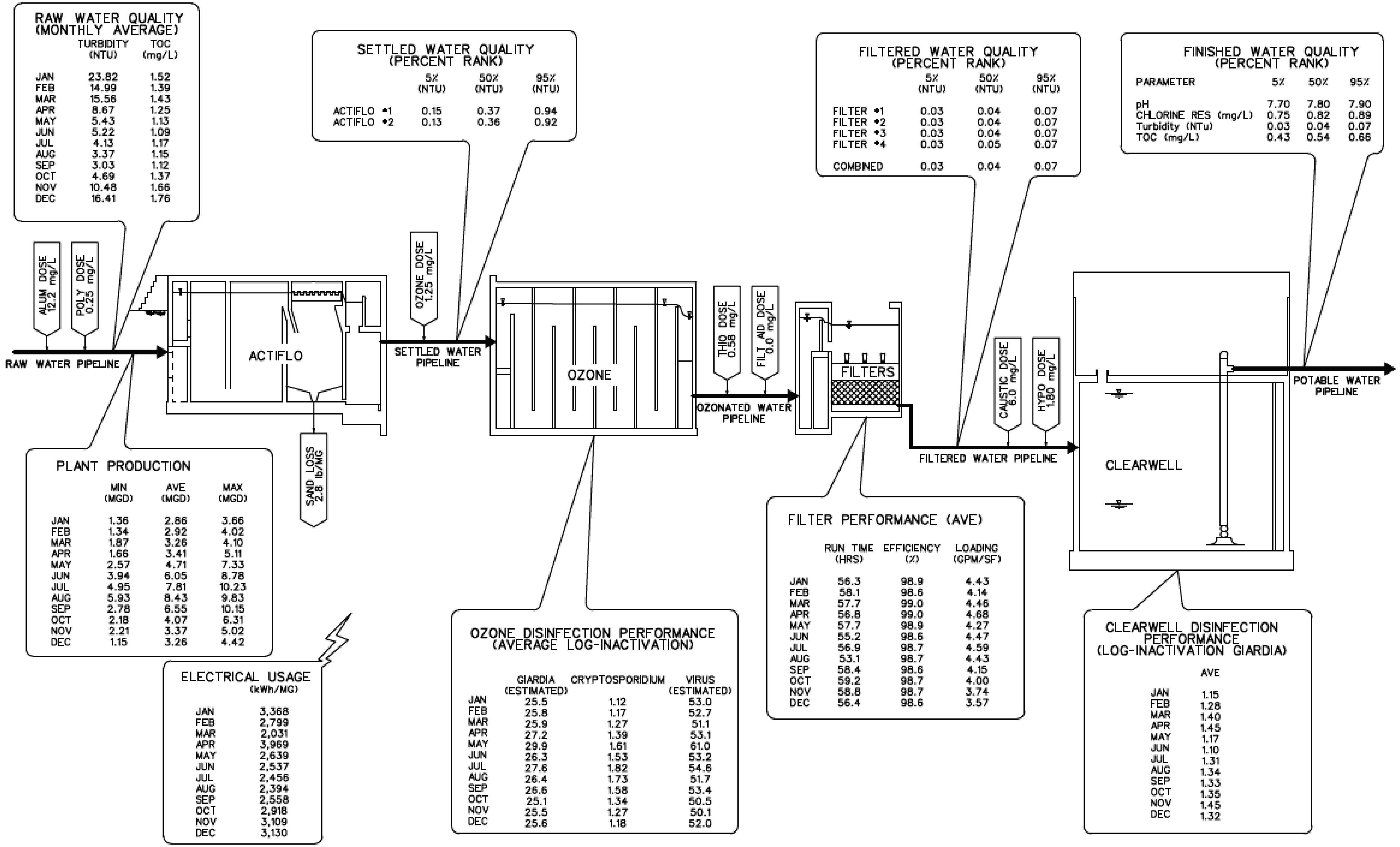

RAW WATER QUALITY (MONTHLY AVERAGE)

	TURBIDITY (NTU)	TOC (mg/L)
JAN	23.82	1.52
FEB	14.99	1.39
MAR	15.56	1.43
APR	8.67	1.25
MAY	5.43	1.13
JUN	5.22	1.09
JUL	4.13	1.17
AUG	3.37	1.15
SEP	3.03	1.12
OCT	4.69	1.37
NOV	10.48	1.66
DEC	16.41	1.76

SETTLED WATER QUALITY (PERCENT RANK)

	5% (NTU)	50% (NTU)	95% (NTU)
ACTIFLO #1	0.15	0.37	0.94
ACTIFLO #2	0.13	0.36	0.92

FILTERED WATER QUALITY (PERCENT RANK)

	5% (NTU)	50% (NTU)	95% (NTU)
FILTER #1	0.03	0.04	0.07
FILTER #2	0.03	0.04	0.07
FILTER #3	0.03	0.04	0.07
FILTER #4	0.03	0.05	0.07
COMBINED	0.03	0.04	0.07

FINISHED WATER QUALITY (PERCENT RANK)

PARAMETER	5%	50%	95%
pH	7.70	7.80	7.90
CHLORINE RES (mg/L)	0.75	0.82	0.89
Turbidity (NTu)	0.03	0.04	0.07
TOC (mg/L)	0.43	0.54	0.66

PLANT PRODUCTION

	MIN (MGD)	AVE (MGD)	MAX (MGD)
JAN	1.36	2.86	3.66
FEB	1.34	2.92	4.02
MAR	1.87	3.26	4.10
APR	1.66	3.41	5.11
MAY	2.57	4.71	7.33
JUN	3.94	6.05	8.78
JUL	4.95	7.81	10.23
AUG	5.93	8.43	9.83
SEP	2.78	6.55	10.15
OCT	2.18	4.07	6.31
NOV	2.21	3.37	5.02
DEC	1.15	3.26	4.42

ELECTRICAL USAGE

	(kWh/MG)
JAN	3,368
FEB	2,799
MAR	2,031
APR	3,969
MAY	2,639
JUN	2,537
JUL	2,456
AUG	2,394
SEP	2,558
OCT	2,918
NOV	3,109
DEC	3,130

OZONE DISINFECTION PERFORMANCE (AVERAGE LOG-INACTIVATION)

	GIARDIA (ESTIMATED)	CRYPTOSPORIDIUM	VIRUS (ESTIMATED)
JAN	25.5	1.12	53.0
FEB	25.8	1.17	52.7
MAR	25.9	1.27	51.1
APR	27.2	1.39	53.1
MAY	29.9	1.61	61.0
JUN	26.3	1.53	53.2
JUL	27.6	1.82	54.6
AUG	26.4	1.73	51.7
SEP	26.6	1.58	53.4
OCT	25.1	1.34	50.5
NOV	25.5	1.27	50.1
DEC	25.6	1.18	52.0

FILTER PERFORMANCE (AVE)

	RUN TIME (HRS)	EFFICIENCY (%)	LOADING (GPM/SF)
JAN	56.3	98.9	4.43
FEB	58.1	98.6	4.14
MAR	57.7	99.0	4.46
APR	56.8	99.0	4.68
MAY	57.7	98.9	4.27
JUN	55.2	98.6	4.47
JUL	56.9	98.7	4.59
AUG	53.1	98.7	4.43
SEP	58.4	98.6	4.15
OCT	59.2	98.7	4.00
NOV	58.8	98.7	3.74
DEC	56.4	98.6	3.57

CLEARWELL DISINFECTION PERFORMANCE (LOG-INACTIVATION GIARDIA)

	AVE
JAN	1.15
FEB	1.28
MAR	1.40
APR	1.45
MAY	1.17
JUN	1.10
JUL	1.31
AUG	1.34
SEP	1.33
OCT	1.35
NOV	1.45
DEC	1.32

GENERAL SHEET NOTES

1. RAW WATER QUALITY (MONTHLY AVERAGE) CALCULATED USING DATA FROM 2006-2014. ALL OTHER DATA PRESENTED IS FROM 2012-2014.

Figure 3.4 WRWTP Process Performance Summary

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Plant performance data was limited to a three-year period (2012 to 2014) due to the significant increase in plant production and change from batch to continuous operation once the WRWTP started serving the City of Sherwood. Parameters in the figure include monthly finished water production, electrical usage, chemical usage, sand loss, settled water, filtered water and finished water turbidity, ozone disinfection performance, filter production efficiency, and clearwell disinfection performance.

Before Sherwood took water in early 2012, the plant was operated on a daily on/off cycle for 8 to 16 hours per day to meet Wilsonville's water demands. The average annual production ranged from 2.8 to 3.2 mgd, with a peak day demand of 6.6 mgd. Since early 2012, the plant has operated continuously to meet water demand for both Wilsonville and Sherwood. During 2012 to 2014, the annual average plant production ranged from 4.5 to 4.9 mgd, with a peak day demand of 12.5 mgd. Table 3.2 shows the WRWTP production data from 2006 to 2014. Figure 3.5 shows raw water turbidity levels from January 2006 to June 2015, which have ranged from approximately 1 to 147 Nephelometric Turbidity Units (NTU).

The Actiflo® process has performed well, consistently producing clarified water with less than 0.95 NTU. Sand loss through the Actiflo® system has been relatively low (2.8 pounds per million gallons [lbs/mg]) during the evaluation period, well below the manufacturer's maximum anticipated loss of 25 lbs/mg at other Actiflo® plants on the West Coast.

The ozonation process has achieved a minimum of 1.0-log *Cryptosporidium* inactivation and greater than 3.0-log inactivation of *Giardia*, meeting the stringent requirements of the operations contract, though OHA does not grant any disinfection credit for ozonation. A minimum of 0.5-log *Giardia* inactivation is also achieved after filtration in the clearwell using free chlorine. Using the ozone system CT values and the EPA ozone disinfection tables, the plant consistently achieves greater than 8.0-log of *Giardia* removal or inactivation; OHA only requires 3.0-log of *Giardia* removal or inactivation.

Table 3.2 WRWTP Production (mgd)

Year	Annual Average	Peak Season Average(1)	Low Season Average(2)	Minimum Monthly Average		Maximum Monthly Average		Maximum Weekly Average		Maximum Daily	
				Month	Value	Month	Value	Dates	Value	Date	Value
2006	3.1	4.7	2	Feb	1.9	Jul	5.4	07/20 - 07/26	6	07/22	6.3
2007	3.2	4.8	2.2	Dec	2.1	Jul	5.3	07/10 - 07/16	5.9	07/12	6.3
2008	3.1	4.7	2.1	Jan	2.1	Jul	5.5	08/11 - 08/17	6.2	08/15	6.5
2009	3.1	4.7	2.1	Feb	2.1	Jul	5.3	07/27 - 08/02	6	08/01	6.9
2010	2.8	4.1	2.1	Jan	2	Aug	5.2	07/22 - 07/28	5.6	07/25	6.2
2011	2.8	4.2	2	Jan	2	Aug	4.9	09/02 - 09/08	5.7	08/29	6.0
2012	4.5	6.9	2.5	Jan	2.1	Aug	8.4	08/15 - 08/21	8.7	08/17	9
2013	4.8	6.9	3.3	Jan	3.2	Jul	8	08/06 - 08/12	8.4	08/06	8.8
2014	4.9	7.8	3.2	Dec	3.2	Aug	8.9	08/04 - 08/10	9.2	07/11	10.2
										07/31	12.5
										08/24	11.4

Notes:

(1) Peak season is defined as June through September.

(2) Low season is defined as December through February.

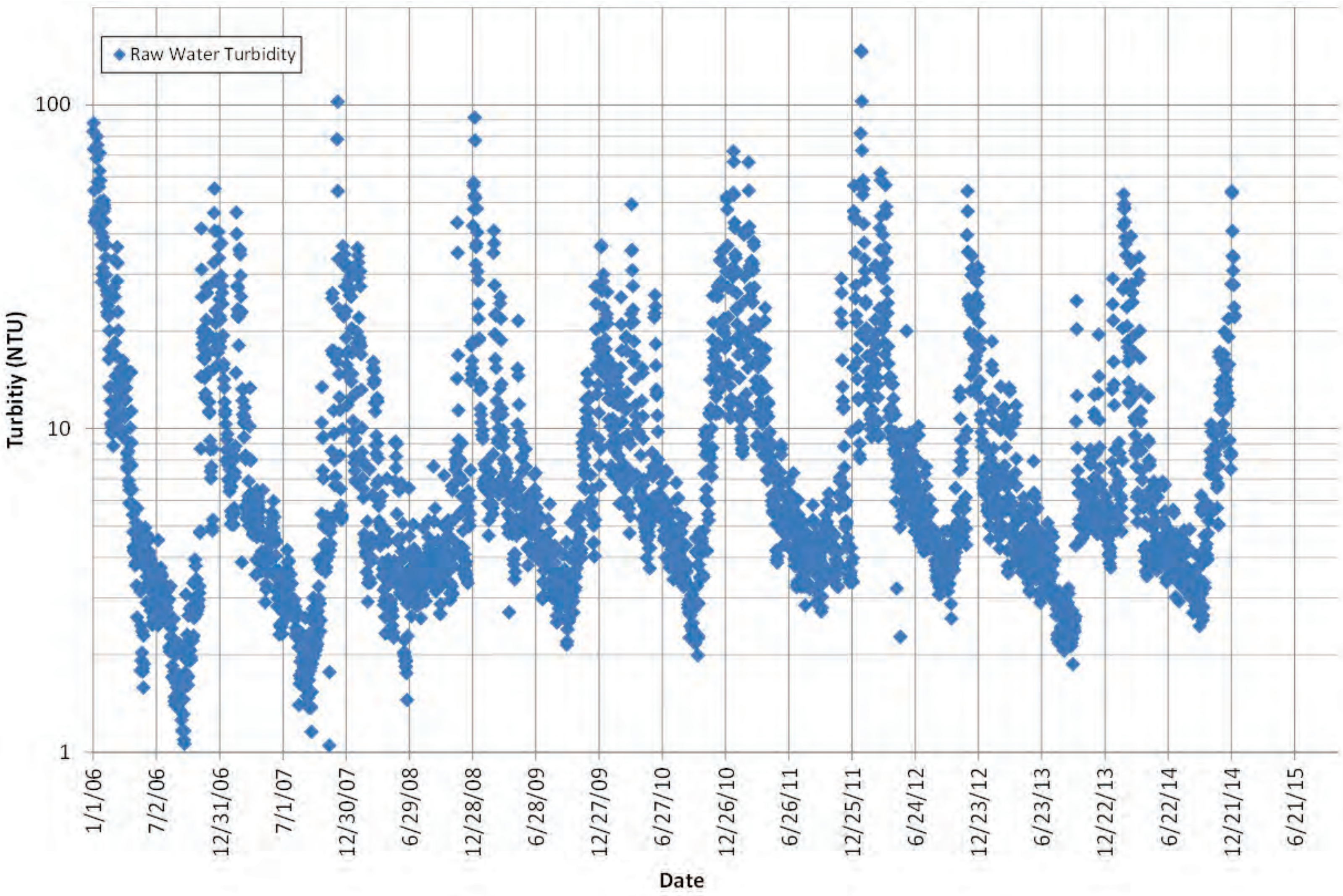

Figure 3.5 WRWTP Raw Water Turbidity

Average monthly raw water total organic carbon (TOC) levels ranged from 1.1 milligrams per liter (mg/L) to 1.8 mg/L. As shown in Figure 3.6, TOC removal is excellent, resulting in a low chlorine demand in the finished water and in the distribution systems, and low disinfection by-product (DBP) formation (based on evaluation of total trihalomethanes [TTHMs] and haloacetic acid 5 [HAA5, the sum of 5 HAA compound concentrations]). Average TOC percent removal between raw and finished water has ranged seasonally between 46 percent and 77 percent, with an average of 60 percent.

Various filter performance indicators were reviewed and analyzed, including filtered water turbidity and filter run times. Filtered water turbidities have always been less than 0.10 NTU, well below both regulatory standards and the stringent performance requirements in the operations contract. Since the plant started operating continuously in early 2012, the filtration production efficiency has been very high (>98 percent), resulting in low backwash water usage.

During 2012 to 2014, the plant used between 225 and 637 megawatt hours (mWh) per month. More power is used during the peak plant production months of June through September due to the increased pumping capacity at the raw water and finished water pump stations. The average unit power usage has been 2.7 mWh per MG produced. Figure 3.7 summarizes electrical power usage as a function of monthly finished water production.

During 2012 to 2014, the plant produced between 14 and 69 wet tons per month of dewatered alum solids (sludge). More solids are generally produced during the fall and winter months when the raw water turbidity is elevated. A single centrifuge operates 10 to 20 hours per week, typically producing dewatered solids at a concentration of greater than 25 percent. The dewatered solids are hauled to a landfill (currently Coffin Butte Landfill located north of Corvallis) via a waste management contract. The average unit solids production has been 0.2 wet tons per MG produced, or approximately 0.05 dry tons/MG assuming 25-percent solids concentration. Figure 3.8 summarizes solids production as a function of monthly finished water production.

3.5 Conclusions

The data demonstrate exceptional operational plant performance for turbidity removal, disinfection levels, TOC removal, and low DBP formation potential. The extremely narrow range between the 5 and 95 percentile value for key water quality parameters such as turbidity, pH, and chlorine residual is a testament to the plant's robust design and the operator's attention to continuous optimal performance.

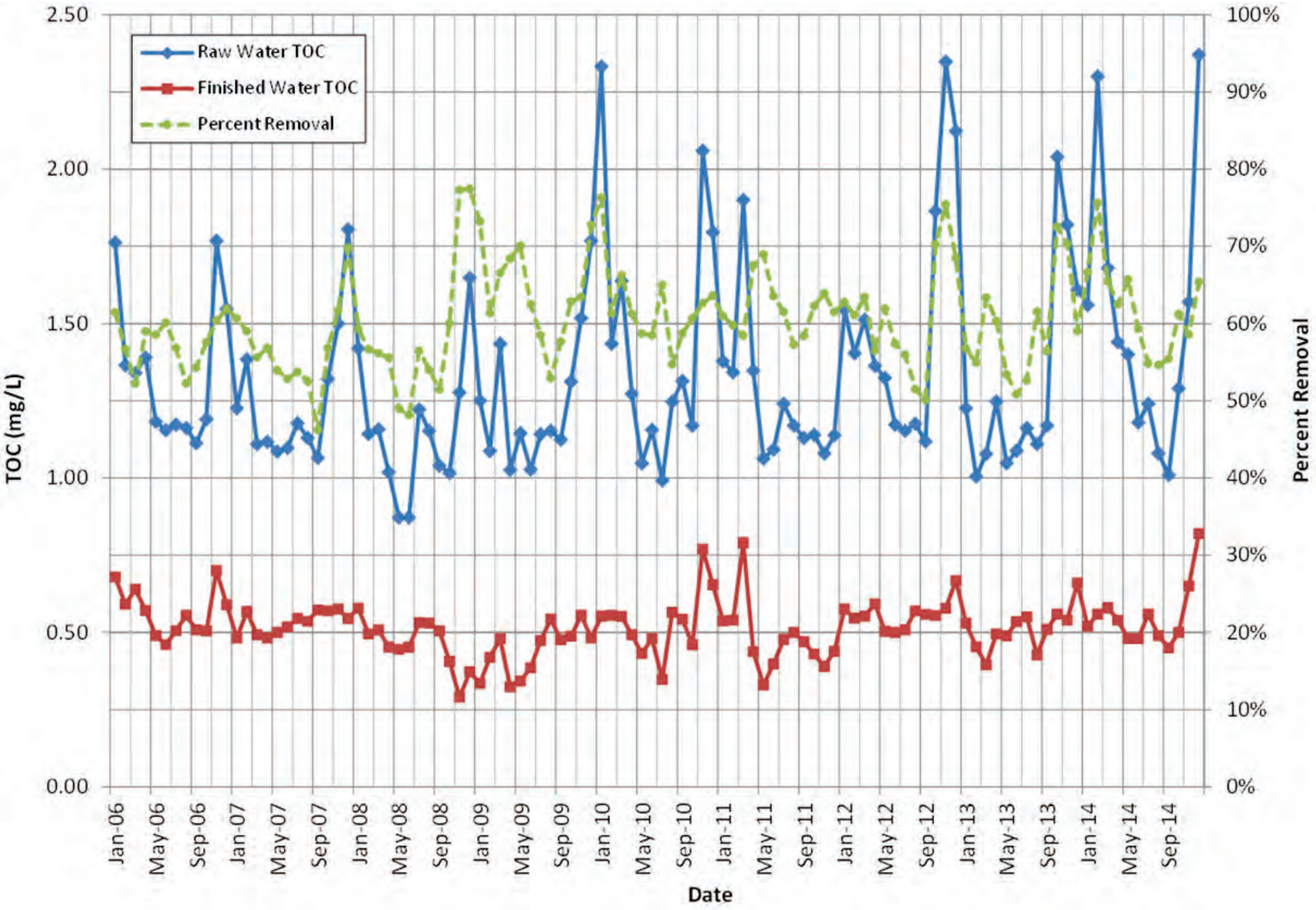

Figure 3.6 WRWTP Raw Water and Finished Water

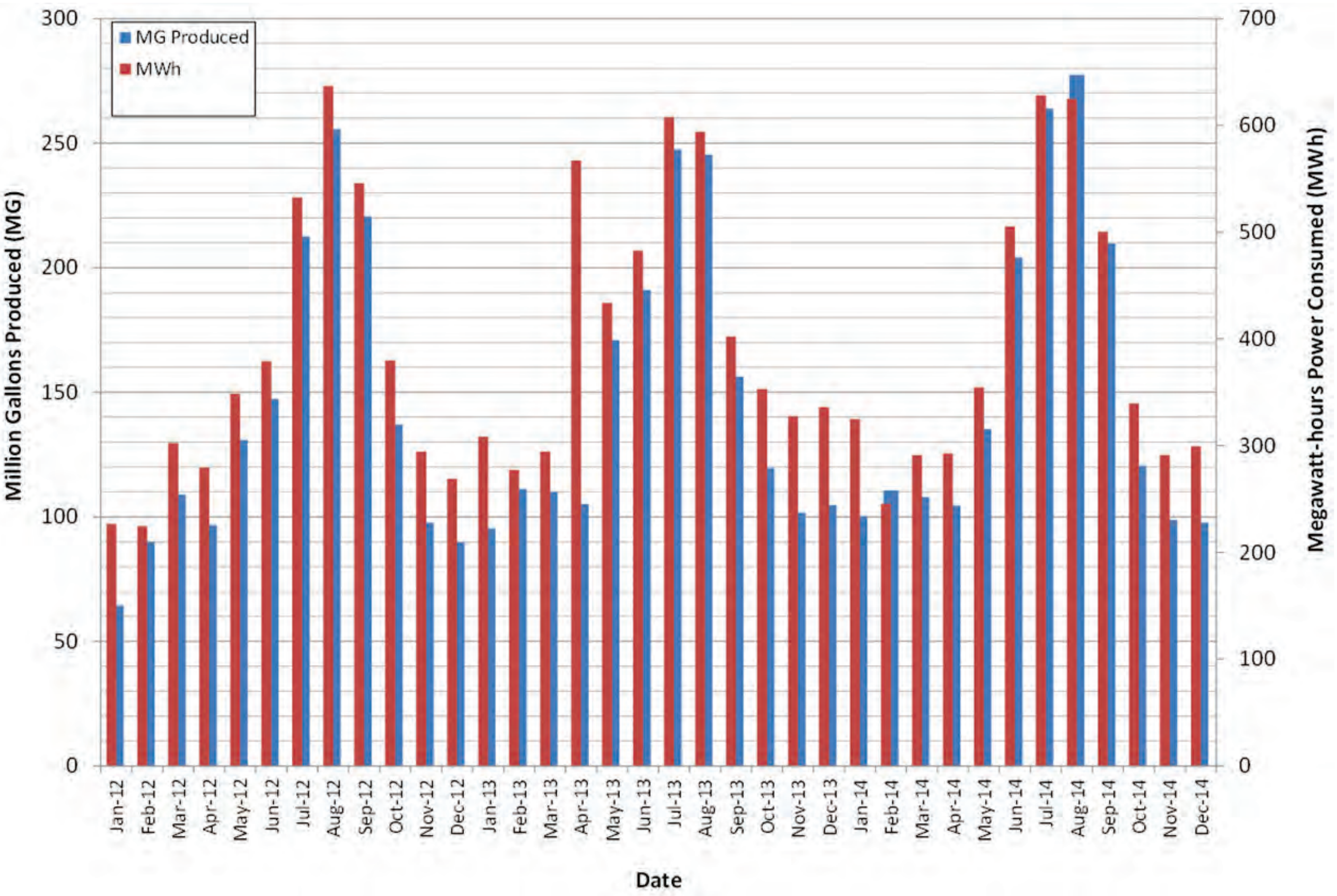

Figure 3.7 WRWTP Monthly Finished Water Production and Power Consumption

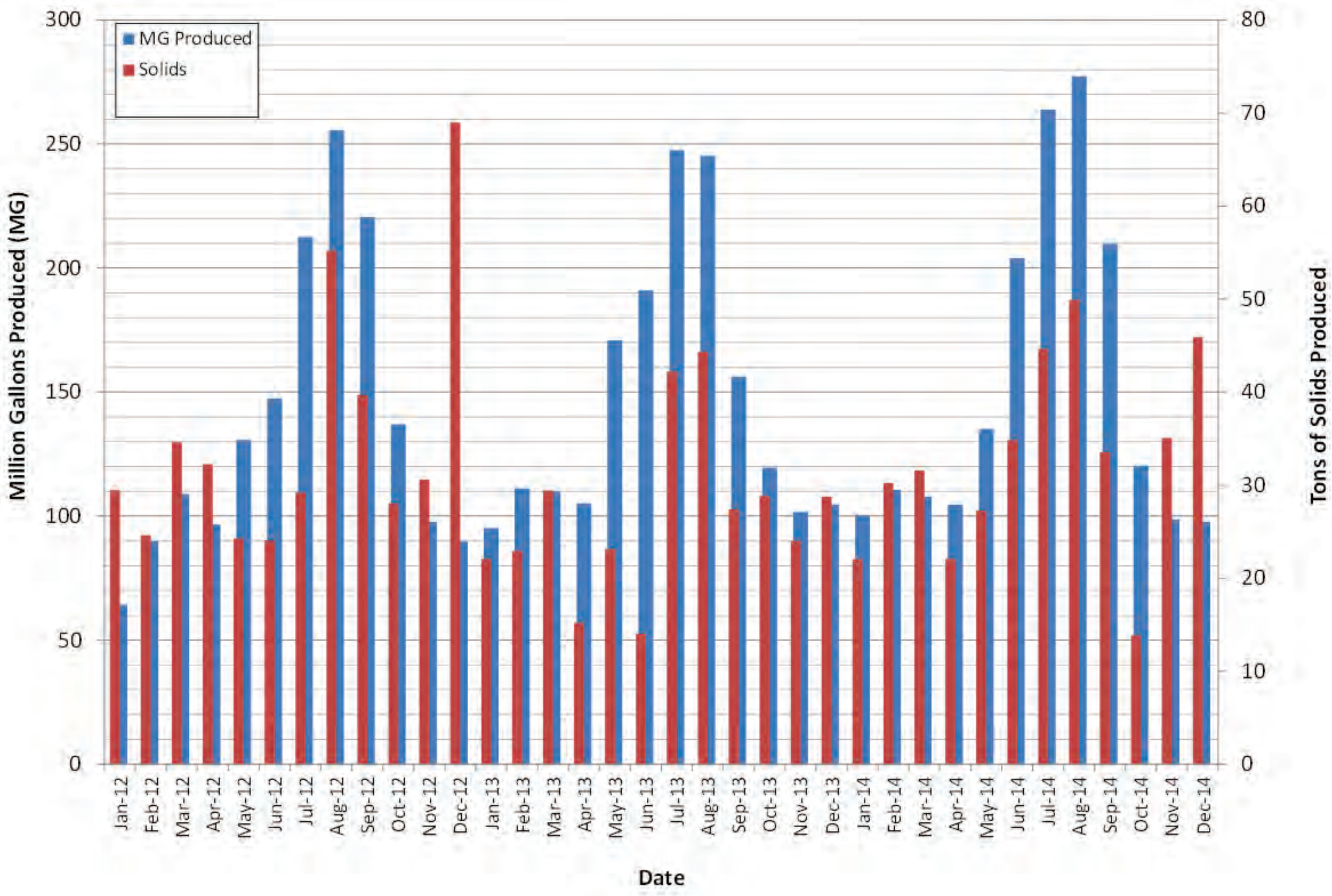

Figure 3.8 WRWTP Monthly Finished Water Production and Solids Production

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Chapter 4

HISTORICAL WATER QUALITY AND REGULATORY COMPLIANCE

4.1 Introduction

This Chapter summarizes Willamette River raw water quality, Willamette River Water Treatment Plant (WRWTP) finished water quality, and current and anticipated water quality regulations, including Contaminants of Emerging Concern (CECs). It also compares contractual and regulatory requirements. The Chapter shows raw and finished water quality data from May 2006 through December 2014; no additional water quality analysis was done for this master plan update. The 2006 Master Plan supplied data from April 2002 through April 2006.

The WRWTP was commissioned in 2002 and is operated by Veolia through an agreement with the City. For some contaminants, water quality and operational contractual requirements are more stringent than regulations require.

4.2 Historical Water Quality

The Oregon Drinking Water Quality Act (the Act) includes the Oregon Revised Statutes (ORS), with periodic amendments. Per the OHA, the Act:

- Ensures that all Oregonians have safe drinking water.
- Is a simple and effective regulatory program for drinking water systems.
- Recommends ways to improve inadequate drinking water systems.

ORS 448.131 authorizes the OHA to adopt administrative rules that ensure safe drinking water. Oregon Administrative Rule (OAR) Chapter 333 Division 061 regulates public water systems.

Table 4.1 compares the sampling frequency of finished and raw water quality to comply with OAR requirements and the Veolia operating contract.

Table 4.1 WRWTP Comparison of Regulatory and Contract Sampling Frequencies

Contaminant	OAR Requirement	Contract Requirement
Physical Chemical Inorganic Parameters		
Conductivity	-	Weekly
Temperature	-	Continuous
Total Alkalinity	-	Weekly (Daily in the winter)
Total Hardness	-	Weekly
Calcium Hardness	-	Weekly
TON	-	Weekly
Iron	-	Monthly
Turbidity	Continuous	Continuous
Particles		Continuous
Color	-	Weekly
Physical Chemical Inorganic Parameters		Continuous
Chlorine Residual	Continuous	Continuous
Total Dissolved Solids (TDS)	-	Weekly
Microbiological and Organic Parameters		
Total Coliform	40/month in Dist. Sys.	n/a
E. coli	If TC Positive	n/a
Viruses	-	Quarterly
Giardia	-	Monthly
Cryptosporidium	-	Monthly
Total Trihalomethanes	Quarterly	Monthly
Haloacetic Acids	Quarterly	Monthly
Bromate	Quarterly	Monthly
Regulated VOCs/SOCs (+dioxin)	Varies (Annually/ 3 Years)	Quarterly
Regulated IOCs	Varies (Annually/3 Years/ 9 Years)	Quarterly
Unregulated IOCs (Al, B, Cr-6, Mn, Ag, V, Zn)	-	Quarterly
TOC	Monthly	Weekly
Geosmin	-	Monthly

Table 4.1 contains the contractual requirements for finished and raw water sampling. During the project's planning stages, the City set WRWTP treated water quality goals, which have been slightly modified since the plant was commissioned.

Table 4.2 compares the contractual treated water quality goals with existing regulations from the OAR. The contractual finished water quality goal meets or exceeds regulatory requirements for all water quality parameters.

Table 4.2 Comparison of Regulatory and Contract Finished Water Parameters

Water Quality Parameter	Unit	Existing Regulations	Contract Requirement
Total/fecal coliform	MPN/100 mL	<5% positive in system	0% positive leaving plant
Turbidity	NTU	≤0.3 95% of time; Always <1.0	<0.1 each filter 95% of filter run time(1); Always <0.3
Particles (>2 µm)	Count/mL	None	<50 95% of filter run time(1)
Pathogen Removal/Inactivation			
Viruses		4-log inactivation	Provide multi-barrier 2-log removal and 2-log inactivation
Giardia		2.5-log removal and 0.5-log inactivation (post filtration)	Provide multi-barrier 3-log removal and 1-log inactivation
Cryptosporidium		2-log removal	Provide multi-barrier 3-log removal and 1-log inactivation
Disinfection By-Products(2)			
TTHMs	µg/L	80	<40
HAA5	µg/L	60	<30
Bromate	µg/L	10	<5
Synthetic Organic Chemicals (including dioxins(3))	µg/L	Varies	<detection limit
Volatile Organic Chemicals	µg/L	Varies	<detection limit
Unregulated IOCs (Al, B, Cr-6, Mn, Ag, V Zn)(3)	µg/L	Varies	<50% MCL
Alkalinity	mg/L as $CaCO_3$	None	>=20
pH		None	>=7.5 95% of time(1): Always ≥7.0
Arsenic	µg/L	2 to 10	≤2
Sulfate	mg/L	250	<MCL
TOC	mg/L	35% reduction in TOC if raw water in TOC is from 2-4 mg/L. 45% reduction if raw water TOC is from 4-8 mg/L	Same as OAR
T&O Compounds			
Geosmin	ng/L	None	<7
Odors	TON	3	<3

Notes:

(1) Within a 24-hour period from midnight to midnight.

(2) Data presented is from the finished water at the WTP effluent and not from the distribution system.

(3) Added analyses per Owner's request.

Veolia staff and the Cities of Wilsonville and Sherwood personnel helped obtain raw and finished water quality information. Along with regularly calibrating field instruments, operations staff continually monitors raw and finished water quality, the data for which is summarized in Table 4.3. The multi-barrier treatment approach at the WRWTP continues to produce finished water quality that meets or surpasses state and federal regulatory requirements. The tables show finished water quality maximum contaminant level (MCL) along with number of samples, value range, average, and median data.

The 2006–2015 raw water quality data was compared to that in the 2006 Master Plan. The few raw water contaminants detected at trace levels were not found in the finished water, meaning they were removed in the treatment process. Table 4.4 summarizes the WRWTP's finished water quality.

Table 4.3 WRWTP Summary of Raw Water Quality and Corresponding Finished Water MCL (May 2006 through 2014)

Contaminant	Unit	Finished Water MCL	No. of Samples	Value Range	Average	Median
General						
Turbidity	NTU	TT(2): ≤0.3 95% of time; Always <1.0	3,167	1-147	9	5.2
TOC	mg/L	35% reduction in TOC if raw water in TOC is from 2-4 mg/L. 45% reduction if raw water TOC is from 4-8 mg/L	104	0.9 - 2.4	1.3	1.2
Alkalinity	mg/L as $CaCO_3$	None	1,000	0 - 31.3	22.9	22.9
Secondary Contaminants						
Color	-	15 color units	457	0 - 75	12.6	10
Corrosivity(1)	-	Non-corrosive				
Foaming Agents(1)	mg/L	0.5	n/a	n/a	n/a	n/a
pH	-	6.5-8.5	3,152	6.47-7.75	7.24	7.25
Hardness	mg/L as $CaCO_3$	-	463	0 - 38.1	23.5	23.2
Odor	-	3 TON	457	0 - 12	4.1	4.7
Total Dissolved Solids (TDS)(1)	mg/L	500	n/a	n/a	n/a	n/a
Aluminum	mg/L	0.05-2	35	0 - 3.76	0.46	0.24
Chloride(1)	mg/L	250	n/a	n/a	n/a	n/a
Copper	mg/L	1 (MCL TT(2))	35	0.0052 - 0.0435	0.02	0.02
Fluoride	mg/L	2 (MCL 4.0)	35	0 - 0	0	0
Iron	mg/L	0.3	106	0 - 49.6	1.0	0.3
Manganese	mg/L	0.05	35	0.0035 - 0.169	0.02	0.01
Silver	mg/L	0.10	35	0 - 0	0	0
Sulfate	mg/L	250	35	2.5 - 9.46	4.3	3.9
Zinc	mg/L	5	35	0 - 0.0136	0.001	0

Contaminant	Unit	Finished Water MCL	No. of Samples	No. of Detects	Value Range	Median
Inorganic Contaminants (IOCs)						
Antimony	mg/L	0.006	35	1	0 - 0.00128	-
Arsenic	mg/L	0.010	35	1	0 - 0.0008	-
Barium	mg/L	2	35	35	0.00371 - 0.0268	0.0057
Beryllium	mg/L	0.004	35	1	0 - 0.00008	-
Boron	mg/L	Non-regulated	35	1	0 - 0.0543	-
Cadmium	mg/L	0.005	35	0	ND	ND
Chromium (total)	mg/L	0.1	35	6	0 - 0.00309	-
Cyanide (as free cyanide)	mg/L	0.2	35	1	0 - 0.0446	-
Lead	mg/L	TT(2)	35	2	0 - 0.00103	0
Mercury	mg/L	0.002	35	0	ND	ND
Nickel	mg/L	Non-Regulated	35	0	ND	ND
Nitrate-N	mg/L	10	35	35	0.17 - 0.74	0.37
Nitrite-N	mg/L	1	35	0	ND	ND
Selenium	mg/L	0.05	35	0	ND	ND
Sodium	mg/L	Non-regulated	35	35	3.16 - 8	4.6
Thallium	mg/L	0.002	35	0	ND	ND
Vanadium	mg/L	Non-regulated	35	23	0 - 0.0103	0.0023
Synthetic Organic Contaminants (SOCs)						
2,4-D	mg/L	0.07	35	0	ND	ND
2,4,5-TP Silvex	mg/L	0.05	35	1	0 - 0.00029	-
Bis (2ethylhexyl)adipate	mg/L	0.4	35	0	ND	ND
Alachlor	mg/L	0.002	35	0	ND	ND
Atrazine	mg/L	0.003	35	0	ND	ND
Benzo(a)pyrene	mg/L	0.0002	35	0	ND	ND
Lindane(1)	mg/L	0.0002	n/a	n/a	n/a	n/a
Carbofuran	mg/L	0.04	35	0	ND	ND
Chlordane	mg/L	0.002	35	0	ND	ND
Dalapon	mg/L	0.2	35	0	ND	ND
Dibromochloropropane (DB CP)	mg/L	0.0002	35	0	ND	ND

Table 4.3 WRWTP Summary of Raw Water Quality and Corresponding Finished Water MCL (May 2006 through 2014) – (Continued)

Contaminant	Unit	Finished Water MCL	No. of Samples	No. of Detects	Value Range	Median
Dinoseb	mg/L	0.007	35	0	ND	ND
Dioxin (2,3,7,8-TCDD)	mg/L	0.00000003	35	0	ND	ND
Diquat	mg/L	0.02	35	0	ND	ND
Endothall	mg/L	0.1	35	0	ND	ND
Endrin	mg/L	0.002	35	0	ND	ND
Ethylene Dibromide	mg/L	0.00005	35	0	ND	ND
Heptachlor	mg/L	0.0004	35	0	ND	ND
Heptachor epoxide	mg/L	0.0002	35	0	ND	ND
Hexachlorobenzene	mg/L	0.001	35	0	ND	ND
Hexachlorocyclopentadiene	mg/L	0.05	35	0	ND	ND
Methoxychlor	mg/L	0.04	35	0	ND	ND
Pentachlorophenol	mg/L	0.001	35	0	ND	ND
Bis(2-ethylhexyl)phthalate	mg/L	0.006	35	1	0 - 0.0013	-
Picloram	mg/L	0.5	35	0	ND	ND
Polychlorinated Biphenyls	mg/L	0.0005	35	0	ND	ND
Simazine	mg/L	0.004	35	0	ND	ND
Toxaphene	mg/L	0.003	35	0	ND	ND
Oxamyl(Vydate)	mg/L	0.2	35	0	ND	ND
Volatile Organic Contaminants (VOCs)						
Benzene	mg/L	0.005	35	0	ND	ND
Bromobenzene	mg/L	Non-regulated	35	0	ND	ND
Bromochlormethane	mg/L	Non-regulated	35	0	ND	ND
Bromodichlormethane	mg/L	Non-regulated	35	0	ND	ND
Bromoform	ug/L	10	35	0	ND	ND
Bromomethane	mg/L	Non-regulated	35	0	ND	ND
n-Butylbenzene	mg/L	Non-regulated	35	0	ND	ND
sec-Butylbenzene	mg/L	Non-regulated	35	0	ND	ND
tert-Butylbenzene	mg/L	Non-regulated	35	0	ND	ND
Chlorobenzene	mg/L	0.1	35	0	ND	ND
Carbon Tetrachloride	mg/L	0.005	35	0	ND	ND
Chloroethane	mg/L	Non-regulated	35	0	ND	ND
Chloroform	mg/L	Non-regulated	35	3	0 - 0.00138	-
Chloromethane	ug/L	10	35	0	ND	ND
2-Chlorotoluene	mg/L	Non-regulated	35	0	ND	ND
1,2-Dibromo- 3Chloropropane	mg/L	Non-regulated	35	0	ND	ND
Dibromochloromethane	ug/L	10	35	0	ND	ND
1,2-Dibromoethane	mg/L	Non-regulated	35	0	ND	ND
Dibromomethane	mg/L	Non-regulated	35	0	ND	ND
1,2-Dichlorobenzene	mg/L	0.6	35	0	ND	ND
1,3-Dichlorobenzene	mg/L	Non-regulated	35	0	ND	ND
1,4-Dichlorobenzene	mg/L	0.075	35	0	ND	ND
Dichlorodiflouromethane	mg/L	Non-regulated	35	0	ND	ND
1,1-Dichloroethane	mg/L	Non-regulated	35	0	ND	ND
1,2-Dichloroethane	mg/L	0.005	35	0	ND	ND
1,1-Dichloroethylene	mg/L	0.007	35	0	ND	ND
cis-1,2-Dichloroethylene	mg/L	0.07	35	0	ND	ND
trans-1,2-Dichloroethylene	mg/L	0.1	35	0	ND	ND
1,2-Dichloropropane	mg/L	0.005	35	0	ND	ND
1,3-Dichloropropane	mg/L	Non-regulated	35	0	ND	ND
2,2-Dichloropropane	mg/L	Non-regulated	35	0	ND	ND
1,1-Dichloropropene	mg/L	Non-regulated	35	0	ND	ND
cis-1,3-Dichloropropane	mg/L	Non-regulated	35	0	ND	ND
trans-1,3-Dichloropropene	mg/L	Non-regulated	35	0	ND	ND
Ethylbenzene	mg/L	0.7	35	0	ND	ND
Hexachlorobutsadiens	mg/L	Non-regulated	35	0	ND	ND
Isopropylbenzene	mg/L	Non-regulated	35	0	ND	ND
p-Isopropylbenzene	mg/L	Non-regulated	35	0	ND	ND

Table 4.3 WRWTP Summary of Raw Water Quality and Corresponding Finished Water MCL (May 2006 through 2014) – (Continued)

Contaminant	Unit	Finished Water MCL	No. of Samples	No. of Detects	Value Range	Median
Methylene Chloride	mg/L	Non-regulated	35	0	ND	ND
Napthalene	mg/L	Non-regulated	35	0	ND	ND
n-Propylbenzene	mg/L	Non-regulated	35	0	ND	ND
Styrene	mg/L	0.1	35	0	ND	ND
1,1,1,2-Tetrachloroethane	mg/L	Non-regulated	35	0	ND	ND
1,1,2,2-Tetrachloroethane	mg/L	Non-regulated	35	0	ND	ND
Tetrachloroethylene	mg/L	0.005	35	0	ND	ND
Toluene	mg/L	1	35	0	ND	ND
1,2,3-Trichlorobenzene	mg/L	Non-regulated	35	0	ND	ND
1,2,4-Trichlorobenzene	mg/L	0.07	35	0	ND	ND
1,1,1-Trichloroethane	mg/L	0.2	35	0	ND	ND
1,1,2-Trichloroethane	mg/L	0.005	35	0	ND	ND
Trichloroethylene	mg/L	0.005	35	0	ND	ND
Trichloroflouromethane	mg/L	Non-regulated	35	0	ND	ND
1,2,3-Trichlorpropane	mg/L	Non-regulated	35	0	ND	ND
1,2,4-Trimethylbenzene	mg/L	Non-regulated	35	0	ND	ND
1,3,5-Trimethylbenzene	mg/L	Non-regulated	35	0	ND	ND
Vinyl Chloride	mg/L	0.002	35	0	ND	ND
Xylenes (total)	mg/L	10	35	0	ND	ND
Dichloromethane	mg/L	0.0005	35	0	ND	ND

Contaminant	Unit	Finished Water MCL	No. of Samples	% Detected	Value Range	Median
Microbial Contaminants						
Total Coliform	MPN/100 mL	<5% positive in system	1,000	100%	1 - 11200	301
E. Coli	MPN/100 mL		1,000	98%	0 - 866	6
Viruses	MPN/100 L	4-log	35	63%	0 - 78.8	3.36
Giardia	MPN/100 L	3-log	105	13%	0 - 93.2	0
Cryptosporidium	MPN/100 L	2-log removal	105	2%	0 - 10	0

Notes:
(1) Parameter not actively sampled.
(2) TT: Treatment Technique.

Table 4.4 WRWTP Summary of Finished Water Quality (May 2006 through 2014)

Contaminant	Unit	Finished Water MCL	No. of Samples	Value Range	Average	Median
General						
Turbidity	NTU	TT(2): ≤0.3 95% of time; Always <1.0	3,167	0.02-0.06	0.04	0.04
TOC	mg/L	Non-regulated	104	0.29 - 0.82	0.51	0.54
Alkalinity	mg/L as $CaCO_3$	None	942	19 - 33.	25	25
Taste and Odor (T&O)						
Geosmin	ng/L	None	104	0 - 0	0.00	0
Secondary Contaminants						
Color	color units	15	450	0 - 5	0.01	0
pH	-	6.5-8.5	3,167	7.50-8.10	7.8	7.8
Hardness	mg/L as $CaCO_3$	250	453	16.7 - 36.2	24.0	23.5
Odor	TON	3	448	0 - 3.3	1.1	1.2
Total Dissolved Solids (TDS)	mg/L	500	453	26.2 - 91.5	63.4	63.9
Aluminum	mg/L	0.05-2	34	0 - 0.016	0.0005	0
Chloride(1)	mg/L	250	n/a	n/a	n/a	n/a
Copper	mg/L	1 (MCL TT(2))	34	0.0078 - 0.036	0.015	0.0132
Fluoride	mg/L	2 (MCL 4.0)	33	0 - 0	0	0
Iron	mg/L	0.3	104	0 - 0	0	0
Manganese	mg/L	0.05	34	0 - 0.007	0.002	0.002
Silver	mg/L	0.1	34	0 - 0	0	0
Sulfate	mg/L	250	34	7.4 - 18	10.19	9.83
Zinc	mg/L	5	34	0 - 0.0196	0.001	0

Contaminant	Unit	Finished Water MCL	No. of Samples	No. of Detects	Value Range	Median
Inorganic Contaminants (IOCs)						
Antimony	mg/L	0.006	34	0	ND	ND
Arsenic	mg/L	0.010	34	0	ND	ND
Barium	mg/L	2	34	34	0.0029 - 0.0064	0.0047
Beryllium	mg/L	0.004	34	0	ND	ND
Boron	mg/L	Non-regulated	0	0	ND	ND
Cadmium	mg/L	0.005	0	0	ND	ND
Cyanide (as free cyanide)	mg/L	0.2	34	0	ND	ND
Lead	mg/L	TT(2)	34	7	0 - 0.00171	0
Mercury	mg/L	0.002	0	0	ND	ND
Nickel	mg/L	Non-regulated	34	1	0 - 0.05	0
Nitrate-N	mg/L	10	34	34	0.16 - 0.8	0.4
Nitrite-N	mg/L	1	0	0	ND	ND
Selenium	mg/L	0.05	0	0	ND	ND
Sodium	mg/L	Non-regulated	34	34	7.6 - 15	9.4
Thallium	mg/L	0.002	0	0	ND	ND
Synthetic Organic Contaminants (SOCs)						
2,4-D	mg/L	0.07	0	0	ND	ND
2,4,5-TP Silvex	mg/L	0.05	0	0	ND	ND
Bis (2ethylhexyl)adipate	mg/L	0.4	32	0	ND	ND
Alachlor	mg/L	0.002	0	0	ND	ND
Atrazine	mg/L	0.003	0	0	ND	ND
Benzo(a)pyrene	mg/L	0.0002	33	1	0 - 0.00003	0
Lindane(1)	mg/L	0.0002	n/a	n/a	n/a	n/a
Carbofuran	mg/L	0.04	0	0	ND	ND
Chlordane	mg/L	0.002	0	0	ND	ND
Dalapon	mg/L	0.2	0	0	ND	ND
Dibromochloropropane(DB CP)	mg/L	0.0002	0	0	ND	ND
Dinoseb	mg/L	0.007	0	0	ND	ND
Dioxin (2,3,7,8-TCDD)	mg/L	0.00000003	0	0	ND	ND
Diquat	mg/L	0.02	0	0	ND	ND
Endothall	mg/L	0.1	0	0	ND	ND
Endrin	mg/L	0.002	0	0	ND	ND

Table 4.4 WRWTP Summary of Finished Water Quality (May 2006 through 2014) – (Continued)

Contaminant	Unit	Finished Water MCL	No. of Samples	No. of Detects	Value Range	Median
Ethylene Dibromide	mg/L	0.00005	0	0	ND	ND
Glyphosate	mg/L	0.7	0	0	ND	ND
Heptachlor	mg/L	0.0004	0	0	ND	ND
Heptachor epoxide	mg/L	0.0002	0	0	ND	ND
Hexachlorobenzene	mg/L	0.001	33	0	ND	ND
Hexachlorocyclopentadiene	mg/L	0.05	0	0	ND	ND
Methoxychlor	mg/L	0.04	0	0	ND	ND
Pentachlorophenol	mg/L	0.001	0	0	ND	ND
Bis(2-ethylhexyl)phthalate	mg/L	0.006	31	0	ND	ND
Picloram	mg/L	0.5	0	0	ND	ND
Polychlorinated Biphenyls	mg/L	0.0005	0	0	ND	ND
Simazine	mg/L	0.004	0	0	ND	ND
Toxaphene	mg/L	0.003	0	0	ND	ND
Oxamyl(Vydate)	mg/L	0.2	0	0	ND	ND
Volatile Organic Contaminants (VOCs)						
Benzene	mg/L	0.005	0	0	ND	ND
Bromobenzene		Non-regulated	35	0	ND	ND
Bromochlormethane		Non-regulated	35	0	ND	ND
n-Butylbenzene		Non-regulated	34	0	ND	ND
sec-Butylbenzene		Non-regulated	34	0	ND	ND
tert-Butylbenzene		Non-regulated	33	0	ND	ND
Carbon Tetrachloride	mg/L	0.005	34	0	ND	ND
Chlorobenzene	mg/L	0.1	34	0	ND	ND
Chloroethane		Non-regulated	34	0	ND	ND
2-Chlorotoluene		Non-regulated	34	0	ND	ND
4-Chlorotoluene		Non-regulated	35	0	ND	ND
1,2-Dibromo- 3Chloropropane		Non-regulated	33	0	ND	ND
1,2-Dibromoethane		Non-regulated	35	0	ND	ND
Dibromomethane		Non-regulated	34	0	ND	ND
1,2-Dichlorobenzene	mg/L	0.6	34	0	ND	ND
1,3-Dichlorobenzene		Non-regulated	34	0	ND	ND
1,4-Dichlorobenzene	mg/L	0.075	34	0	ND	ND
Dichlorodiflouromethane		Non-regulated	33	0	ND	ND
1,2-Dichloroethane	mg/L	0.005	34	0	ND	ND
1,1-Dichloroethylene	mg/L	0.007	34	0	ND	ND
cis-1,2-Dichloroethylene	mg/L	0.07	34	0	ND	ND
trans-1,2-Dichloroethylene	mg/L	0.1	34	0	ND	ND
1,2-Dichloropropane	mg/L	0.005	34	0	ND	ND
1,3-Dichloropropane		Non-regulated	34	0	ND	ND
2,2-Dichloropropane		Non-regulated	34	0	ND	ND
1,1-Dichloropropene		Non-regulated	34	0	ND	ND
cis-1,3-Dichloropropane		Non-regulated	34	0	ND	ND
trans-1,3-Dichloropropene		Non-regulated	33	0	ND	ND
Ethylbenzene	mg/L	0.7	34	0	ND	ND
Hexachlorobutsadiens		Non-regulated	33	0	ND	ND
Isopropylbenzene		Non-regulated	34	0	ND	ND
p-Isopropylbenzene		Non-regulated	34	0	ND	ND
Methylene Chloride		Non-regulated	35	0	ND	ND
Napthalene		Non-regulated	35	0	ND	ND
n-Propylbenzene		Non-regulated	33	0	ND	ND
Styrene	mg/L	0.1	34	0	ND	ND
1,1,1,2-Tetrachloroethane		Non-regulated	33	0	ND	ND
1,1,2,2-Tetrachloroethane		Non-regulated	34	0	ND	ND
Tetrachloroethylene	mg/L	0.005	34	0	ND	ND
Toluene	mg/L	1	34	0	ND	ND
1,2,3-Trichlorobenzene		Non-regulated	33	0	ND	ND
1,2,4-Trichlorobenzene	mg/L	0.07	34	0	ND	ND

Table 4.4 WRWTP Summary of Finished Water Quality (May 2006 through 2014) – (Continued)

Contaminant	Unit	Finished Water MCL	No. of Samples	No. of Detects	Value Range	Median
1,1,1-Trichloroethane	mg/L	0.2	34	0	ND	ND
1,1,2-Trichloroethane	mg/L	0.005	34	0	ND	ND
Trichloroethylene	mg/L	0.005	33	0	ND	ND
Trichloroflouromethane		Non-regulated	33	0	ND	ND
1,2,4-Trimethylbenzene		Non-regulated	35	0	ND	ND
1,3,5-Trimethylbenzene		Non-regulated	33	0	ND	ND
Vinyl Chloride	mg/L	0.002	34	0	ND	ND
Xylenes (total)	mg/L	10	34	0	ND	ND
Disinfectant Residuals and Disinfection Byproducts (DBPs)						
Bromate	mg/L	0.01	104	22	0 - 0.0044	0
Bromoform	ug/L	10	35	0	ND	ND
Chloroform		Non-regulated	34	33	0 - 0.014	0.0049
Dibromochloromethane	ug/L	10	34	19	0 - 0.00134	0.00056
Dichloromethane	mg/L	0.00050	34	19	0 - 0.00134	0.00056
Bromodichlormethane		Non-regulated	35	34	0 - 0.00401	0.00176
Chlorine	mg/L	4.0	941	941	0.64 - 0.95	0.81
TTHM	mg/L	0.08	104	104	0.00261 - 0.0171	0.007095
HAA5	mg/L	0.06	104	95	0 - 0.0123	0.00473
Contaminant	Unit	Finished Water MCL	No. of Samples	% Detected	Value Range	Median
Microbial Contaminants						
Total Coliform	MPN/100 mL	<5% positive	940	0%	ND	ND
E. Coli	MPN/100 mL		941	0%	ND	ND
Viruses	MPN/100 L	2-log removal/2-log inactivation	36	0%	ND	ND
Giardia	MPN/100 L	2.5-log removal/ 0.5-log inactivation	14	0%	ND	ND
Cryptosporidium	MPN/100 L	2-log removal	14	0%	ND	ND

Notes:

(1) Parameter not actively sampled.

(2) TT: Treatment Technique.

All contaminants detected in the finished water were well below their respective MCLs. The WRWTP's finished water quality continues to meet or surpass regulatory requirements. Section 4.3.3 summarizes additional finished water quality data, collected in compliance with the Unregulated Contaminant Monitoring Rule (UCMR).

Data shown in Tables 4.1 through 4.4 were collected at the WRWTP. Table 4.5 gives the distribution system water quality, as reported in the City of Wilsonville *2014 Annual Water Quality Report.*

Table 4.5 Summary of Wilsonville Distribution System Water Quality Data

Contaminant	Sample Frequency	Minimum	Average	Maximum
VOCs				
TTHM	Quarterly	1.3	13.7	25.8
HAA5	Quarterly	2.1	8.3	18
Bromate	Monthly	ND		3.6
TOC	Quarterly	0.416	0.552	0.608
Chlorine	Monthly	0.35		0.98

All contaminants in Table 4.5 are below the MCL and maximum contaminant level goal (MCLG) as applicable, further illustrating reliable finished water quality for the WRWTP and distribution system.

4.3 Regulatory Compliance

4.3.1 Existing Regulations

The WRWTP must comply with the following current state and federal drinking water regulations.

- National Primary Drinking Water Regulations (1975).
- Secondary Drinking Water Regulations (1979, 1991).
- Phase I, II, and V Regulations for IOCs, SOCs, and VOCs (1987, 1991, 1992; respectively).
- Surface Water Treatment Rule (1989).
- Total Coliform Rule (1989).
- Lead and Copper Rule (1991).
- Consumer Confidence Reports Rule (1998).
- Stage 2 Disinfection By-Product Rule (State 2 D/DBPR) (2006).
- Long-Term Stage 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) (2006).

4.3.2 Unregulated Contaminant Monitoring

The EPA uses the Unregulated Contaminant Monitoring (UCM) program to collect data for contaminants that are suspected in drinking water but lack health-based standards set by the Safe Drinking Water Act (SDWA). Every five years, the EPA reviews the list of contaminants, largely based on the Contaminant Candidate List. The SDWA Amendments of 1996 provide for:

- Monitoring no more than 30 contaminants every five years.
- Monitoring only a representative sample of public water systems serving fewer than 10,000 people.

- Storing analytical results in a National Contaminant Occurrence Database (NCOD).

The EPA manages the UCM program as specified in the UCMR. Historically, the program has progressed in several stages:

- UCM – State Rounds 1&2 (1988-1997) - State drinking water programs managed the original program and required public water systems (PWSs) serving more than 500 people to monitor contaminants.
- UCMR 1 (2001-2005) - The SDWA Amendments of 1996 redesigned the UCM program to incorporate a tiered monitoring approach and require monitoring for 25 contaminants (24 chemicals and one bacterial genus) during 2001-2003.
- UCMR 2 (2007-2011) - Established a new set of 25 chemical contaminants sampled during 2008-2010; EPA began monitoring UCMR 2 compliance.
- UCMR 3 (2012-2016) - Current regulation requires monitoring for 30 contaminants (28 chemicals and 2 viruses) from 2012-2015. These contaminants are separated into three lists. All public water systems serving populations >10,000 required to sample for List 1 (21 contaminants), and public water systems serving populations >100,000 required to sample for List 1 and List 2 (7 hormones). Unchlorinated public water systems with populations <1,000 required to sample for two viruses as part of List 3.
- UCMR 4 takes effect in 2018. The EPA administrator signed UCMR 4 on December 8, 2016, and the EPA submitted it for publication in the Federal Register. UCMR 4 requires monitoring 30 chemical contaminants between 2018 and 2022, including the following:
    - Ten cyanotoxin chemical contaminants.
    - Two metals.
    - Eight pesticides and one pesticide manufacturing by-product.
    - Three brominated haloacetic acid (HAA) groups.
    - Three alcohols.
    - Three semi-volatile chemicals.
    - One metal.

Table 4.6 summarizes the UCMR 3 data collected for Wilsonville's distribution system and compares it to the other water utilities in Oregon and Washington. Water samples were collected at the distribution system entry point downstream of WRWTP (at the maximum residence time point) and compared to the other drinking water utilities in Oregon and Washington.

Table 4.6 Summary of UCMR 3 Finished and Distribution Water Quality

Contaminant	Range of Detects OR/WA (ug/L)	Range of Detects Wilsonville (ug/L)
List 1		
1,1-dichloroethane	0.036	-
1,2,3-trichloropropane	-	-
1,3-butadiene	-	-
1,4-dioxane	0.07-0.28	-
bromomethane	-	-
chlorate	20-3,000	43-130
chloromethane	0.2-2.2	-

Table 4.6 Summary of UCMR 3 Finished and Distribution Water Quality (Continued)

Contaminant	Range of Detects OR/WA (ug/L)	Range of Detects Wilsonville (ug/L)
chromium	0.2-55	0.2
chromium-6 (Cr-6)	0.03-4.0	0.038-0.072
cobalt	1.8-1.9	-
Halon 1011	0.087-1.0	-
HCFC-22	0.088-0.67	-
manganese	1-820	
molybdenum	1-13	-
PFBS	-	-
PFHpA	0.013-0.026	-
PFHxS	0.20-0.24	-
PFNA	0.027-0.028	-
PFOA	0.02-0.03	-
PFOS	0.51-0.60	-
strontium	0.9-531	36-41
vanadium	0.2-41.9	1.0-2.5
List 2 (*not required for Wilsonville*)		
17-alpha-ethynylestradiol	-	N/A
17-beta-estradiol	-	N/A
4-androstene-3,17-dione	0.0004	N/A
equilin	-	N/A
estriol	-	N/A
estrone	-	N/A
testosterone	0.0005	N/A

Of the UCMR 3 contaminants sampled for Wilsonville's distribution system, only select metals and chlorate were detected at levels similar to those seen regionally and nationally. For additional information, see the discussion on *emerging contaminants* below. The concentration of detected contaminants is well below current published health reference levels and public heath goals.

4.3.3 Contact Time Compliance

The WRWTP has always met the regulatory requirement of a minimum of 0.5-log *Giardia* inactivation downstream of filtration. As a contract requirement, the WRWTP has also met a minimum of 1.0-log *Cryptosporidium* inactivation using intermediate ozone.

Although the OHA does not recognize the use of intermediate ozone for *Giardia* or virus inactivation, the contact time (CT) required to achieve *Cryptosporidium* inactivation causes an excess of 10-fold inactivation of *Giardia* and viruses. The Ozone Coalition, supported by Oregon Water Utility Council (OWUC), has petitioned the OHA to change its rules by recognizing the disinfection benefits of pre- or intermediate ozone disinfection in Oregon. This petition coincides with this 2017 MPU and is ongoing. A formal waiver application is planned for submission in spring 2018. If the collaboration changes the regulations, the CT compliance point for the WRWTP should be reevaluated.

4.3.4 Future Regulations

Although not expected to affect treatment process recommendations, several federal regulations are under development:

- **Lead and Copper Rule (LCR).** EPA is considering Long-Term Revisions to the LCR to further protect public health and streamline the rule's requirements. EPA's primary goals in considering LCR Long-Term Revisions are to:
  - Improve the effectiveness of corrosion control treatment in reducing exposure to lead and copper.
  - Trigger additional actions that equitably reduce the public's exposure to lead and copper when corrosion control treatment alone is not effective.
- **Perchlorate**. Perchlorate is a naturally-occurring and manufactured chemical anion that consists of one chlorine atom bonded to four oxygen atoms (ClO_4-). It is commonly used as an oxidizer in rocket propellants, fireworks, airbag initiators for vehicles, matches, and signal flares. In 2011, the EPA determined that perchlorate meets the Safe Drinking Water Act (SDWA) criteria for regulation as a contaminant. Since then, the EPA has been reviewing the best available scientific data on a range of issues related to perchlorate in drinking water, including its occurrence, treatment technologies, analytical methods, and the costs and benefits of potential standards.

4.4 Emerging Contaminants

Numerous papers and presentations have documented a multitude of CECs in water supplies throughout the United States and elsewhere. Although the impacts of CECs are not fully understood, it is clear that drinking water regulations will change as more data is gathered via the UCM efforts (the current UCMR 3 and the future UCMR 4). This section focuses on the UCMR program, which likely encompasses future regulations. This chapter also discusses site-specific compounds of interest.

Typically characterized as particles of less than 100 nanometers (nm), manufactured nanomaterials can be found in electronics, personal care products, medical supplies, clothing, and other household items. They can help impart disinfectant/antimicrobial properties (nanosilver), are used in ultraviolet (UV) protection (nanoscale zinc oxide/titanium dioxide), and provide unique optical/electrical properties.

Although increased use of manufactured nanomaterials may introduce them to surface water supplies via stormwater runoff, industrial, and/or wastewater treatment plant discharges, research on the long-term impacts on public health and the environment is limited. Because the topic is nascent and the EPA has yet to take further action, this Chapter does not consider nanomaterials in its review.

The potential for CECs to be present in the Willamette River also needs to be better understood. CECs can influence the expanded WRWTP treatment process and procedure selection, capital and operations/maintenance costs, and water quality monitoring requirements. To better account for these impacts, CECs were evaluated from national, regional, and local perspectives. Summarized below, this evaluation includes a review of recent literature, such as articles in national trade journals, a summary of data obtained from the national EPA UCMR 3 database, consultation with national water quality experts, and a summary of interviews with various local and regional water suppliers.

4.4.1 National Perspective and Literature Review

To quantify the occurrence of CECs throughout the United States, Carollo reviewed pertinent literature and the data from the National EPA Database summarizing UCMR 3 sampling results. Table 4.7 summarizes the results of this review.

Chlorate, vanadium, strontium, molybdenum, trichloropropane, and dioxane are the predominant contaminants. The prevalence of low levels of chlorate in drinking water is likely tied to widespread use of sodium hypochlorite, which in the past decade has replaced chlorine gas as the preferred chlorine chemical.

Low levels of some metals occur in various parts of the country, including the three most common--vanadium, strontium, and molybdenum--which occur naturally in some water supplies. Of the 14 compounds being tested in UCMR 3, 2 organic compounds (trichloropropane, a VOC, and dioxane, an SOC) were found in drinking water supplies across the nation, albeit at very low concentrations.

Although not part of the UCMR 3 testing, harmful algal blooms (HABs) and algal toxins captured national attention after a 2015 algal bloom on Lake Erie resulted in a "Do Not Use" order in Toledo, OH. Algal toxin monitoring will likely become a requirement for the upcoming UCMR 4 since the proposed list includes ten cyanotoxin chemical contaminants.

Table 4.7 Summary of Preliminary UCMR 3 Results(1)

Contaminant	MRL(2) (ug/L)	Reference Concentration (ug/L)(3)	Total Number of Results	Results >MRL %	Results >HRL(2) %	Total # of PWSs with Results	PWSs with Results >MRL %	PWSs with Results >HRL %
Oxyhalide Anion								
Chlorate	20	210	25,533	56.2	14.4	2,648	67.3	32.4
Metals								
Vanadium	0.2	21	25,683	60.8	2.9	2,640	69.8	3.3
Strontium	0.3	4,000	25,635	99.5	0.4	2,640	100	0.9
Molybdenum	1	40	25,685	42.6	0.5	2,640	50.7	0.6
SOCs								
1,2,3-Trichloropropane	0.03	0.0004/0.042	15,145	0.8	0.7-0.8	2,626	1.5	1.2-1.5
VOCs								
1,4-Dioxane	0.07	0.35/352	15,084	11.4	0-3.3	2,623	19.7	0-6.6

Notes:

(1) Russell, C. "Status of Unregulated Contaminant Monitoring Rule 3 (UCMR 3)." Journal AWWA March 2015: 43-44. Print.

(2) HRL - health reference level; MRL - minimum reporting level.

(3) For reference concentrations with two values, first value is associated with 10-6 cancer risk and second is associated with a 10-4 cancer risk. Single values refer to contaminants with non-cancer reference values.

4.4.2 Regional Perspective

For a regional perspective on CEC-related issues, Carollo interviewed four regional utilities to collect and compile results from UCMR 3 testing and discuss issues of water quality, such as public concerns. Several of these utilities are now using or are considering using the Willamette River as a supply source. For all agencies, the primary question was, "In what way will CEC-related issues influence the agency's decisions regarding water treatment in the future?"

Appendix A of the 2015 MPU includes a copy of the interview questionnaire, and Table 4.8 summarizes the results. These regional UCMR 3 testing results are consistent with national findings for chlorate, strontium, and vanadium. However, they differ from national results since Pacific Northwest (PNW) utilities detected total and hexavalent chromium but not molybdenum, VOCs, or SOCs. Furthermore, most utilities have expressed concerns about algae and algal toxins, and some are concerned about the potential for regulating perchlorate/chlorate and chromium/hexavalent chromium.

Table 4.8 Summary of CECs Interview Responses by Regional Surface Water Suppliers

Water Supplier	Source of Supply	UCMR 3 Detects	Comments/Concerns - Re: CECs
Oak Lodge Water District	Clackamas River	Chlorate Total chromium Hexavalent chromium Strontium Vanadium	Concern about algal toxins, non-point source pollution.
City of Corvallis	Willamette River and Rock Creek Reservoir	Chlorate Total chromium Hexavalent chromium Strontium Vanadium	Algal toxins. Dioxins were of concern historically (no recent detects).
Tacoma Water	Green River	Total chromium Hexavalent chromium Strontium Vanadium No hormones detected	Will begin algal toxin monitoring and additional surveillance for algae in reservoir/source water.
Seattle Public Utilities	Cedar River and Tolt Reservoir	Total chromium Hexavalent chromium Strontium Vanadium No hormones detected	Algae in source water/reservoirs. Have performed PPCP testing (hormones) with no detects. Observation that chlorate levels are related to disinfectant usage; chlorine gas vs. sodium hypochlorite.
Eugene Water and Electric Board	McKenzie River	Chlorate Total chromium Hexavalent chromium Strontium Vanadium	Algal toxins.

Note that Seattle, Tacoma, and Eugene Water and Electric Board (EWEB) are large enough to be required to test both List 1 and List 2 contaminants for the UCMR 3. No hormones were detected in any of their supplies. Furthermore, other Pacific Northwestern utilities are concerned about algae and algal toxins: several in Tacoma and Bellingham, Washington, and one along the South Umpqua River in Oregon. This summary does not review these studies, but they should be considered in future design efforts.

4.4.3 2015 MPU Participant Interviews

Representatives were interviewed for each 2015 MPU participant potentially receiving water from the WWSP WTP. Discussions focused on each agency's concerns about using the Willamette River as a supply, as shown in Table 4.9. In addition, UCMR 3 data was discussed for each agency's current sources of supply.

Table 4.9 Summary of CECs Interview Responses by 2015 MPU Participant Water Suppliers

Water Supplier	Source of Supply	UCMR 3 Detects	Comments/Concerns - Re: CECs
City of Beaverton	JWC WTP, ASR	n/a	n/a
City of Hillsboro	JWC WTP	Total chromium Hexavalent chromium Strontium Vanadium	No chlorate detects, presumably due to use of chlorine gas at JWC WTP. Source water monitoring program to address algae or other changes in water quality.
City of Sherwood	WRWTP, PWB	Chlorate Total chromium Hexavalent chromium Strontium Vanadium	Limited complaints since switching to using Willamette River WTP as primary supply.
City of Tigard	PWB, LOTWTP, ASR	Chlorate Total chromium Hexavalent chromium Strontium Vanadium	Noticed that chlorate was tied to ASR well sites that use sodium hypochlorite for disinfection.
TVWD	PWB, JWC WTP, ASR	Total chromium Hexavalent chromium Strontium Vanadium Chlorate	Concern about algal toxins. Public perception about source switch and impacts to distribution system. No hormones were detected.
City of Wilsonville	WRWTP	Chlorate Total chromium Hexavalent chromium Strontium Vanadium	Some concern about potential strontium regulations. Levels of UCMR 3 detects well below published health reference goals.

Of all the participants, only TVWD was large enough to require testing for both List 1 and List 2 from the UCMR 3. No hormones were detected.

From all interviews and data collected for UCMR 3, the highest-profile CECs which should be seriously considered for the WRWTP are:

- Algal toxins.
- Chromium/hexavalent chromium.
- Vanadium and/or strontium.
- Chlorate.
- Low concentrations of site-specific trace organic compounds.

4.5 Conclusion

Historical water quality data confirms that the plant consistently meets or surpasses existing finished water regulatory requirements. The high-quality source water and robust treatment process produce excellent finished water in the region. With minor modifications, the current process train, with the built-in capability of adding UV or advanced oxidation (by adding hydrogen peroxide in conjunction with either ozone or UV treatment), or the implementation of biological filtration is expected to meet future regulatory requirements. See Chapter 6 for additional discussion on this topic.

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Chapter 5

EXISTING INFRASTRUCTURE

5.1 Introduction

This chapter summarizes the Willamette River Water Treatment Plant (WRWTP) infrastructure and lays the groundwork for evaluating future expansion alternatives. The following topics are discussed:

- Site mapping
- Hydraulic assessment
- Electrical assessment
- Seismic evaluation and mitigation alternatives
- Life safety analysis
- Transient surge analysis

Additional analyses, such as river surveying, major plant component evaluation, computational fluid dynamic evaluation of the raw water pump station, and a geotechnical investigation, are found in Chapter 5 of the 2015 MPU.

5.2 Site Mapping

In June 2015, Compass Land Surveyors, using the North American Vertical Datum (NAVD) 1988, identified utility locations for the WRWTP. The work was coordinated with record drawings and input from Veolia staff. Figure 5.1 shows pertinent features for the existing site.

Included in the site mapping was a multi-beam bathymetric survey of the Willamette River from approximately one mile downstream to approximately 1/4-mile upstream of the existing raw water intake. This information helped to support the river hydrology analysis and HEC-RAS modeling.

To determine expected flows and elevations at the raw water intake, a hydrological model was developed in 2015 for the mid-Willamette River. The river stage (elevation) data from the United States Geological Survey (USGS) stations was in the National Geodetic Vertical Datum of 1929 (NGVD 29). To match the new site and bathymetric survey, the data were converted to NAVD 88, using a conversion factor consistent with that used by the Federal Emergency Management Agency (FEMA) in 2008 to update its Wilsonville flood plain mapping elevations. The resulting offset is +3.5 feet when going from NGVD 29 to NAVD 88 (NGVD29+3.5=NAVD88).

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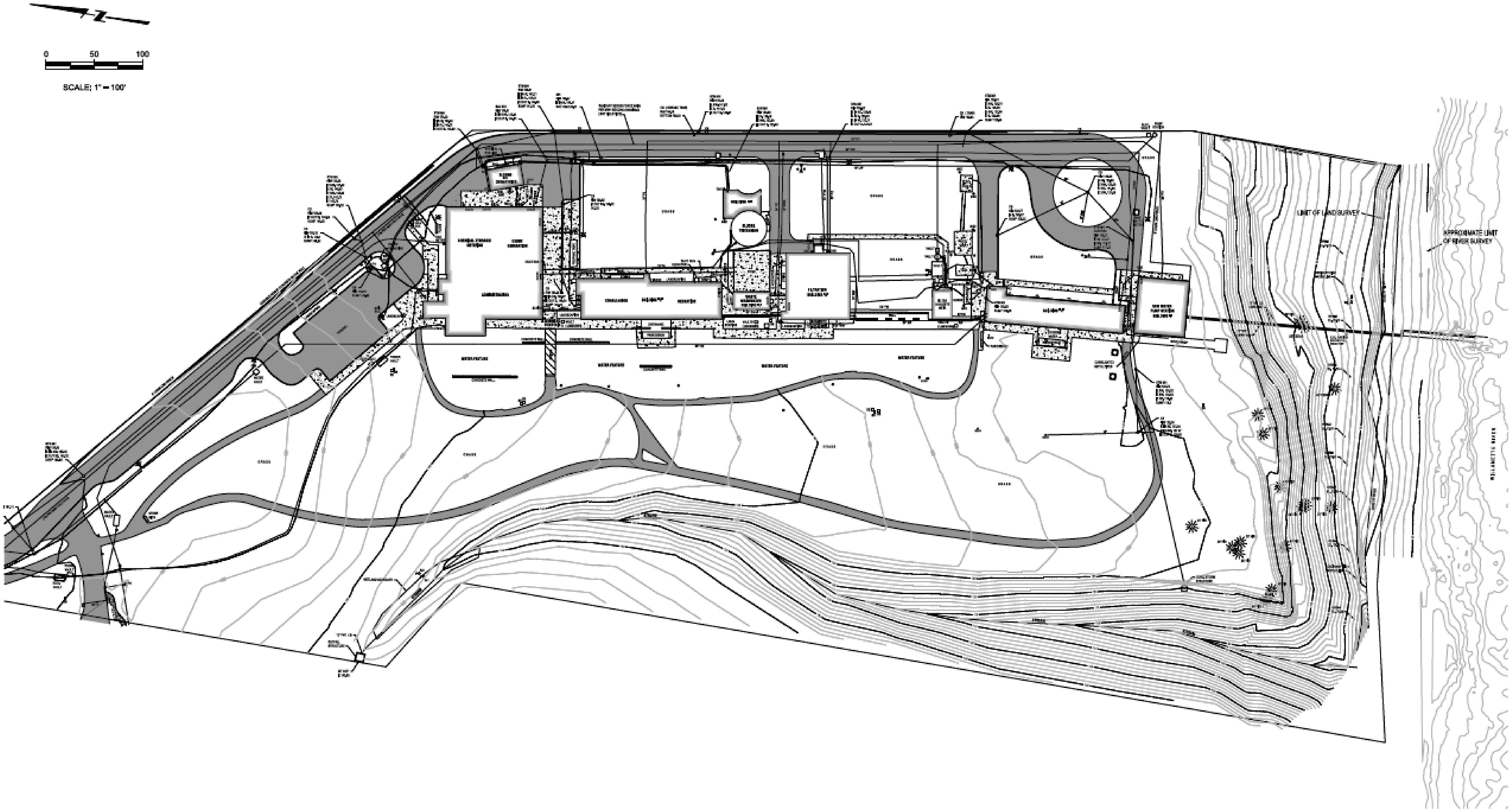

Figure 5.1 Lower Site Survey

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Originally, the raw water intake pump station caisson was to be constructed with a finished floor at an elevation of approximately 24.0 ft (NGVD29). However, during construction, groundwater was hit before the desired elevation was reached, so the finished caisson floor was built at an elevation of 34.0 ft. With this, the intake pipeline was required to have two 45-degree fittings to reach the bottom of the river. To confirm the elevation of the caisson, the depth was measured from the top deck to the caisson floor. The depth was 81 feet, which coincides with a caisson floor at elevation 34.0 feet (NGVD29).

Comparing the 500-year flood, 100-year flood, low water elevations, and WRWTP construction record drawings to the most recent FEMA maps and to the hydrologic model confirmed that NGVD 29 was used for vertical control.

While low-flow conditions would typically correlate with low water elevations, the Willamette River elevation by the WRWTP intake is artificially raised during the summer, from July through August. As part of Portland General Electric (PGE) operations at the Willamette Falls Dam, the upstream water surface is elevated nominally 1.5 feet by inserting 18-inch flashboards. The reliable summer increase in river elevation observed from 2008 to 2015 coincides with PGE's Federal Energy Regulatory Commission (FERC) 2005 license conditions and publication of the 2008 Willamette River Biological Opinion.

This elevation information was used to develop the computational fluid dynamic (CFD) model for the caisson and raw water pumps to evaluate hydraulic capacity. Intake piping and screen head losses at different flows were calculated and provided by screen manufacturers. Table 5.1 summarizes the elevation and resultant static water column depth in the caisson. As indicated in the table, the caisson maintains a high static water level even when the river is at minimum levels. Head loss information at varied flows and corresponding dynamic water column depths were evaluated for the WWSP RWF project (B&V, 2017).

Table 5.1 WRWTP Caisson and Willamette River Elevations

	Unit	NGVD 29	NAVD 88	Static Water Column
Raw Water Intake Caisson (finished floor)	feet	34.0	37.5	-
Willamette River Minimum Level (September-June)	feet	52.5	56.0	18.5
Willamette River Minimum Level (July-August 95% flow exceedance)	feet	54.0	57.5	20.0

5.3 Hydraulic Assessment

A hydraulic model of the WRWTP was developed in Carollo's Hydraulix® software to compare water surface elevations in the treatment train at 15 mgd and 20 mgd to determine the feasibility of an interim expansion using the existing WRWTP infrastructure. The model also includes 10 percent internal recycle flow through the Actiflo®, Ozonation, and filter systems. The primary metric for feasibility of expansion in this analysis was flooding of control weirs in key process areas, but pipeline velocities and head losses were also considered.

The City's WRWTP record drawings were used to develop the hydraulic model from the inlet of the Actiflo® basins to the Filter Control Weir. Weir crest elevations were obtained from Sheet G-6 and verified from structural details. General dimensions of process areas were obtained from the structural and mechanical drawings. All piping and fittings between process areas were incorporated into the model from yard piping and mechanical drawings. Major and minor losses for piping were calculated using the Darcy-Weisbach equations. The modeling approach used for each of the three major process areas is described below and the hydraulic calculations are presented in Appendix A.

An analysis was conducted to define the impacts of increasing the maximum flow of each Actiflo® basin from 7.5 mgd to 10 mgd. The analysis of the WRWTP treatment trains included a hydraulic model of each tank and the launder system. The analysis concluded that water surface elevations through the trains would rise slightly with higher flow rates, but that head loss across the entire treatment train would not increase substantially. The results of this analysis were included in the hydraulic calculations as a total head loss and linear interpolation was used to identify head loss at flows not included in the analysis, such as the impact of a 10 percent recycle on the treatment trains.

The ozone system was modeled as two trains consisting of serpentine systems of four contactor over/under baffles with control weirs on either end. Increasing the flow through these contactors is anticipated to have minimal impact on the overall hydraulics. The head loss increase of less than one inch was observed from the maximum flow increase from 7.5 to 10 mgd.

The WRWTP's filters are operated in a constant head mode. Under this operation, a downstream control valve is used to throttle flow through the operating filters, with highest filter rates occurring when one filter is down for backwashing (i.e., when three out of four are operating). In this evaluation, the clean bed head loss was evaluated and compared to the maximum acceptable water surface elevation in the filters (145.65 feet) to determine the amount of head available for solids accumulation during operations. The hydraulic model indicated that the clean bed head loss is 1.97 feet at 15 mgd and 2.69 feet at 20 mgd. Therefore, the head available to solids accumulation is approximately 9.34 feet at 20 mgd, a reduction of 1.52 from the available head at 15 mgd. This decrease in solids accumulation capacity is not expected to impact plant operations as the City's filters are typically operated a minimum of 24 hours before requiring backwashing under normal conditions.

To verify the hydraulic profile, the results from the hydraulic analysis modeled with 15 mgd WRWTP flow were compared to the data obtained during plant start-up and from the initial design of the facility. Some small differences were observed in the record drawings compared to the hydraulic model, but were not considered to be significant. The hydraulic profile of the 20 mgd capacity expansion (including model results from 15 mgd flow) is shown in Figure 5.2.

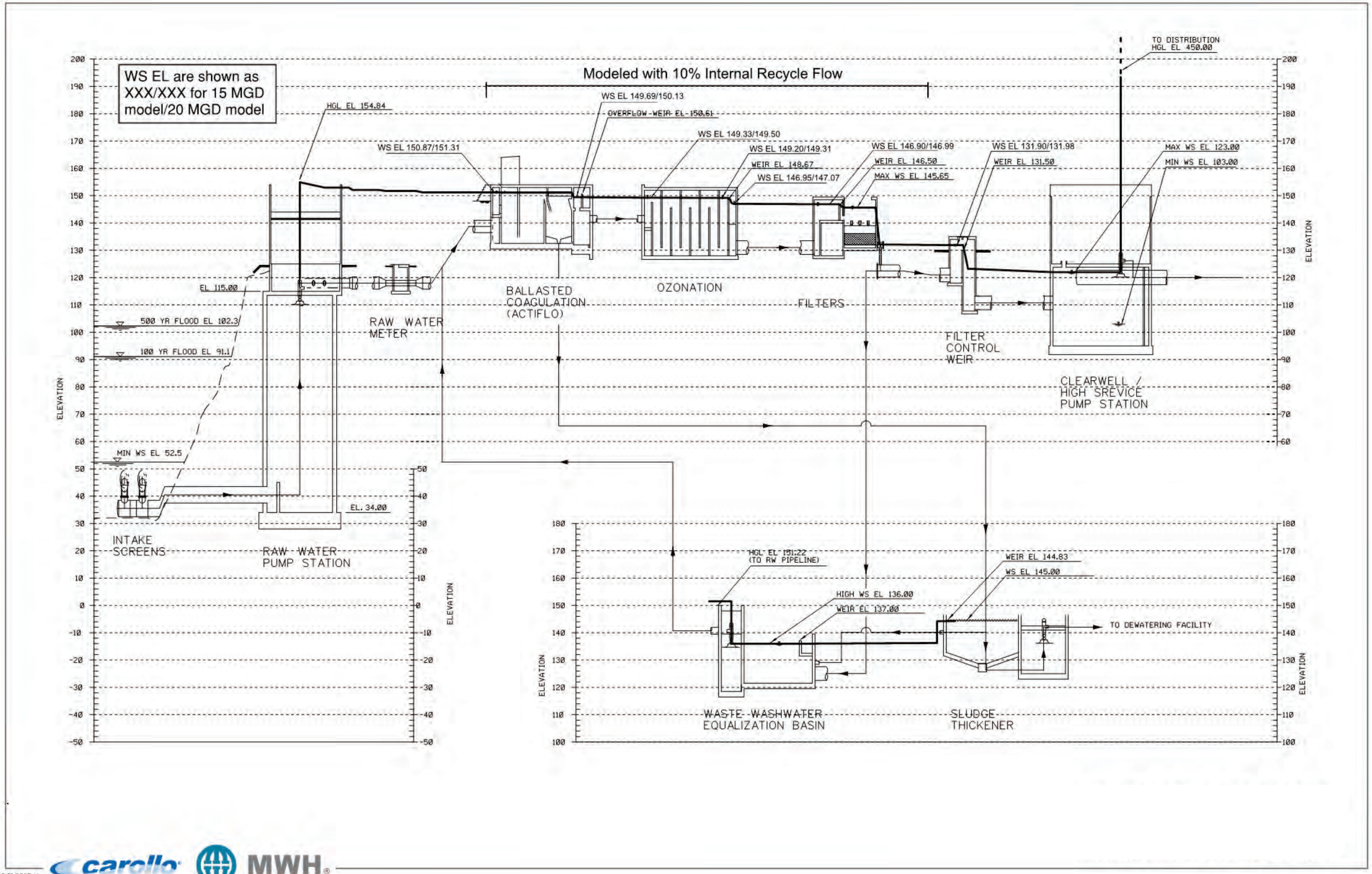

Figure 5.2 WRWTP Hydraulic Profile – 20 mgd Design Capacity

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5.4 Equipment Assessment

An assessment of the existing plant facilities was included to determine how equipment replacement would be included in the 20-year planning horizon. This evaluation was used to identify likely equipment replacement periods in order to ensure continued successful operation. The equipment assessment was performed using two methods: (1) Veolia's equipment database management system; (2) Plant staff input.

Veolia maintains a database of WRWTP equipment that includes cost, service life, installation date, and estimated service life remaining. The database output was modified to exclude equipment costing less than $10,000, electrical equipment (evaluated separately), and infrastructure. Following this modification, the remaining equipment service life was reviewed to identify the replacement period. This was then compared to the planned capacity expansions to identify when service life expiration would coincide with capacity increases requiring equipment upgrades. Equipment with a service life expiration that did not coincide with a capacity expansion were identified for replacement (either "in-kind" or upgraded) during an interim project. A copy of the Veolia Equipment Database is included in Appendix A.

Review of the plant equipment database was supplemented with plant staff interviews to identify equipment issues not included in the database. Staff interviews identified issues with performance, obsolescence, serviceability, and similar issues that indicate equipment replacement may be necessary sooner than is indicated by its service life. Additionally, the interviews were used to verify the evaluation of Veolia's Equipment Database to ensure plant staff agreed with the approach and results. Results of this discussion were documented in meeting minutes, included in Appendix A.

5.5 Electrical Assessment

The electrical assessment was conducted to evaluate the current status of the system and identify any upgrades or improvements that would be necessary for the planned capacity expansions. An initial site visit was performed to discuss the electrical system with plant staff and compare existing conditions to as-built drawings, solicit maintenance and operations observations, and identify outstanding issues. As-built one-line drawings were supplemented by reviewing MCC loads and photographing equipment name plates. Calculations were developed using this information to evaluate the connected and operating loads on the electrical distribution system. These calculations considered both existing loads and potential future loads to identify potential equipment or capacity deficiencies.

5.5.1 Evaluation Results

The power distribution system is a single-ended, simple radial system with a 15-kilovolt (KV) outdoor main switchgear (MS) receiving power from Portland General Electric (PGE) and distributing it to downstream switchboards.

New 15-KV feeder fuse sections can be added to the existing MS to allow expansion of this gear, however, the switchgear may not be upgradeable to a double-ended (main-tie-main) configuration because the location of existing feeder fuses may prevent extension of switchgear bus to the west. Using a double-ended switchgear along with redundant substation transformers will provide additional reliability and redundancy while also providing ease of maintenance.

Two existing outdoor liquid-filled unit substation-type transformers (T-1 and T-2) transform utility 12.47-KV voltage from MS to lower distribution voltages of 4.16-KV and 480-V at the two downstream distribution equipment locations.

- T-1 provides power to the medium-voltage (5KV) switchgear 17-MVMCC-A, which feeds three 500-hp high service pumps. It is an outdoor, liquid-filled primary unit substation type transformer with neutral resistance grounding, 65 degrees Celsius (C) temperature rise, rated OA (1,500 KVA)/FFA (1,725 KVA). OA rating is a transformer's normal liquid (oil) cooled rating and FFA is the Future Forced Air cooled rating, which means the rating of T-1 would increase from 1,500 KVA to 1,750 KVA if a fan cooling option is provided in the future. Therefore, the existing maximum continuous rating of T-1 is 1,500 KVA, or 208 amps at 4,160 V.
- T-2 provides power to the low voltage (480 volt [V]) switchboard 17-SWBD-A, which feeds two 200-hp raw water pumps and several distribution motor control centers (MCCs). It is an outdoor liquid-filled secondary unit substation type transformer with a 65 C temperature rise, rated OA (2,000 KVA)/ FFA (2,300 KVA). The existing maximum continuous rating of T-2 is 2,000 KVA, or 2,405 amps at 480 volts (V).

Table 5.2 shows the 100 percent and 80 percent rated capacity of all major electrical distribution equipment and transformers in the existing plant and current operating load demands on each equipment for 15 mgd plant flow condition. Based on standard engineering design guidelines, electrical distribution equipment and transformers should be loaded to approximately 80 percent of their capacity with 20 percent spare capacity reserved for future loads or unpredicted overload conditions. Hence, the available capacity values shown are based on comparison with 80 percent equipment rating values.

Table 5.2 WRWTP Electrical Load Summary

Equipment	Voltage	100% Capacity (Amps)	80% Capacity (Amps)	80% Capacity (KVA)	Existing Demand (Amps)	Existing Demand (KVA)	Available Capacity (Amps)[4]	Available Capacity (KVA)[4]
Main Switchgear "MS"	12.47 KV	600	480	10,368	168	3,629	312	6,739
XFMR T1	4.16 KV	208	166	1,200	210	1,513	(44)	(313)
17-MVMCC-A	4.16 KV	208[1]	166	1,200	210	1,513	(44)	(313)
XFMR T2	480 V	2,405	1,924	1,600	2,543[3]	2,114	(619)	(190)
17-SWBD-A	480 V	2,405[2]	1,924	1,600	2,543[3]	2,114	(619)	(190)
15-MCC-A	480 V	1,200	960	798	491	408	469	398
13-DP-A	480 V	800	640	532	116	96	524	436
8-MCC-A	480 V	600	480	400	36	30	444	370
6-MCC-A	480 V	600	480	400	137	114	343	286
4-MCC-A	480 V	600	480	400	62	52	418	348
2-MCC-A	480 V	600	480	400	11	9	469	391

Table 5.2 WRWTP Electrical Load Summary (Continued)

Equipment	Voltage	100% Capacity (Amps)	80% Capacity (Amps)	80% Capacity (KVA)	Existing Demand (Amps)	Existing Demand (KVA)	Available Capacity (Amps)(4)	Available Capacity (KVA)(4)
Standby Equipment								
GEN1	480 V	1,500	1,200	998	1,222	1.016	(22)	(18)
19-MCC-A	480V	600	480	400	156	130	324	270
15-SWBD-B	480 V	2,000	1,600	1,330	1,222	1,016	378	314
13-DP-B	480 V	800	640	532	439	365	201	167
6-DP-B	480V	100	80	67	0(5)	0(5)	80	67
4-MCC-B	480 V	600	480	400	168	140	312	260
2-DP-B	480V	100	80	67	11	69	56	58

Notes:
(1) 3,000-amp capacity. Limited by transformer T1 to 208 amps.
(2) 3,000-amp capacity. Limited by transformer T2 to 2,405 amps.
(3) Values retrieved from as-built one line drawings, which indicate the transformer and switchboard are overloaded.
(4) Based on 80-percent capacity.
(5) Load information not available.

Existing demand values were obtained from as-built drawings. Numbers in parentheses indicate negative capacity or under-rated equipment. In particular, existing demand values for switchboard 17-SWBD-A are too large, resulting in negative available capacity values, and suggesting the equipment may be overloaded or under-rated. Existing demand values for switchgear 17-MVMCC-A indicates the switchgear is operating at maximum capacity.

Calculations shown in Appendix A indicate the existing standby generator can provide power to all existing standby demand loads connected to switchboard 15-SWBD-B. The values in this evaluation should be field verified during design when the WRWTP is expanded.

5.5.2 Recommendations

Some of the main electrical equipment in the electrical system are loaded above 80 percent of listed capacity and are considered overloaded. Additionally, the existing emergency generator is not connected to all WRWTP equipment (e.g., it is wired only to Actiflo® Basin 2) and has sufficient capacity to power only the 4 mgd raw and finished water pumps.

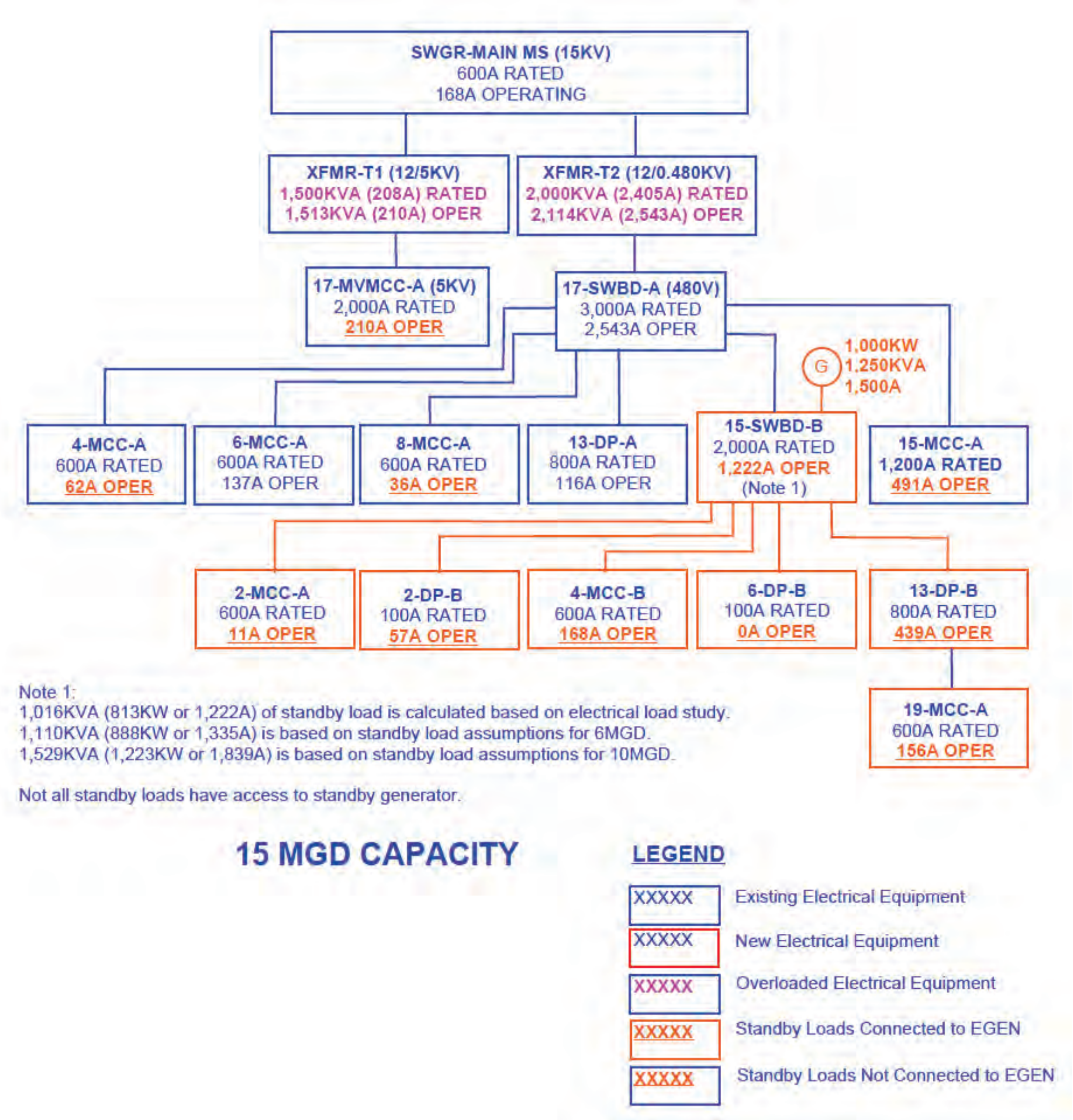
Figure 5.3 shows the existing electrical load distribution configuration (at 15 mgd). Figure 5.4 depicts the existing electrical configuration and overloaded equipment following the 20-mgd WRWTP expansion if no improvements are provided for the plant's electrical infrastructure.

Based on the evaluation of the existing electrical system configuration and anticipated plant process upgrades, the 2017 MPU recommend that the existing electrical distribution system be upgraded under the 20-mgd expansion. The recommended upgrades will provide a more robust and reliable system along with ease of maintenance for plant staff. The following upgrades are recommended:

- **Switchgear Replacement**: Replace the existing single-ended 15-KV switchgear with a new double-ended main-tie-main type 15-KV metering switchgear, which would be sufficient to power the WRWTP through 60 mgd.
- **Transformers**: Provide redundant 5KV and 480V transformers for redundancy.

- **Emergency Generator Replacement**: Replace with a 2-MW generator wired directly to the 15-KV metering switchgear. This will allow all plant equipment to be run on the emergency generator.
- **Plant Re-wiring**: Connect all finished water pumps to the 5-KV transformer/switchgear, leaving sufficient capacity on the remaining transformers to power the rest of the plant.

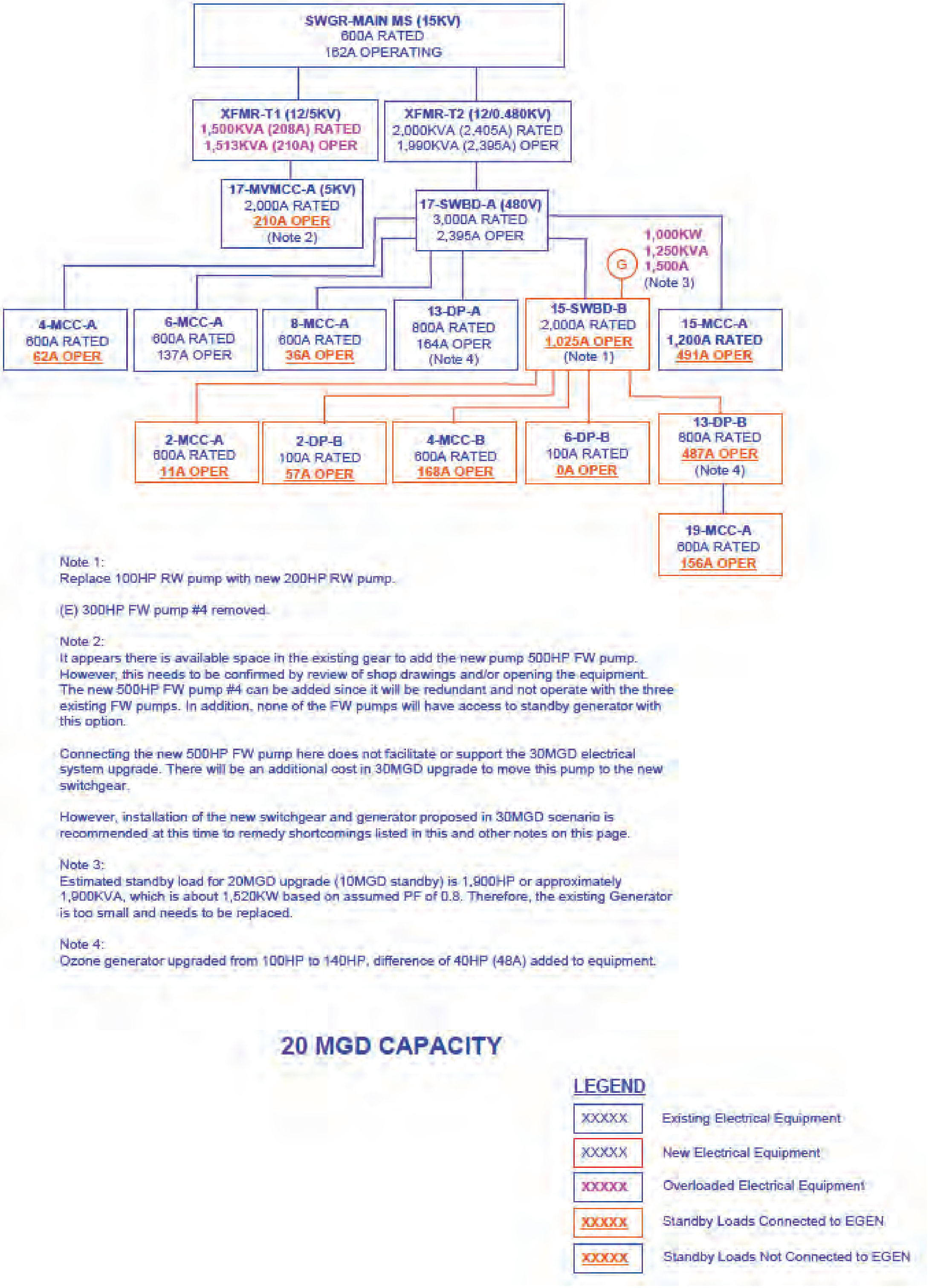
Figure 5.5 depicts the electrical system following the improvements recommended above for the 20 mgd capacity expansion. These improvements lay the foundation for simple, low-risk expansion(s) in the future (for 30 mgd and beyond). Figure 5.6 illustrates the ease of adding future pumps and loads to the upgraded electrical system for the 30 mgd expansion. Note that Figures 5.3 through 5.6 are diagrammatic in nature and do not show the individual transformers or switchgears. A complete one-line diagram should be included during the design phase to depict the new and existing equipment.



Note 1:
1,016KVA (813KW or 1,222A) of standby load is calculated based on electrical load study.
1,110KVA (888KW or 1,335A) is based on standby load assumptions for 6MGD.
1,529KVA (1,223KW or 1,839A) is based on standby load assumptions for 10MGD.

Not all standby loads have access to standby generator.

Figure 5.3 Current Electrical Load Distribution Diagram



Note 1:
Replace 100HP RW pump with new 200HP RW pump.

(E) 300HP FW pump #4 removed.

Note 2:
It appears there is available space in the existing gear to add the new pump 500HP FW pump. However, this needs to be confirmed by review of shop drawings and/or opening the equipment. The new 500HP FW pump #4 can be added since it will be redundant and not operate with the three existing FW pumps. In addition, none of the FW pumps will have access to standby generator with this option.

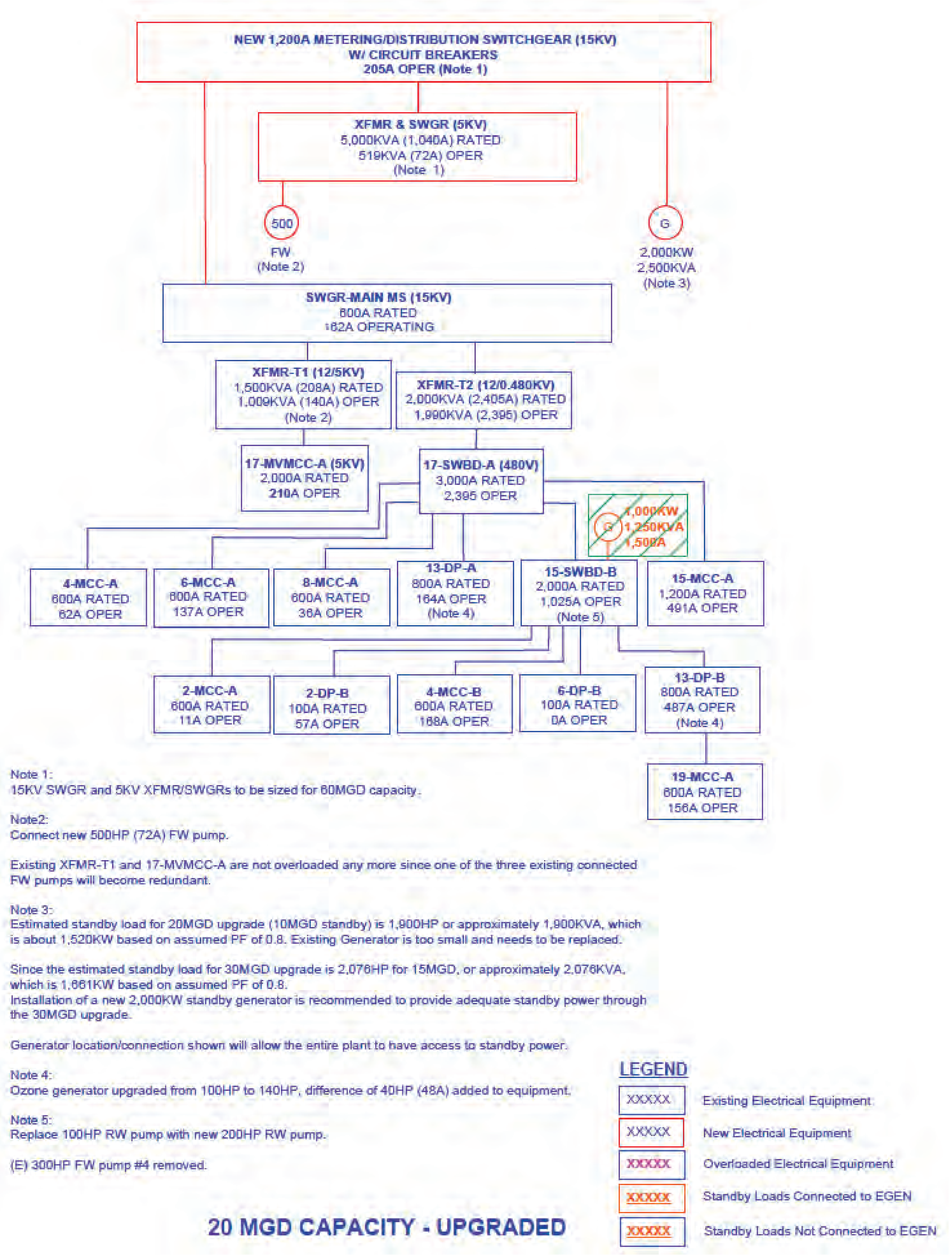
Connecting the new 500HP FW pump here does not facilitate or support the 30MGD electrical system upgrade. There will be an additional cost in 30MGD upgrade to move this pump to the new switchgear.

However, installation of the new switchgear and generator proposed in 30MGD scenario is recommended at this time to remedy shortcomings listed in this and other notes on this page.

Note 3:
Estimated standby load for 20MGD upgrade (10MGD standby) is 1,900HP or approximately 1,900KVA, which is about 1,520KW based on assumed PF of 0.8. Therefore, the existing Generator is too small and needs to be replaced.

Note 4:
Ozone generator upgraded from 100HP to 140HP, difference of 40HP (48A) added to equipment.

Figure 5.4 Existing Electrical System – 20 mgd Capacity



Note 1:
15KV SWGR and 5KV XFMR/SWGRs to be sized for 60MGD capacity.

Note2:
Connect new 500HP (72A) FW pump.

Existing XFMR-T1 and 17-MVMCC-A are not overloaded any more since one of the three existing connected FW pumps will become redundant.

Note 3:
Estimated standby load for 20MGD upgrade (10MGD standby) is 1,900HP or approximately 1,900KVA, which is about 1,520KW based on assumed PF of 0.8. Existing Generator is too small and needs to be replaced.

Since the estimated standby load for 30MGD upgrade is 2,076HP for 15MGD, or approximately 2,076KVA, which is 1,661KW based on assumed PF of 0.8.
Installation of a new 2,000KW standby generator is recommended to provide adequate standby power through the 30MGD upgrade.

Generator location/connection shown will allow the entire plant to have access to standby power.

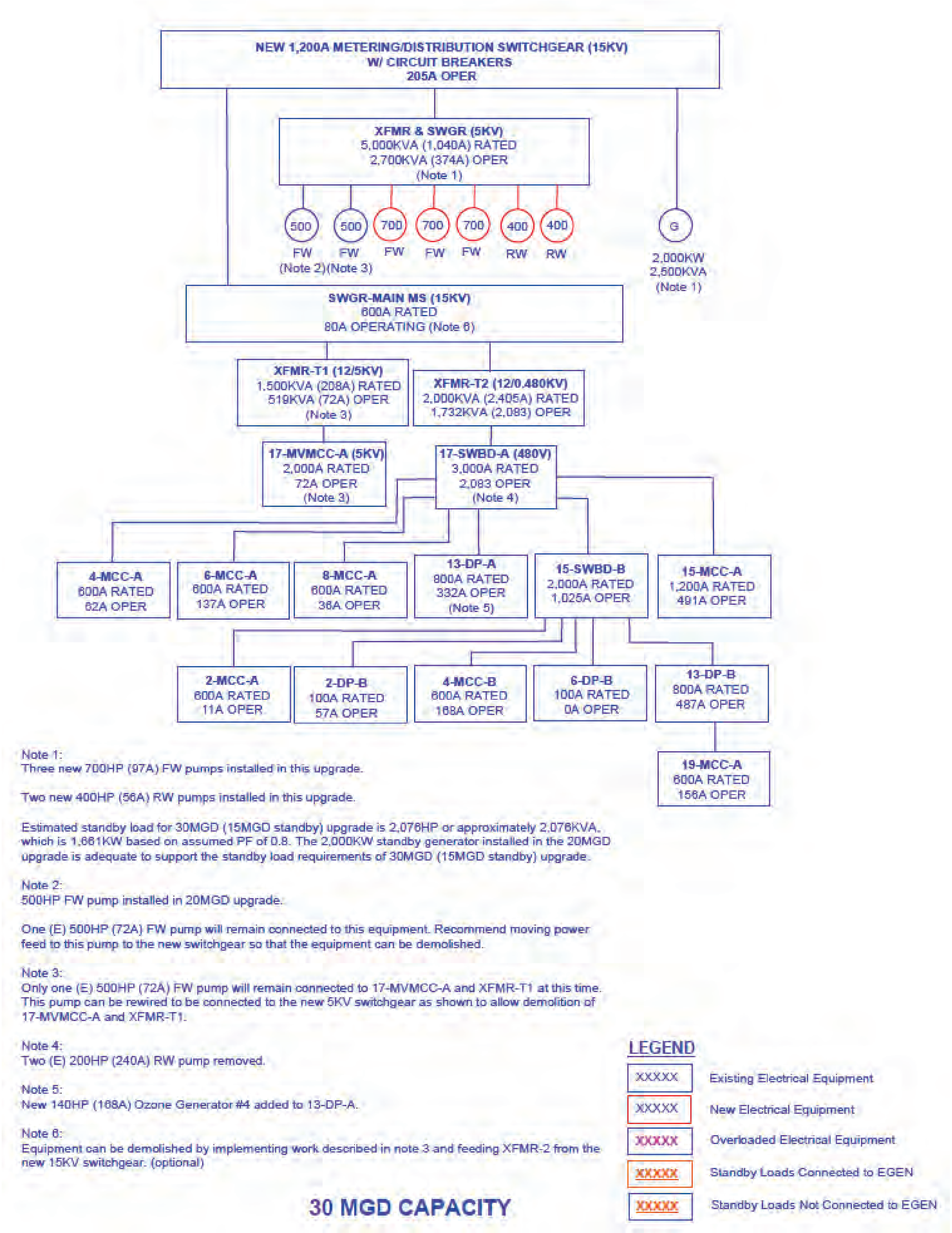
Note 4:
Ozone generator upgraded from 100HP to 140HP, difference of 40HP (48A) added to equipment.

Note 5:
Replace 100HP RW pump with new 200HP RW pump.

(E) 300HP FW pump #4 removed.

20 MGD CAPACITY - UPGRADED

Figure 5.5 Upgraded Electrical System – 20 mgd Capacity



Note 1:
Three new 700HP (97A) FW pumps installed in this upgrade.

Two new 400HP (56A) RW pumps installed in this upgrade.

Estimated standby load for 30MGD (15MGD standby) upgrade is 2,076HP or approximately 2,076KVA, which is 1,661KW based on assumed PF of 0.8. The 2,000KW standby generator installed in the 20MGD upgrade is adequate to support the standby load requirements of 30MGD (15MGD standby) upgrade.

Note 2:
500HP FW pump installed in 20MGD upgrade.

One (E) 500HP (72A) FW pump will remain connected to this equipment. Recommend moving power feed to this pump to the new switchgear so that the equipment can be demolished.

Note 3:
Only one (E) 500HP (72A) FW pump will remain connected to 17-MVMCC-A and XFMR-T1 at this time. This pump can be rewired to be connected to the new 5KV switchgear as shown to allow demolition of 17-MVMCC-A and XFMR-T1.

Note 4:
Two (E) 200HP (240A) RW pump removed.

Note 5:
New 140HP (168A) Ozone Generator #4 added to 13-DP-A.

Note 6:
Equipment can be demolished by implementing work described in note 3 and feeding XFMR-2 from the new 15KV switchgear. (optional)

Figure 5.6 Upgraded Electrical System – 30 mgd Capacity

5.6 Seismic Evaluation and Mitigation Alternatives

5.6.1 Oregon Seismic Requirements

Seismic design and construction of Oregon structures is governed by a series of statewide building codes dating back to when the first code was adopted in 1974. That code, called the State of Oregon Structural Specialty and Fire and Life Safety Code (OSSC), incorporated the 1973 Uniform Building Code (UBC).

Based on the OSSC, all of Oregon was deemed to be in Seismic Risk Zone 2, meaning structures sustaining moderate damage in a seismic event are equivalent to intensity VII on the Modified Mercalli Scale (M.M.) and carry a 0.5 multiplier in the formation. An intensity of VII was defined as *Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Richter Scale Magnitude (RM) = 6.1.*

In 1976, a second statewide building code was adopted using the 1976 UBC. The Seismic Risk Zone for Oregon did not change, but the multiplier factor was changed to 0.375. The statewide building codes were subsequently modified in 1979 and 1985; however, the modifications had little or no effect on the seismic design criteria.

A significant shift occurred in the 1988 UBC (1990 OSSC) when the Seismic Risk Zone in Oregon was designated 2B. By adopting the 1991 UBC (1993 OSSC), additional significant changes in treating and analyzing seismic loading occurred. Counties west of the Cascade Mountains were designated Seismic Zone 3, and those east of the Cascades were designated Seismic Zone 2.

When the 1994 UBC (1996 OSSC, amended in 1998) was adopted, the seismic design criterion remained the same, but the tables delineating Occupancy Categories and Seismic Importance Factors were enhanced to provide more-intense design values for higher risk, important, and essential facilities. The overall seismic design values for loading did not increase under this code adoption; however the code considered the facilities' proximity to known seismic faults and the site's soils conditions. This code cycle revised the seismic zone mapping along the southern Oregon coast, upgrading it to Seismic Zone 4. The rest of the state remained at the previous zones. The 1998 OSSC remained in force for roughly six years with very few seismic-related revisions.

In 2004, the state of Oregon moved from the Uniform Building Code to the International Building Code (IBC) and adopted the amended 2003 International Building Code as the 2004 Oregon Structural Specialty Code. The IBC upgraded its design parameters by requiring design to a 2,500-year return period earthquake instead of the 500-year return period earthquake required by previous UBC codes.

The change to the IBC code was a substantial shift in earthquake regulations and in determining seismic base shear. The new formulation used very specific site characteristics and required specific latitude and longitude in conjunction with the United States Geological Survey (USGS) soils/ground response information. Advances in technology allowed for using spectral response acceleration for short and one-second periods and soil definitions that accounted for shear waves, penetration resistance, and shear strength of soils.

In addition, the Seismic Use Group was established, a modification of the previous Seismic Importance Factor. Types of structural systems were expanded considerably and, when used with the revised base-shear formulation, gave very site-specific seismic loading. The net result of the new technology and more precise method of loading determination was an overall lowering of the seismic base-shear forces.

In 2007, the 2006 IBC was adopted with modifications. The 2009 IBC was adopted as the 2010 Oregon Structural Specialty Code and was carried forward from the previous code cycle with little change for earthquake design.

With the building codes' evolution over the years, substantially safer buildings are being constructed in the state of Oregon. The most recent codes have minimum design standards to maintain public safety during an earthquake's extreme ground shaking. Requirements are geared toward safeguarding against major failures and loss of life, not just limiting damage, maintaining function, or providing for easy repair.

Buildings that house essential facilities will have a greater level of protection because additional expenditures will make the facilities more stable. A structure's ability to resist earthquake ground-motion depends on many factors:

- Distance to the earthquake's epicenter,
- Type and location of the fault,
- Type of soil structure the building is sited on, and
- Type and quality of the building's construction.

For the original Willamette River Water Treatment Plant, the 1998 OSSC was the enforceable building code at the time. The 1998 OSSC required a structure's seismic design to meet a Seismic Zone 3 with a seismic event equivalent to intensity VII and corresponding to a Richter Scale Magnitude (RM) of 6.1. Since then, much more about the Cascadia Subduction Zone seismic event has become understood, an understanding that has heavily influenced subsequent building codes. The Oregon Resilience Plan (ORP) further assessed and determined that water systems built after the year 2000 have “stringent lateral force requirements” and are “likely to remain intact” after a large Cascadia Subduction Zone earthquake.

5.6.2 Geotechnical Investigation Summary

Shannon & Wilson prepared the Geotechnical Report for the WRWTP Lower Site and Upper Site (S&W, 2015), found in Appendix H of the 2015 MPU. This 2017 MPU summarizes the conceptual geotechnical engineering evaluations and recommendations and includes a seismic evaluation of the major existing process structures. This information can be used in future expansions and to develop potential mitigation alternatives. Appendix H also includes supplemental recommendations for the raw water pump station caisson mitigation.

5.6.3 Seismic Evaluation of Existing Facilities

A seismic and structural evaluation was performed for the WRWTP's existing facilities. The plant was designed to comply with the enforceable building code at the time--the 1998 Oregon Structural Specialty Code. The 1998 OSSC required seismic design to meet a Seismic Zone 3 with a seismic event equivalent to intensity VII and corresponding to an RM of 6.1.

5.6.3.1 Evaluation Approach

The existing facilities were structurally evaluated using American Society of Civil Engineers (ASCE) 41-13 for buildings and ASCE 7-10, ACI 350.3-06, and ACI 350-06 for the caisson and tanks. Seismic forces (hydrodynamic forces) were calculated using ASCE 7-10, Chapter 15. The seismic response spectral accelerations for tankage, S_{DS} and S_{D1}, were based on data provided by Shannon & Wilson (S&W, 2015). The seismic response spectral accelerations for buildings, S_{XS} and S_{X1}, were based on 2008 seismic hazard data published by the United States Geological Survey (USGS).

5.6.3.2 Evaluation Results

Table 5.3 summarizes the structural retrofit requirements. Appendix B includes a technical memorandum (TM) detailing the evaluation parameters and calculations.

5.7 Life Safety Evaluation

In conjunction with the seismic assessment, life safety at the WRWTP was assessed. Table 5.4 summarizes the findings and includes seismic vulnerabilities that are potential life safety hazards. Where building code provisions and standards are applicable, the relevant sections are noted. Photographs in Appendix B illustrate the identified issues.

5.8 Transient Surge Analysis

For this 2017 MPU, a transient analysis was performed on the finished water pumping and delivery system to confirm the findings of *Hydraulic Transient Analysis – City of Wilsonville* (MWH, 2011). The 2011 analysis evaluated numerous scenarios with WRWTP flow rates up to 15 mgd. Modeling results led to a recommendation that a minimum 750-cubic foot (CF) (5,600 gallon) surge tank be located at the WRWTP. The surge tank would prevent negative pressure formation in the distribution system if power were lost at the WRWTP when Wilsonville demand exceeds 10 mgd or combined Wilsonville and Sherwood demands exceeds 12.5 mgd.

5.8.1 Evaluation Methodology

The City of Wilsonville's 2017 Innovyze Infowater hydraulic model was used for this hydraulic transient analysis. Based on discussions with the City of Wilsonville, the *2011 MDDW48, Existing Demand with Priority 1 Improvements* model scenario was used for the analyses in the demand scenarios shown in Table 5.5. In addition, the model was used to determine if a surge tank is required assuming no Sherwood demand. Table 5.5 summarizes the demand scenarios. Note that WRWTP currently operates at demands up to Scenario 3.

Table 5.3 Summary of Seismic Vulnerabilities

ID	Location	Description	Reference	Recommendation	Priority[1]
S1	Waste Washwater Equalization	The horizontal reinforcing steel in the north and south basin walls at the east corners (#8 @ 12" oc) have a demand to capacity ratio (DCR) of 1.53 for soil seismic loads..	ACI 350.3-06	Install three (3) concrete braces across the width of the basin with intermediate column support as required to brace the north and south walls. Braces should be located at the mid-height of the wall.	L[2]
S2	Waste Washwater Equalization	The out-of-plane wall shear at the north and south walls where the existing concrete beam below the east wall of the building intersects the walls has a DCR of 1.67 for soil seismic loads.	ACI 350.3-06	Install three (3) concrete braces across the width of the basin with intermediate column support as required to brace the north and south walls. Braces should be located at the mid-height of the wall.	L[2]
S3	High Service Pump Station	The roof joist wall anchorage along the east and west walls of the pump station have a DCR of 1.55.	ASCE 41-13, Tier 1	Add new wall anchorage along the east and west walls midway between the existing roof joists.	H
S4	High Service Pump Station	The roof diaphragm shear capacity is exceeded at approximately 50% of the roof deck area with DCR's that vary from 1.82 to 2.25.	ASCE 41-13, Tier 1	Replace existing deficient deck sections with 16 GA corrugated steel decking.	H
S5	High Service Pump Station	The tension capacity of the diaphragm chord at the pump room has a DCR of 1.20 at the connections at the east windows	ASCE 41-13, Tier 1	Strengthen the existing chord connections as required.	M
S6	High Service Pump Station	Roof deck shear transfer to the interior wall ledger bolts have DCR's of 3.20 to 3.90.	ASCE 41-13, Tier 1	Add a new top plate over the interior shear walls and install epoxied anchors as required.	H[3]
S7	Solids Dewatering Building	The building has no lateral load resisting system in the transverse direction at the first floor level. The existing concrete joint at the elevated slab to the east and west walls does not have any seismic detailing to establish any concrete moment frame.	ASCE 41-13, Tier 1	Provide steel braced frames at the exterior of the building at the east side that brace the building at the second floor level. This system is anticipated to include three braces, each with its own concrete grade beam. It is assumed that the existing stair will need to be relocated to the west side of the building.	H

Table 5.3 Summary of Seismic Vulnerabilities (Continued)

ID	Location	Description	Reference	Recommendation	Priority[1]
S8	Solids Dewatering Building	The roof joist wall anchorage along the east and west walls of the building have a DCR of 1.17.	ASCE 41-13, Tier 1	Add new wall anchorage along the east and west walls midway between the existing roof joists.	M
S9	Solids Dewatering Building	The foundation elements do not have adequate ties across the building, as the floor slab is not connected to the walls or the footing.	ASCE 41-13, Tier 1	Tie the existing floor slab to the walls, which are already doweled to the existing footings. The retrofit is anticipated to include stainless steel angles and epoxy anchors.	M
S10	Various (estimated at 8 locations)	The space heaters at all facilities are laterally braced above their center of gravity, which allows the heaters to sway during an earthquake. The space heaters at the Switchgear Room at the High Service Pump Station are not braced at all.	ASCE 41-13, Tier 1	Provide seismic bracing.	H
S11	Ozonation	The ozone destruct piping located on the top deck of the Ozonation basin is not seismically braced.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipe down to the concrete deck.	M
S12	High Service Pump Station	The cable trays lack longitudinal seismic bracing.	ASCE 41-13, Tier 1	Provide longitudinal seismic bracing of the cable trays.	M
S13	Chemical Storage / Ozone Generation Room	The chemical pipes that run through the center of the Chemical Storage Room are not seismically braced. The balance of the chemical pipes in the Chemical Storage Room and Ozone Generation Room lack longitudinal seismic bracing.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	M
S14	Ozone Generation Room	The ozone and LOX piping is not seismically braced.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	M

Notes:

1. H = High, M = Medium, L = Low.
2. The same mitigation recommended for vulnerability S1 will address S2.
3. Assumes that vulnerability S4 is addressed simultaneously; otherwise the cost will need to include removal/replacement of the roofing.

Table 5.4 Summary of Life Safety Findings

ID	Location	Description	Code Reference	Recommendation	Priority(1)
LS1	Various	Tread plate hatches do not typically have any provisions for installing temporary fall protection barriers when in use.	OSHA 1910.23	Install sleeves or other hardware for temporary fall protection systems around hatches.	H
LS2	Various	Color coded chemical safety warning signs at exterior locations are faded so that colors are no longer clear.	2014 OFC (NFPA 704)	Replace safety signs throughout the plant as required.	H
LS3	Actiflo® / Ozonation / Filters	Exterior stair guardrail height is less than 42 inches above the stair tread and has no dedicated handrail. Installation met 1997 UBC provisions but not current code.	2014 OSSC, Chpt 10	Replace guardrail with current code-compliant installation.	M
LS4	Actiflo® / Higher Service PS / Chemical Storage	Doors exiting rooms with rated electrical service of 1,200 amps or greater do not have panic hardware.	2014 OSSC, Chpt 10	Provide panic door hardware on 4 affected doors.	H
LS5	Ozone Generation / Chemical Storage	Doors serving occupancy Group H are lacking panic hardware. Also, the door that connects the Ozone Generation Room to the Administration Building swings into the Ozone Generation Room, which is a Group H occupancy.	2014 OSSC, Chpt 10	Provide panic door hardware on 3 doors and replace the door between the Ozone Generation Room and the Administration Building to reverse the door swing direction.	H
LS6	Ozone Generation / Chemical Storage	Chemical piping passes directly over exit egress routes at the southwest door of the Ozone Generation Room, the east door of the Chemical Room, and the west door of the Chemical Room.		Add secondary containment pans below the chemical piping over exit routes.	M
LS7	Various	Doors were found propped open during the site visit, which suggests that the ventilation in the rooms may not be operating effectively and/or efficiently.		Verify that the ventilation system is operating as intended.	L
LS8	Actiflo® / Filters	The west guardrail on the top deck of the Actiflo® Basin and the top side of the ladder pit at the filters lack kickplates.		Install new kickplates at these locations.	L
LS9	Actiflo® / Ozonation / Filters	The below-grade galleries have active weeping leaks coming from cracks in the tank walls and through expansion joints, making the floor wet and potentially slippery.		Pressure inject a hydrophobic sealant into active leaks to seal them. Apply an exterior (negative side) waterstop on the surface of the joint.	M

Table 5.4 Summary of Life Safety Findings (Continued)

ID	Location	Description	Code Reference	Recommendation	Priority(1)
LS10	Actiflo® / Ozonation / Filters	The below-grade galleries typically have wet floors due to leaking walls and leaking pipes/equipment. The electrical receptacles do not appear to have any GFCI protection.		Remove and replace the electrical receptacles with ones that are GFCI protected.	M
LS11	Ozonation	The south stairwell does not have a dedicated ventilation system that serves it directly.		Investigate if ventilation is sufficient and provide as required.	M
LS12	Filters	The maximum distance of travel to exit the north door is approximately 85 feet. The maximum distance to a single exit per the building code is 75 feet. The doors at the east end of the Filter Gallery exit to a ladder pit, which is not considered an exit for egress determination.	2014 OSSC, Chpt 10	Add a fire-rated door at the bottom of the stairs and add signage to the existing ladder pit door to clarify that it is not an exit. This may also require revision to the ventilation of the existing stair.	M
LS13	Waste Washwater	The ladder into the basin does not have any permanent tie-off points for a fall restraint system.		Verify how fall restraint is provided when using the ladder and provide additional hardware as required.	M
LS14	Sludge Dewatering	The building roof does not appear to have any overflow scuppers.	2014 OSSC, Chpt 15	Saw-cut a notch in the parapet wall and install a scupper and downspout.	L
LS15	Ozone Generation Room	The emergency shut-off switch for the ozone generation equipment is located between the sensor and the generation equipment.		Install emergency shut-off switch at two other exits from the building.	M
LS16 (S4)	High Service Pump Station	The roof diaphragm shear capacity is exceeded at approximately 50% of the roof deck area with DCR's that vary from 1.82 to 2.25.	ASCE 41-13, Tier 1	Replace existing deficient deck sections with 16 GA corrugated steel decking.	H
LS17 (S6)	High Service Pump Station	Roof deck shear transfer to the interior wall ledger bolts have DCR's of 3.20 to 3.90.	ASCE 41-13, Tier 1	Add a new top plate over the interior shear walls and install epoxied anchors as required.	H(2)

Table 5.4 Summary of Life Safety Findings (Continued)

ID	Location	Description	Code Reference	Recommendation	Priority(1)
LS18 (S7)	Solids Dewatering Building	The building has no lateral load resisting system in the transverse direction at the first floor level. The existing concrete joint at the elevated slab to the east and west walls does not have any seismic detailing to establish any concrete moment frame.	ASCE 41-13, Tier 1	Provide steel braced frames at the exterior of the building at the east side that braces the building at the second floor level. This system is anticipated to include three braces, each with its own concrete grade beam. It is assumed that the existing stair will need to be relocated to the west side of the building. Refer to	H
LS19 (S10)	Various (estimated at 8 locations)	The space heaters at all facilities are laterally braced above their center of gravity, which allows the heaters to sway during an earthquake. The space heaters at the Switchgear Room at the High Service Pump Station are not braced at all.	ASCE 41-13, Tier 1	Provide seismic bracing.	H
LS20 (S13)	Chemical Storage / Ozone Generation Room	The chemical pipes that run through the center of the Chemical Storage Room are not seismically braced. The balance of the chemical pipes in the Chemical Storage Room and Ozone Generation Room lack longitudinal seismic bracing.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	M
LS21 (S14)	Ozone Generation Room	The ozone and LOX piping is not seismically braced.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	M

Notes:

(1) H = High, M = Medium, L = Low.

(2) Assumes that vulnerability S4 is addressed simultaneously; otherwise the cost will need to include removal/replacement of the roofing.

Table 5.5 Hydraulic Transient Analysis Demand Scenarios

Scenario	WRWTP Flow Rate (mgd)	Wilsonville Demand (mgd)	Sherwood Demand (mgd)
1	12.5	12.5	0
2	15	15	0
3	15	10	5
4	20	15	5
5	25	17.5	7.5
6	30	22.5	7.5

5.8.2 Evaluation Results

For Scenarios 3 through 6, a hydropneumatic tank is recommended to mitigate the downsurge in the finished water piping system due to a power failure at the WRWTP. Recommended tank sizes for each scenario are listed in Table 5.6. For each scenario, model runs varied tank volume, air volume, and size of the connecting pipe until an optimized solution was reached.

Hydropneumatic tank sizing was evaluated assuming a 24-inch diameter pipe connected to the upstream end of the FWPS discharge header and air volume at 50 percent of the total volume. Table 5.6 summarizes the findings of the analysis. Appendix C includes a TM detailing the evaluation approach and transient analysis findings.

Table 5.6 Hydropneumatic Tank Sizing Recommendations

Scenario	WRWTP Flow Rate (mgd)	Wilsonville Demand (mgd)	Sherwood Demand (mgd)	Minimum Tank Size (CF)
1	12.5	12.5	0	N/A [1]
2	15	15	0	N/A [1]
3	15	10	5	750
4	20	15	5	1,000
5	25	17.5	7.5	1,250
6	30	22.5	7.5	1,500

Notes:
(1) Scenario was evaluated to determine maximum demand before surge mitigation is recommended.

5.8.3 Recommendations

Modeling confirmed the following results from previous studies: a hydropneumatic tank located at the WRWTP is recommended when the demand approaches 15 mgd; a 750 cubic foot (CF) hydropneumatic tank is recommended for a WRWTP flow of 15 mgd to meet current demand; and the recommended tank sizing increases by 250 CF with each 5 mgd increase in flow up to 1,500 CF at 30 mgd. Because costs are similar for each scenario, a 1,500 CF surge tank is recommended for the current installation. It will enhance near-term surge protection and eliminate the need for additional construction during the 20 and 30 mgd capacity expansions. Note that the surge tank project is being pursued as a separate construction project outside of the 2017 MPU and therefore is not included in the capital improvement plan (CIP).

Chapter 6

EXPANSION ALTERNATIVES ANALYSIS

6.1 Introduction

This Chapter describes the methodology used to determine the approach to expanding the Willamette River Water Treatment Plant (WRWTP) in increments, starting with a capacity expansion to 20 million gallons per day (mgd) and then to 30 mgd, as well as on-going repair and replacement capital improvement plan (CIP) coordination. For an explanation of alternative capacities for the expansion, the reader is referred to Chapter 2 and Chapter 6 of the 2015 Master Plan Update (MPU). The recommended approach in this chapter covers all existing and future treatment processes at the WRTWP:

1. Raw water pumping.
2. Rapid Mixing.
3. Ballasted flocculation/clarification (Actiflo®).
4. Ozonation.
5. Filtration with a deep bed of granular activated carbon (GAC) over sand.
6. Clearwell/chlorine disinfection.
7. Finished water pumping.
8. Waste washwater recovery.
9. Mechanical solids dewatering.
10. Chemical storage and metering facilities.

6.2 Treatment Technologies

To evaluate treatment processes, Carollo considered the water quality and redundancy/ resiliency level of service goals (LOS) summarized in Chapter 2. This included treatment implications, such as the plant's ability to meet current and potential future regulatory MCLs, reduce DBP formation, meet *Cryptosporidium* removal/inactivation requirements, and remove potential contaminants of emerging concern (CECs), pharmaceutical and personal care products (PPCPs), and algal toxins. LOS goals were the basis for determining the overall treatment process redundancy and dictated the procedures a treatment process operates under.

6.3 Confirmation of Treatment Recommendation

In Spring 2016, a Blue Ribbon Panel (BRP) of treatment experts convened to evaluate and confirm the recommended treatment steps in the 2015 MPU. Appendix J of 2015 MPU documents the results of this effort in the *Blue Ribbon Panel Report*.

In summary, the BRP confirmed that the WRWTP's current treatment technologies are the most appropriate for continued treatment of the Willamette River at the expanded WRWTP, with the following provisions for minor process enhancements:

- Advanced oxidation using hydrogen peroxide with ozone.
- Enhanced biological filtration.
- Ultraviolet (UV) irradiation with or without hydrogen peroxide.

Leaving room for these enhancements creates future flexibility at the expanded WRWTP to accommodate and treat any CEC detected in the raw water.

6.4 20 mgd Expansion

As outlined in Chapter 2 and Chapter 6 of the 2015 MPU, expansion of the WRWTP to 20 mgd will rely on up-rating the existing treatment processes rather than installing additional concrete basins and equipment. Up-rating the equipment for the 20 mgd capacity increase (as opposed to constructing new process basins) will reduce plant capital and operating costs for this expansion. Additionally, since the up-rated design criteria will be used to design additional process units for the 30 mgd and future capacity increases, it will also reduce plant capital and operating costs and future expansions.

This section describes the approach used to up-rate the treatment systems and provides any steps required to demonstrate up-rated treatment efficacy. This section also describes any steps necessary to increase equipment redundancy or reliability.

As noted in Section 2.3.4 of this 2017 MPU, the WRWTP will not be able to meet their LOS goal until they construct additional infrastructure that meets the current seismic requirement. Since there is no new infrastructure included in the 20 mgd capacity expansion, WRWTP will not meet their LOS goals through this project.

Table 6.1 (included at the end of Section 6.4) summarizes flow projections, equipment quantities, and equipment sizing for the 20-mgd capacity expansion. This table presents two potential expansion options that can be implemented based on owner and operator preference or equipment performance. Though both options are viable, only Option 1 was included in the expansion cost estimate and CIP.

Figure 6.1 and Figure 6.2 show the site layout and hydraulic profile of the 20-mgd capacity expansion.

6.4.1 Flow Projections

The cities of Wilsonville and Sherwood provided future anticipated peak day flow projections. Projections for minimum and average day flow rates were calculated using the plant's current peak:minimum and peak:average ratios. The minimum and average day projections were then used to evaluate equipment performance and loadings as well as turn-down requirements for raw and finished water pumps, chemical feed facilities, and ozone generation units. Flow projections are listed in Table 6.1.

6.4.2 Raw Water Pumping

Current raw water pumping capacities were evaluated to determine if they can meet the 20 mgd firm capacity, which is the total pumping capacity when largest pump is out of service. Based on the current pump configuration, the raw water pumps provide only 19 mgd firm capacity. Therefore, to meet the firm capacity for the 20 mgd expansion, replacing the 4-mgd, VFD-controlled pump with a larger unit is recommended.

For this capacity analysis and related cost estimate, the pump is assumed to be replaced with a 7.5-mgd, VFD-controlled unit. Because this is a similar size with other installed pumps, it will use the same spare parts and have similar maintenance and operational requirements.

It should be noted that if installing a smaller pump were desired to meet low-demand requirements, a pump as small as 5 mgd would meet the firm capacity requirements. Regardless, improvements to the standby power system will be required, as the existing generator is not capable of meeting the plant's LOS goals.

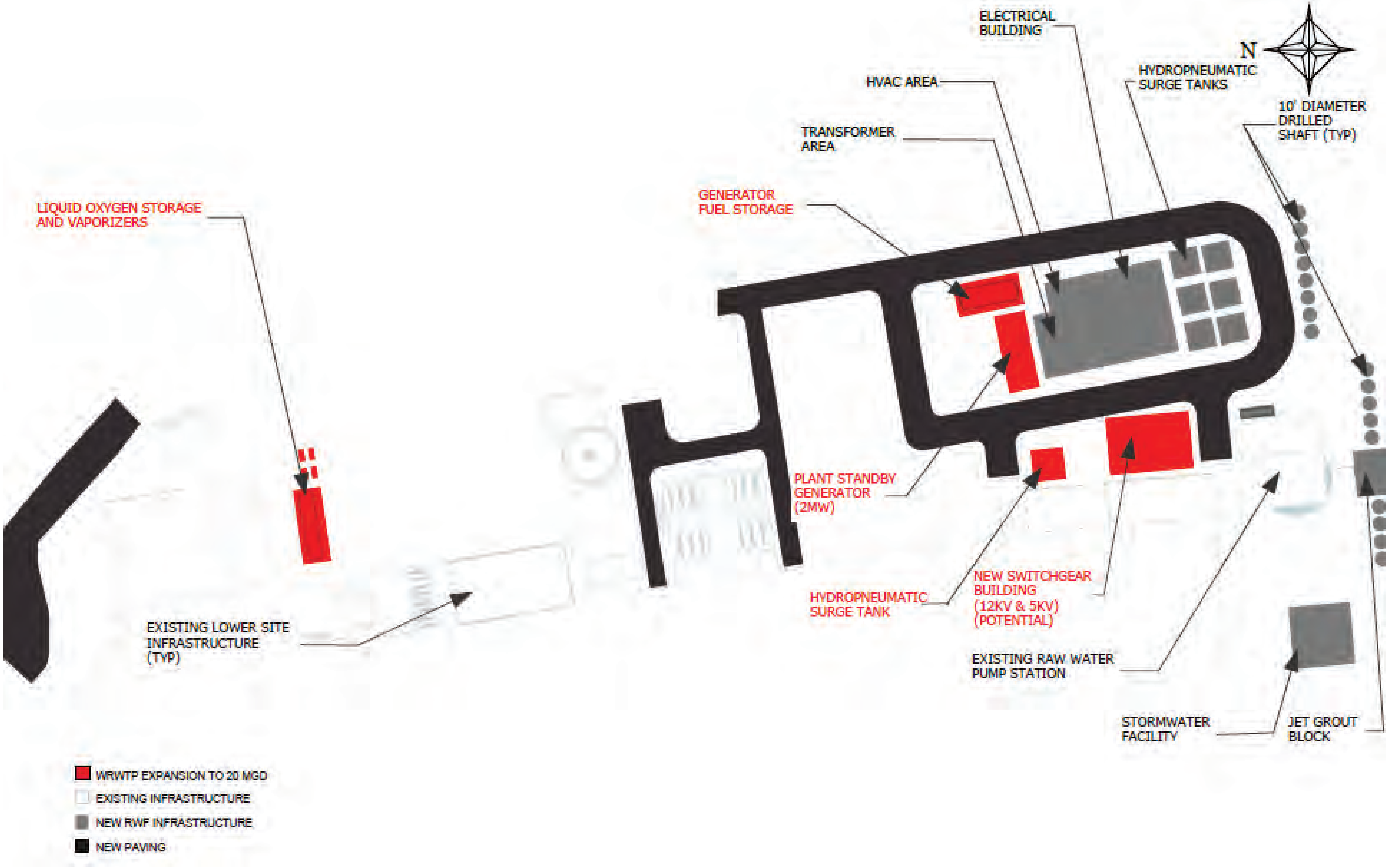


Figure 6.1 WRWTP Site Layout – 20 mgd Capacity

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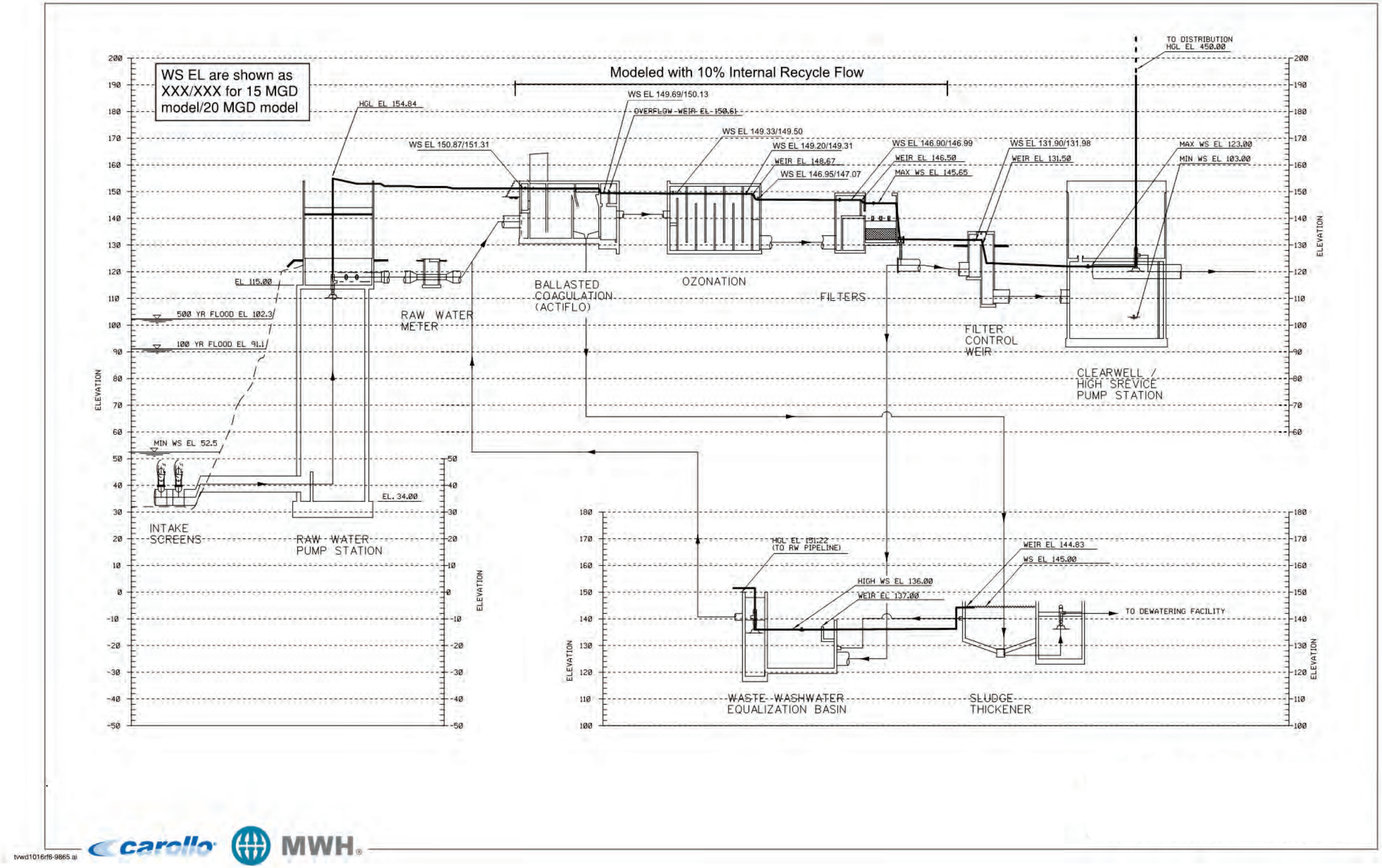

Figure 6.2 WRWTP Hydraulic Profile – 20 mgd Design Capacity

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6.4.3 Flash Mix

The current flash mix system consists of one installed and one shelf-spare pump operating at approximately 10 percent of total plant flow. At the 20 mgd capacity expansion, this system will operate at approximately 7 percent of total plant flow. Since the recommended flash mix rate is 2 to 5 percent of the total plant flow, this system is still sufficiently sized. If installed redundancy is preferred, a permanent shelf-spare pump could be installed. However, it is not entirely necessary because of a potential for chemical addition at the Actiflo® coagulation basin.

6.4.4 Ballasted Flocculation (Actiflo®)

6.4.4.1 System Up-rating

The 2015 MPU evaluated the feasibility of up-rating the Actiflo® process. Though the system is rated at 7.5 mgd per basin as currently designed, it can operate up to 10 mgd per basin without changes to the equipment's size or configuration, which includes the sand recycle pumps. To facilitate the capacity expansion, then, the Actiflo® system will be up-rated to 10 mgd per basin.

6.4.4.2 Equipment Redundancy

For this 2017 MPU evaluation, WRWTP operations staff was interviewed to identify equipment that may need additional redundancy for ideal system performance. For the Actiflo® system, plant operators recommended purchasing an additional "shelf-spare" sand recirculation pump, since these pumps can be difficult to service and parts have a long lead time.

6.4.5 Ozonation and Ozone Generation

6.4.5.1 System Up-rating

The feasibility of up-rating the ozone system was evaluated in the 2015 MPU. The ozonation system operates with both basins in service for a total treatment capacity of 15 mgd, or 7.5 mgd per basin. As mentioned in Chapter 3, the minimum ozone contact time at 15 mgd is 15 minutes when both basins operate and 7.5 minutes when one basin is down for maintenance.

Up-rating the ozone contact basins to 20 mgd will allow for 11 minutes of contact time when both basins are operating, or 5.5 minutes when one basin is down for maintenance. This is still sufficient contact time to meet the 1-log *Cryptosporidium* inactivation goal, as long as higher doses of ozone are maintained. This dose will also achieve the required 0.5-log inactivation of *Giardia* and will serve as the primary disinfection system for the plant. This means that up-rating the basins from 15 mgd to 20 mgd will not affect finished water quality.

To accommodate the increased ozone dosages, the 20 mgd expansion should include the following:

- Conduct tracer study in Finished Water Pump Station clearwell to identify contact time (CT).
- Upgrade ozone diffusers in ozonation basins.
- Replace existing, leased 6,000-gallon LOX storage tank with a new 12,000- to 15,000-gallon tank to ensure sufficient onsite storage. This additional capacity will also suffice for the 30 mgd expansion.
- Install one additional 300 ppd ozone generator for a total of three **OR** replace two existing units with two 400 ppd ozone generators.

6.4.5.2 Equipment Redundancy

No equipment redundancy upgrades are necessary for the ozonation or ozone generation system.

6.4.6 Filtration

6.4.6.1 System Up-rating

As designed, the four filters were rated at 7.5 gallons per minute per square-foot (gpm/sf) with one filter out of service for backwashing, and at 5.7 gpm/sf when all four filters are in service. When one filter was off-line, empty bed contact time (EBCT) through the GAC media was 5.9 minutes. When all filters are operating, it is 7.9 minutes.

The feasibility of up-rating the filtration system was evaluated in the 2015 MPU. Up-rating the filters to 20 mgd will increase the maximum filtration rate to 10 gpm/sf with one filter out of service for backwashing, and 7.5 gpm/sf when all four filters are operating. The EBCT through the GAC media will be 4.5 minutes when one filter is off-line, and 5.9 minutes when all filters are operating.

OHA requires a full year of pilot data to support filter operations exceeding 6 gpm/sf. As documented in Chapter 6 of the 2015 MPU, filtration rates of 10 to 12 gpm/sf have already gained OHA approval at two plants with similar raw water quality: the Lake Oswego-Tigard WTP and the proposed new Grants Pass WTP. Despite these precedents, pilot testing will likely be required to demonstrate to OHA that the increased filtration rate will not adversely affect finished water quality.

To save time and expense, this 2017 MPU recommends the Cities of Wilsonville and Sherwood negotiate a different approach to OHA's pilot filter requirements. Instead of pilot testing, the existing plant would gradually increase its filtration rate (e.g., 0.5 gpm/sf increments for an OHA-specified duration, etc.) and collect treated water data to compare to WRWTP finished water requirements. After successful operation in the first increment of the increased rate, the filtration rate can be increased again and the process repeated until the desired rate is achieved and approved.

6.4.6.2 Equipment Redundancy

No equipment redundancy upgrades are necessary for the filtration system.

6.4.7 Clearwell/Chlorine Disinfection

6.4.7.1 System Up-rating

Chlorine is the primary disinfection approach in the clearwell governed by the inactivation of 0.5-log *Giardia*. However, at summer flows greater than 15 mgd and winter flows exceeding 10 mgd, the existing clearwell cannot reach this disinfection level. This deficiency has been well documented, most recently in the *Willamette River WTP Disinfection (CT) Analysis* (MWH, February 2010).

Moving forward, the cities have two alternatives for meeting the disinfection requirements:

- Install UV disinfection downstream of the existing filters.
- Work with OHA to obtain *Giardia* disinfection credit from the intermediate ozonation system.

The cities have already begun the process of petitioning the state. As a founding member of the Oregon Water Utility Council's (OWUC) Ozone Coalition, Wilsonville is drafting a petition to OHA. Final submission, review, and approval are expected in summer 2018, well before plant production rates exceed the existing clearwell's disinfection capabilities. After receiving OHA approval, the clearwell will simply serve as a wet well for the finished water pump station.

6.4.7.2 Equipment Redundancy

No equipment redundancy upgrades are necessary for the clear well.

6.4.8 Finished Water Pumping

An evaluation of the current pump configuration to find out if the finished water pumps could meet 20 mgd firm capacity showed they can deliver only 19 mgd firm capacity. Therefore, the preliminary 2017 MPU recommendation for the 20 mgd expansion is to replace the 4-mgd, variable-frequency drive (VFD)-controlled pump with a 7.5-mgd, VFD-controlled unit. Since this size is similar to other installed pumps, it will use the same spare parts and have similar maintenance and operational requirements. If the Cities and operations staff want to maintain a smaller pump to meet low-demand requirements, two options exist:

- Replace existing 4 mgd pump with a 5 mgd VFD-controlled pump.
- Install a fifth pump to meet at least 20 mgd firm capacity.

6.4.8.1 Equipment Redundancy

Once firm capacity requirements are met, no additional upgrades are necessary in the finished water pump station.

6.4.9 Waste Washwater Recovery

No modifications are necessary for the waste washwater recovery system for the 20-mgd capacity expansion.

6.4.10 Mechanical Solids Dewatering

No modifications are necessary for the mechanical solids dewatering system for the 20-mgd capacity expansion.

6.4.11 Chemical Storage and Metering

The following modifications are recommended for the 20-mgd capacity expansion:

- **Chemical Piping Replacement**: WRWTP operators say the existing chemical lines and spares have become inoperable during their 15-year operating period. Therefore, we recommend that the 20-mgd capacity expansion include replacing all in-place chemical lines.
- **Utilidor Extension**: To facilitate the current and future chemical line replacements, we recommend extending the existing utilidor to the southern half of the WRWTP. To traverse the waste washwater equalization basin, the chemical pipelines should be installed along the interior western wall to route them to the utilidor.
- **Addition of a Second Dry Polymer System**: WRWTP operators say the existing dry polymer batching system unreliable at times. Since this system is key to successful operation of the Actiflo® system, installing a redundant dry polymer batching system is recommended.

- **Increased LOX Storage**: As mentioned, the existing leased 6,000-gallon LOX storage tank and associated evaporators should be replaced with a larger leased system to ensure sufficient onsite storage at the increased plant capacity.
- **Sodium Hypochlorite Tank Replacement**: One of the two 4,400-gallon tanks installed during plant construction failed during plant operation and was replaced with a 3,900-gallon tank. To prevent unexpected failure of the second tank, the WRWTP should plan to replace the remaining 4,400-gallon original tank with a new tank.
- **Strainers on Pump Suction**: WRWTP operators reported difficulty with pump maintenance due to clogging in the suction line. To avoid this in the future, wye or basket strainers should be installed on chemical pump suction lines.
- **Hypochlorite Vent Return**: WRWTP operators reported concerns with the hypochlorite pump vents off-gassing. To ensure a safe work environment, pump and line vents will be plumbed to return to the hypochlorite storage tanks.

6.4.12 Electrical Upgrades

This section summarizes the recommended electrical upgrades for the WRWTP capacity expansions. See Appendix A for more on the electrical evaluation.

As mentioned in Chapter 5, the electrical system is loaded above 80 percent of listed capacity and is considered overloaded. Additionally, the existing emergency generator is not connected to all WRWTP equipment (e.g., it is wired only to Actiflo® Basin 2) and has sufficient capacity to power only the 4-mgd raw and finished water pumps. The existing electrical configuration (at 15 mgd) is included in Chapter 5. Figure 5.4 depicts the electrical configuration and overloaded equipment following the 20-mgd WRWTP expansion if nothing is done to improve the plant's electrical infrastructure.

Based on these evaluations, this 2017 MPU recommend that the plant upgrade its electrical equipment as part of the 20-mgd expansion project to ensure that an electrical fault does not interrupt service. The following upgrades are recommended:

- **Switchgear Replacement**: Replacing with a 15-KV metering switchgear and 5-KV transformer, which should be sufficient to power the WRWTP through 60 mgd.
- **Emergency Generator Replacement**: Replacing with a 2-MW generator wired directly to the 15-KV metering switchgear. This will allow all plant equipment to be run on the emergency generator.
- **Plant Re-wiring**: Connecting all finished water pumps to the 5-KV transformer/switchgear, leaving sufficient capacity on the remaining transformers to power the rest of the plant.

Figure 5.5 depicts the electrical system following the improvements recommended above for the 20 mgd capacity expansion. These improvements lay the foundation for simple, low-risk expansion moving forward. Figure 5.6 depicts the system improvements recommended to accommodate the 30-mgd expansion.

Note that the recommended improvements are limited to the connection of additional finished and raw water pumps to the 5-KV transformer.

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures

Flow Rate	Units	Option 1	Option 2
Minimum	mgd	3.3	3.3
Annual Average	mgd	6.4	6.4
Maximum (Plant Design)	mgd	20	20
	GPM	13,889	13,889
Willamette River			
Minimum River Level	FT	52.5	--
100 Year Flood Elevation	FT	91.1	--
500 Year Flood Elevation	FT	102.3	--
Intake Screens(1)			
Type: Horizontal cylindrical			
Number	#	2	--
Capacity, total	mgd	70	--
Diameter	IN	66	--
Screen Opening Size	mm	1.75	--
Maximum Face Velocity	FPS	0.4	--
Top of Screen Elevation	FT	42.75	--
Screen Cleaning			
Cleaning method: air burst			
Number of Compressors	#	2	--
Compressor Capacity	CFM	200	--
Air receiver volume	CF	2,200	--
Motor Size per compressor	HP	50	--
Raw Water Pumps			
Type: Vertical Turbine, Single-stage			
Number	#	4 (3+1)	--
Total capacity w/ stand-by	mgd	30	--
Firm capacity	mgd	22.5	--
Capacity (each)			
1 VFD Driven pump	mgd	7.5	--
1 VFD Driven Pump	mgd	7.5	--
1 VFD Driven Pump	mgd	7.5	--
1 Constant speed pump	mgd	≥ 7.5	--
Total dynamic head (20 mgd)	FT	111	--
Total motor horsepower	HP	4@200	--

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Initial Flash Mix			
Type: Pumped			
Number (Installed)	#	1	2 (1+1)
Mixing energy (ea)	s^{-1}	1,000	1,000
Pump capacity (ea)	gpm	1,000	1,000
Pump flow as a percentage of plant flow rate (PFR)	%	7%	7%
Total dynamic head	FT	16	16
Total motor horsepower (ea)	HP	7.5	7.5
Clarification Process			
Type: Ballasted Flocculation (Actiflo®)			
Number of Basins	#	2	--
Design flow (per basin)	mgd	10	--
Max process hydraulic flow (per basin)	mgd	15	--
Mixing/Flocculation (per basin)			
Coagulation chamber volume	CF	2,000	--
Coagulation chamber HRT	MIN	2.2	--
Injection chamber volume	CF	2,165	--
Injection chamber HRT	MIN	2.3	--
Maturation chamber volume	CF	6,330	--
Maturation chamber HRT	MIN	6.82	--
Clarification			
Settling chamber volume	CF	7,570	--
Settling chamber HRT	MIN	8.2	--
Lamella tube settlers, surface area (ea)	SF	260	--
Maximum design surface loading rate w/ all basins	GPM/SF	--	--
Design Surface Loading Rate w/ All Basins	GPM/SF	27	--
Maximum surface loading rate (1 basin OOS)	GPM/SF	53	--
Sand slurry recirculation system			
Number of sludge recirculation pumps per Basin	#	2 (2+0)	--
Pumps in operation	#	2	
Sludge recirculation rate	%	4.8	--
Capacity per pump	GPM	165	--
Total design head	FT	75	--
Pump horsepower	HP	10	--
Number of sand hydrocyclones (per basin)	#	2	--
Average Sand Loss Rate	LB/MG	23	--

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Approx. Daily Sand Loss	PPD	460	--
Ozone Contact Basins			
Type: 8-stage counter-co-counter w/ fine-bubble diffusers			
Number of basins	#	2	--
Detention time w/ all in service @ Design Flow	MIN	11.20	--
Detention time w/ one out of service @ Design Flow	MIN	5.60	--
Average water depth	FT	21	--
Inside dimensions (each basin)	FT x FT	6 x 10	--
Volume (total)	CF	20,800	--
Ozone Destruct Units	#	2	--
Ozone Generators			
Number	#	3 (2+1)	2 (1+1)
Feed Gas	-	LOX	LOX
Capacity (ea)	PPD	300	400
% Ozone by Weight (max)	%	8	8
Design Ozone Dose	mg/L	2.4	2.4
Max Ozone Dose @ Design Flow	mg/L	5.40	4.80
Dose with one unit out of service @ Design Flow	mg/L	3.60	2.40
Liquid Oxygen (100% LOX)			
Number of tanks	#	1	-
Storage capacity, total	GAL	12,000	-
Storage (avg dose x max flow)	DAYS	26	-
Average Oxygen Dosage	mg/L	26	-
Storage Density	LB/GAL	9.5	-
Filters			
Type: Deep bed, dual granular media			
with influent flow splitting			
Number of filters	#	4	--
Number of bays/filter	#	1	--
Filter bay dimensions	FT x FT	20 x 23	--
Filter area (each filter)	SF	460	--
Total filter area	SF	1,840	--
Maximum filtration rate (Q/A)			
All filters on-line @ Design Flow	GPM/SF	7.5	--
One filter off-line @ Design Flow	GPM/SF	10.1	--
Hydraulic maximum	GPM/SF	12	--

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Flow Rate Each Filter			
All filters on-line @ Design Flow	mgd	5.0	--
One filter off-line @ Design Flow	mgd	6.7	--
Filter media			
GAC			
Depth	IN	72	--
Effective size	mm	1.4	--
Uniformity coefficient		<1.4	--
Depth: Diameter (L:D)		1,306	--
Minimum Empty bed contact time (EBCT)			
All filters on-line @ Design Flow	MIN	5.9	--
One filter off-line @ Design Flow	MIN	4.5	--
Sand			
Depth	IN	12	--
Effective size	MM	0.45	--
Uniformity coefficient		<1.4	--
Depth: Diameter (L:D)	MM:MM	677	--
Total media			
Depth (maximum)	IN	84	--
Depth: Diameter (L:D)	MM:MM	1,984	--
Filter wash system			
Air scour blowers			
Number	#	2	--
Air scour rate	CFM/SF	3.2	--
Blower capacity (each)	ACFM	1,500	--
Blower horsepower (each)	HP	100	--
Backwash pumps			
Number	#	2	--
Maximum backwash rate	GPM/SF	20	--
Pump capacity (each)	GPM	9,200	--
Pump horsepower (each) – constant speed	HP	150	--
Maximum Backwash Volume	mgd	2.8	
Clearwell			
Type: Buried, reinforced concrete			
Active volume	MG	2.9	--
Max Operating Side Water Depth	FT	21.5	--

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Dimensions	FT x FT	135 x 135	--
Detention Time (HRT) at Design Flow when full	HOURS	3.48	--
Hydraulic Efficiency up to 15 mgd	T10:HRT	0.11	--
Hydraulic Efficiency >15 mgd	T10:HRT	n/a	--
Finished Water Pumps			
Type: Vertical turbine, Two-stage			
Number	#	4 (3+1)	5 (4+1)
Total capacity with stand-by	mgd	30	30.5
Firm capacity	mgd	22.5	23
Capacity each			
1 VFD Driven pump	mgd	7.5	4
1 VFD driven pump	mgd	7.5	7.5
1 VFD driven pump	mgd	7.5	7.5
1 Constant speed pump	mgd	7.5	7.5
1 VFD driven pump		--	4
Total dynamic head	FT	--	--
Motor Size	HP	4@500	2@300 3@500
Waste Washwater Equalization & Pump Station			
Equalization basins			
Type: Concrete			
Number of basins	#	1	--
Volume	GAL	244,000	--
Maximum Backwash Volume	mgd	2.8	--
Hydrocyclone Overflow @ Design Rate	mgd	0.8	
Basin HRT	HRS	1.6	--
Washwater recycle pumps			
Type: Vertical turbine			
Number	#	3 (2+1)	--
Firm capacity	GPM	1,500	--
Capacity each			
1 VFD driven pump	GPM	500	--
1 VFD driven pump	GPM	500	
1 constant speed pump	GPM	500	--
Time to empty basin (all pumps on-line)	HRS	2.7	--
Time to empty basin (one pump off-line)	HRS	4.1	--
Total dynamic head	FT	25	--

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Motor horsepower	HP	3 @ 5	--
Solids Treatment			
Type: Gravity thickener and centrifuges			
Estimated Max Solids Production (dry) @ Design Flow	LB/DAY	2,667	--
Estimated Max Hydraulic Flow Rate @ Design Flow	GPM	321	--
Gravity thickener (circular)			
Number of units (total, existing + new)	#	1	--
Diameter	FT	35	--
Side Water Depth	FT	12	
Max solids loading rate	PPD/SF	8	--
Max hydraulic loading rate	GPM/SF	1	--
Operating solids loading rate	PPD/SF	2.8	--
Operating hydraulic loading rate	GPM/SF	0.33	--
Storage Capacity @ Design Rate (7-day ops)	HRS	4.5	
Storage Capacity @ Design Rate (5-day ops)	HRS	3.2	
Solids Storage & Mixing			
Storage Volume	GAL	33,000	--
Estimated solids flow @ 2.5%	GAL/MG	765	--
	GPD	15,300	--
Mixing Tank HRT (7-day ops)	HRS	51	--
Mixing Tank HRT (5-day ops)	HRS	36	
Mixing Pumps	#	1	--
Pumping capacity	GPM	600	--
Pump horsepower	HP	5	--
Solids pump station			
Progressive Cavity Transfer Pumps	#	2	--
Pumping capacity (ea)	GPM	60	--
Motor Size (ea)	HP	10	--
Total dynamic head	FT	60	--
Centrifuges			
Type		Horz. Scroll	--
Number of units	#	2	--
Capacity, each	GPM	60	--
Max solids loading, each	LB/HR	750	--
Maximum 8-hr Processing Capacity (ea)	PPD	6,000	--
Maximum 8-hr Processing Capacity (ea)	GPD	28,800	

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Motor horsepower-scroll, each	HP	40	--
Motor horsepower-back drive, each	HP	15	--
Centrifuge operation period (1 standby, 7-day ops)	HR/DAY	3.6	--
Centrifuge operation period (1 standby, 5-day ops)	HR/DAY	5.0	
Chemical Storage			
Primary coagulant (49% alum sol'n)			
Number of tanks	#	2	--
Storage capacity, total	GAL	13,000	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	28	--
Average Dosage	mg/L	15	--
Minimum volume for 21-day Storage	GAL	9,750	
Solution Strength (alum)	LB/GAL	5.4	--
Cationic polymer (dry polymer)			
Type	-	Dry Feeder	--
Feed Capacity	LB/HR	17.6	--
Required Days Storage	DAYS	14	--
% solution	%	1	--
Storage (avg dose x max flow)	DAYS	--	--
Mixing Time	min	30	--
Sodium hypochlorite (12.5% NaOCl sol'n)			
Number of tanks	#	2	--
Storage capacity, total	GAL	7,800	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	24	--
Average Dosage	mg/L	2	--
Minimum volume for 21-day Storage	GAL	6,825	
Solution Strength	LB/GAL	1.05	--
Caustic soda (25% NaOH sol'n)			
Number of tanks	#	2	--
Storage capacity, total	GAL	13,000	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	31	--
Average Dosage	mg/L	6.5	--
Minimum volume for 21-day Storage	GAL	8,806	
Solution Strength	LB/GAL	2.65	--

Table 6.1 WRWTP 20 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Aqueous ammonia (19% NH_4OH sol'n)			
Number of tanks	#	1	--
Storage capacity, total	GAL	1,400	--
Anionic polymer			
Number of tanks	#	1	--
Storage capacity, total	GAL	55	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	> 1 year	--
Average Dosage	mg/L	0.4	--
Non-ionic polymer			
Number of tanks	#	1	--
Storage capacity, total	GAL	55	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	> 1 year	--
Average Dosage	mg/L	0.4	--
Calcium Thiosulfate			
Number of tanks	#	2	--
Storage capacity, total	GAL	440	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	47	--
Minimum volume for 21-day Storage	GAL	197	
Average Dosage	mg/L	0.2	--
Solution Strength	LB/GAL	3.6	--

Notes:

(1) Intake screen replacement will be completed as part of the WWSP RWF construction project and is not included in this expansion.

6.5 30-mgd Expansion

To maximize the available space at the WRWTP with the goal of achieving a total ultimate capacity of 60 mgd in the existing site boundary, the 30-mgd capacity expansion will be designed based on updated process design criteria for the 20-mgd capacity expansion. This will allow the plant to maximize the available space at the WRWTP with the intention of achieving a total capacity of 60 mgd within the existing site boundary. Additionally, using the up-rated criteria will allow the WRWTP to deliver high-quality finished water to the cities of Wilsonville, Sherwood, and any potential distribution partners while minimizing rate increases.

As noted in Section 2.3.4 of this 2017 MPU, the WRWTP will not be able to meet their LOS goal until they construct additional infrastructure that meets the current seismic requirement. Since the 30 mgd expansion includes construction of new process trains, WRWTP will be able to meet their LOS goals ahead of the 50-year period recommended in the ORP.

6.5.1 Expansion Alternatives

The 2017 MPU evaluated two 30 mgd expansion alternatives for each of the plant's main treatment processes (i.e., ballasted flocculation, ozonation, and filtration):

Alternative 1.	Expansion at up-rated design criteria.
Alternative 2.	Expansion at up-dated design criteria with post seismic basin redundancy (install a completely redundant basin).

Figures 6.3 and 6.4 show the basins assumed to be active after a seismic event, and Table 6.2 lists them. As the table shows, Alternative 1 would allow the WRWTP to meet its LOS goal following a regional seismic event but would not provide basin redundancy when a basin must be taken off-line.

Alternative 2 provides sufficient redundancy following a regional seismic event, but is significantly more expensive.

Table 6.2 WRWTP 30 mgd Expansion Alternatives

Treatment Process	Number of Basins On-line: Total (Duty + Standby)			
	Alternative 1	Alternative 2	Alternative 1 PRSE	Alternative 2 PRSE
Actiflo®	3 (3+0)	4 (3+1)	1 (1+0)	2 (1+1)
Ozonation	3 (3+0)	4 (3+1)	1 (1+0)	2 (1+1)
Filtration	6 (5+1)	8 (7+1)	2 (2+0)	4 (3+1)

Notes:
(1) PRSE = post regional seismic event.

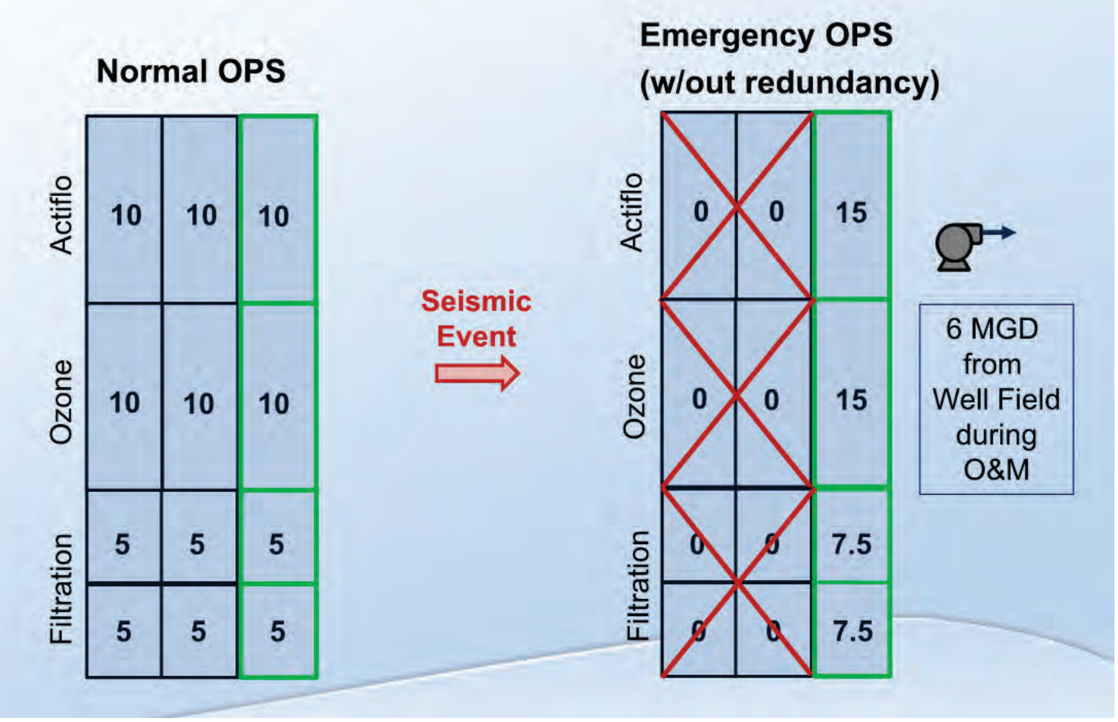

Figure 6.3 WRWTP 30 mgd Expansion – LOS

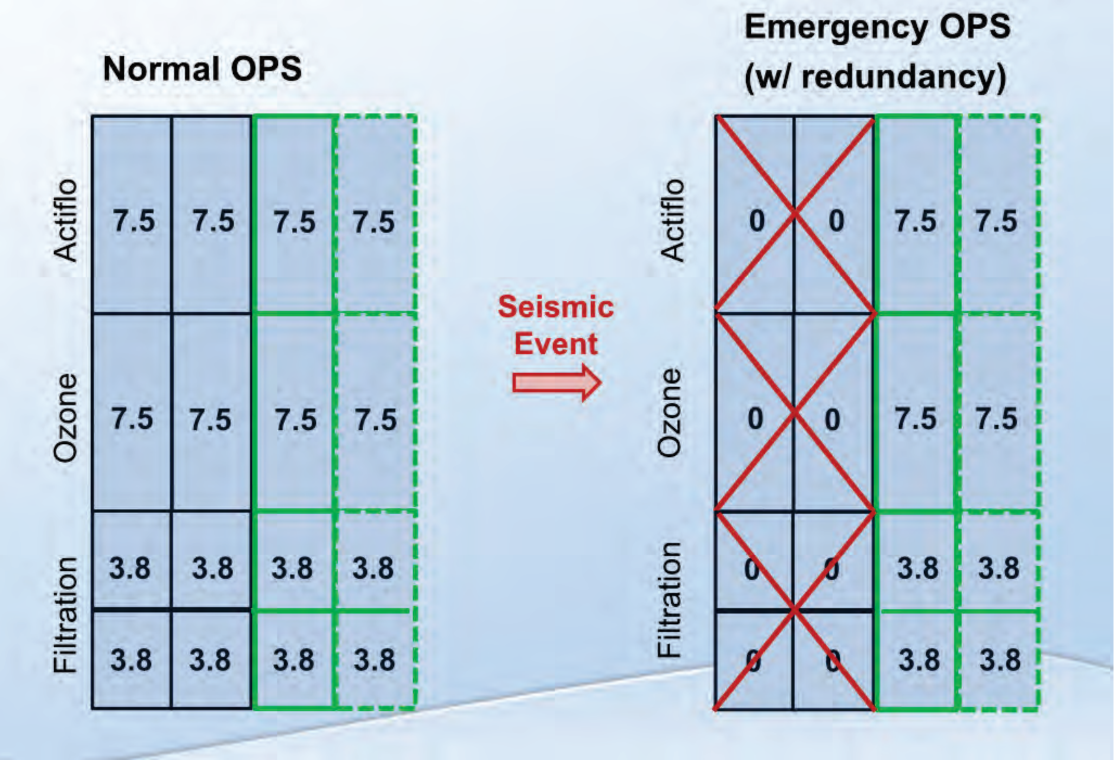

Figure 6.4 WRWTP 30 mgd Expansion – LOS + Post Regional Seismic Event (PRSE) Resiliency

6.5.1.1 Alternatives Evaluation

Per the WRWTP LOS goal presented in Chapter 2, within 48 hours of a regional seismic event the WRWTP would be required to produce half its nameplate capacity of 30 mgd (or 15 mgd) at the minimum potable water standard. For this evaluation, this 2017 MPU assumed the treatment basins installed during initial plant construction would not be initially functional, limiting treatment to the basins installed during the 30-mgd expansion. Table 6.3 shows the primary treatment process operating criteria.

For Alternative 1, the impacts to treatment following a regional seismic event are as follows:

- **Actiflo®:** The remaining Actiflo® basin would treat 15 mgd. Based on discussions with the vendor (Kruger), the basins installed at WRWTP can treat this flow rate. However, both sand pumps must operate in parallel to ensure the basins can maintain a minimum 3 percent solids recycle rate with the existing 165 gpm sand pumps.
- **Ozonation:** The remaining ozone basin would treat 15 mgd, limiting detention time in the ozonation basin to 7.5 minutes. Although this is sufficient to achieve 0.5-log *Giardia* inactivation, the ozonation system would not be operable if the basin required maintenance. Though 1-log inactivation of *Cryptosporidium* isn't necessary because water quality LOS goals are limited to regulatory requirements, ozone redundancy is desirable because the ozone basin would still be providing primary disinfection for the plant. However, at flows up to 15 mgd in the summer and 10 mgd in the winter, the clear well can achieve Giardia disinfection using free chlorine. It could be used on an interim basis to allow maintenance of the ozone facilities.

- **Filtration:** The filtration system would treat 15 mgd through two filters. This would result in a nominal filtration rate of 11.3 gpm/sf and a maximum filtration rate of 22.6 gpm/sf. Plant flows must be limited when one filter is down for backwashing. Assuming the maximum permitted filtration rate is 12 gpm/sf, the WRWTP could produce only 8 mgd instantaneously during backwash cycles.

For Alternative 2, no treatment impacts follow a regional seismic event because the remaining basins and maximum production rate would be identical to the expanded plant under normal operations (with one basin out of service). However, adopting Alternative 2 would approximately double the cost of the 30 mgd capacity expansion. The additional equipment would increase operations and maintenance costs and create stranded capacity for most of the operational life, particularly since the new equipment would be useful only during maximum demand conditions.

This 2017 MPU recommends considering Alternative 1 for the 30-mgd capacity expansion planning and designing all other resiliency options to minimize the risks associated with Alternative 1.

6.5.1.2 Alternative Water Supplies

Since the capital and operating costs of additional basins make Alternative 2 impractical, additional resiliency options were evaluated. These options included alternative supplies that may be necessary when plant demand is 15 mgd but production is reduced, such as during filter backwash or equipment maintenance. Alternative water supplies identified during this evaluation include:

- Wilsonville and Sherwood Well Fields: Both cities maintain well fields plumbed to the potable water distribution system and able to produce approximately 3 mgd each.
- WWSP Supply: Temporary supply could be requested from the WWSP. This would require adding a tie point and meter between the two systems, likely near the site of the future WWSS WTP in Sherwood, as well as a temporary pump station to be used when supply is needed. It would also require an Intergovernmental Agreement (IGA) dictating the costs and maximum allowable diversion to avoid impacting WWSP customers. Additional studies are required to demonstrate what additional infrastructure, such as temporary booster pump stations, may be required to back-feed Wilsonville’s distribution system from Sherwood.
- Alternative Supply from Sherwood: This would require both an additional source of supply to Sherwood (City of Portland, or equal) and the previously mentioned additional infrastructure to convey water to Wilsonville’s distribution system.

Based on this evaluation, sufficient water supply alternatives are in the region and partner cities to supplement the WRWTP.

6.5.1.3 Alternative Recommendation

For the 30-mgd capacity expansion, this 2017 MPU recommends Alternative 1, which requires no redundant basins following a catastrophic seismic event and identifies an alternate water supply source such as existing groundwater to supplement WRWTP production during maintenance. Alternative 1 is considered sufficiently conservative since it is unlikely the original basins will be completely inoperable following a regional seismic event. Identifying an additional water supply will furnish significant regional resiliency.

Table 6.3 WRWTP 30 mgd Expansion Alternatives – Design and Operating Criteria following a Catastrophic Seismic Event

Flow Rate	Units	ALT 1	ALT2
Minimum	mgd	2.5	2.5
Average	mgd	4.8	4.8
Max (Plant Design)	mgd	15	15
	GPM	10,417	10,417
Clarification Process			
Type: Ballasted Flocculation (Actiflo®)			
Number of Basins	#	1	2
PRSE Flow Rate (per basin)	mgd	15	7.5
Max process hydraulic flow (per basin)	mgd	15	15
Mixing/Flocculation (per basin)			
Coagulation chamber volume	CF	2,000	2,000
Coagulation chamber HRT	MIN	1.4	2.9
Injection chamber volume	CF	2,165	2,165
Injection chamber HRT	MIN	1.6	3.1
Maturation chamber volume	CF	6,330	6,330
Maturation chamber HRT	MIN	4.55	9.09
Clarification			
Settling chamber volume	CF	7,570	7,570
Settling chamber HRT	MIN	5.4	10.9
Lamella tube settlers, surface area (ea)	SF	260	520
Design Surface Loading Rate w/ All Basins	GPM/SF	40	20
Maximum surface loading rate	GPM/SF	40	40
Sand slurry recirculation system			
Number of sludge recirculation pumps/basin	#	2	2
Pumps in operation	#	2	1
Sludge recirculation rate	%	3.2	3.1
Capacity per pump	GPM	165	165
Total design head	FT	75	75
Pump horsepower	HP	10	10
Number of sand hydrocyclones (per basin)	#	2	2
Average Sand Loss Rate	LB/MG	23	23
Approx. Daily Sand Loss	PPD	345	345
Ozone Contact Basins			
Number of basins	#	1	2
Detention time w/ all in service @Design Flow	MIN	7.47	14.94

Table6.3 WRWTP 30 mgd Expansion Alternatives – Design and Operating Criteria following a Catastrophic Seismic Event (Continued)

Flow Rate	Units	ALT 1	ALT2
Detention time w/ one out of service @Design Flow	MIN	N/A	7.47
Average water depth	FT	21	21
Inside dimensions (each basin)	FT x FT	6 x 10	6 x 10
Volume (total)	CF	10,400	20,800
Filters			
Number of filters	#	2	4
Number of bays/filter	#	1	1
Filter bay dimensions	FT x FT	20 x 23	20 x 23
Filter area (each filter)	SF	460	460
Total filter area	SF	920	1,840
Maximum filtration rate (Q/A)			
All filters on-line @ Design Flow	GPM/SF	11.3	5.7
One filter off-line @ Design Flow	GPM/SF	22.6	7.5
Hydraulic maximum	GPM/SF	12	12
Flow Rate Each Filter			
All filters on-line @ Design Flow	mgd	7.5	3.8
One filter off-line @ Design Flow	mgd	15.0	5.0
Minimum Empty bed contact time (EBCT)			
All filters on-line @ Design Flow	MIN	4.0	7.9
One filter off-line @ Design Flow	MIN	2.0	5.9

6.5.2 Flow Projections

The Cities of Wilsonville and Sherwood projected future peak day flows. They calculated minimum and average day flow rates using the plant’s current peak:minimum and peak:average ratios. These minimum and average day projections were used to evaluate equipment performance and loadings as well as turn-down requirements for raw and finished water pumps, chemical feed facilities, and ozone generation units. Table 6.4 (located at the end of Section 6.5) lists flow projections. Figure 6.5 shows the site layout for the 30 mgd capacity expansion.

Table 6.4 presents two potential expansion options that can be implemented based on owner and operator preference or equipment performance. Though both options are viable, only Option 1 was included in the expansion cost estimate and CIP.

6.5.3 Raw Water Pumping

Pumps will need replacing to support the 30-mgd expansion. The WRWTP will have three dedicated pumps and share one pump with the WWSP RWF. Assuming four 7.5 mgd pumps are included at the 20-mgd expansion, the WRWTP firm capacity will be 22.5 mgd.

This 2017 MPU recommends replacing two 7.5 mgd pumps with 15 mgd pumps, with will provide a firm capacity of 30 mgd. Additionally, this 2017 MPU recommends that all pumps are VFD-controlled to ensure WRWTP can meet its capacity requirements.

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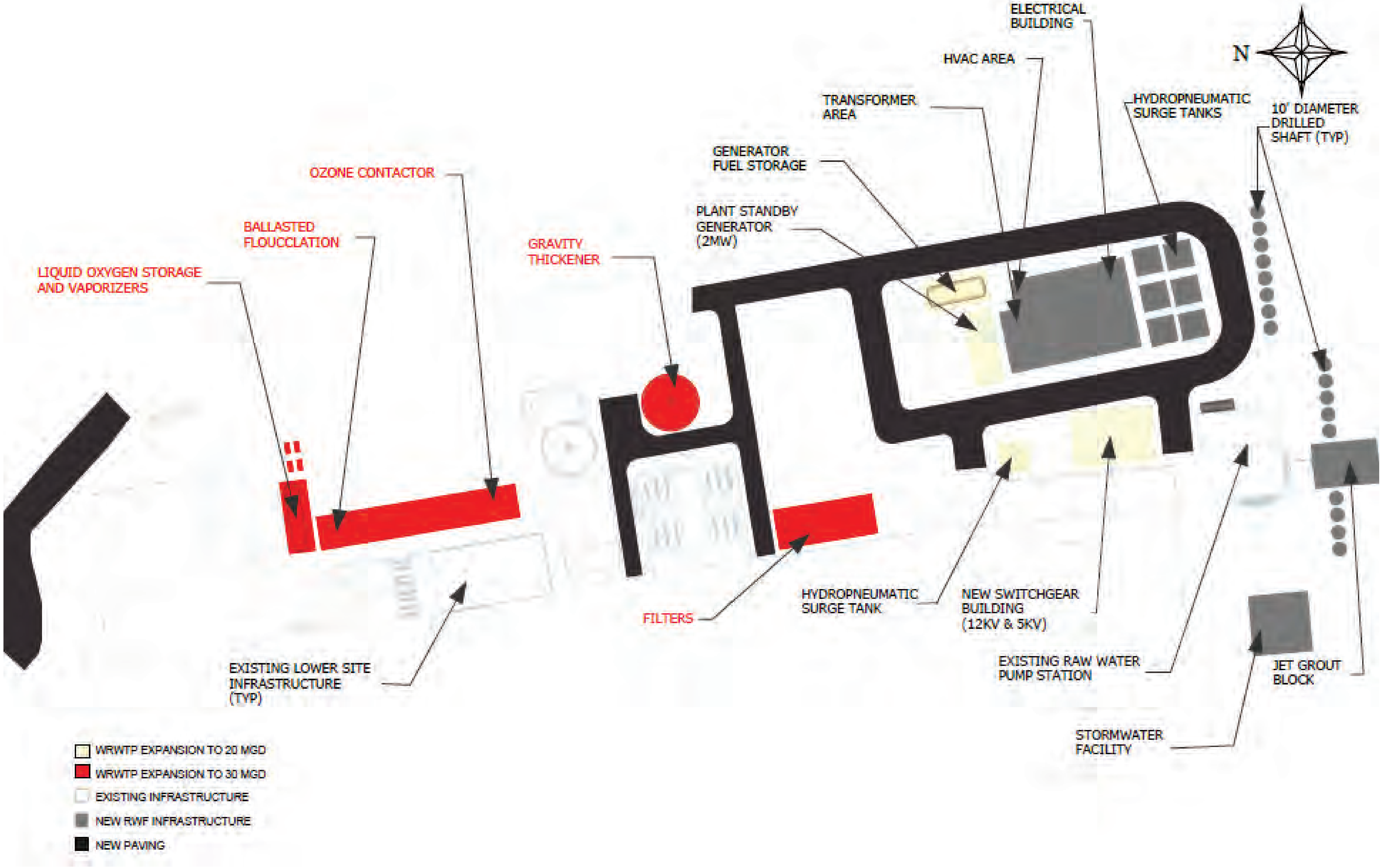

Figure 6.5 WRWTP Site Layout – 30 mgd Design Capacity

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6.5.4 Flash Mix

At the 30-mgd capacity expansion, the flash mix system will operate at approximately 5 percent of total plant flow. Since the recommended flash mix rate is 2 to 5 percent of total plant flow, the system is sufficiently sized. If installed redundancy is preferred, this 2017 MPU recommends permanently installing the shelf-spare pump.

6.5.5 Ballasted Flocculation (Actiflo®)

At the 30-mgd capacity expansion, installing one additional Actiflo® basin is recommended. This will maintain the uprated capacity of 10 mgd per basin as described in the 20 mgd capacity expansion.

6.5.6 Ozonation

At the 30 mgd capacity expansion, installation of one ozone basin is recommended to maintain the uprated capacity of 10 mgd per basin (as described for the 20 mgd capacity expansion). Basin construction will include the shared ozone gallery, common with the fourth ozone basin when it is constructed during the next (i.e. 40 mgd) capacity expansion in the future. This expanded ozone contact facility will be able to provide both the OHA-required 0.5-log inactivation of *Giardia* and the non-regulated 1-log inactivation of *Cryptosporidium*, defined in the plant's LOS goals.

6.5.7 Filtration

At the 30-mgd capacity expansion, installing two additional filters is recommended. This will maintain the uprated maximum filtration rate of 10 gpm/sf when one basin is off-line for backwashing, as described in the 20-mgd capacity expansion.

6.5.8 Clearwell/Chlorine Disinfection

As previously discussed, after OHA approval of the plant's petition to recognize the disinfection benefits of ozone, the clear well will continue to serve as a wet well for the finished water pump station. The clear well can serve in this capacity to flows in excess of 60 mgd, or the plant's ultimate build-out capacity. That being said, the disinfection capability at the clear well should be maintained because free chlorine disinfection at reduced rates can serve as temporary backup to ozone disinfection in a catastrophic event.

6.5.9 Finished Water Pumping

The finished water pumping capacity after the 20-mgd capacity expansion will depend on which option is selected. If four pumps are installed, the firm capacity will be up 22.5 mgd. With a fifth pump, firm capacity rises to 23 mgd. Therefore, replacing or adding a pump is necessary to meet 30 mgd firm capacity. Installation options include:

- Assuming four total pumps: Replace three 7.5 mgd pumps with 12 mgd pumps to give a firm capacity of 31.5 mgd (included as Option 1 in Table 6.4).
- Assuming five total pumps: Replace three 7.5 mgd pumps with 12 mgd pumps to give firm capacity of up to 39 mgd (included as Option 2 in Table 6.4).

Note that the 12-mgd recommended finished water pump size is not consistent with the recommended 15-mgd raw water pump size. Space restrictions in the finished water pump station and greater total dynamic head (TDH) of the finished water pumps make it unlikely that 15-mgd, VFD-controlled pumps could fit in the allotted space.

This 2017 MPU recommends reviewing final pump sizing and required space before beginning design for the 30 mgd capacity expansion to determine if consistent pump sizes can be used in the finished and raw water facilities. Otherwise, the plant control systems will need to be upgraded to compensate for these variations in pump rate.

6.5.10 Waste Washwater Recovery

Expired service life means waste washwater pumps must be replaced for the 30-mgd expansion. To accommodate additional filters and the resulting increase in waste washwater flow rate, the 30-mgd capacity expansion should include upgrading from 500 gpm to 1,000 gpm pumps or installing a fourth 500 gpm pump. This will ensure that the washwater recycle rate is high enough to empty the washwater equalization within one to two hours, as indicated in Table 6.4. The basin itself, which serves as a wet well for the pump station, is adequately sized for flows in excess of 60 mgd, the plant build-out flow rate.

6.5.11 Mechanical Solids Dewatering

6.5.11.1 Gravity Thickener

At 30 mgd, the hydraulic loading rate of the single gravity thickener will be up to 0.50 gpm/sf, which could negatively affect performance. Solids loading rates are still within reasonable range. Therefore, this 2017 MPU recommends installing a second 35-foot diameter gravity thickener at the 30-mgd capacity expansion.

6.5.11.2 Solids Mixing

The solids mixing system is sufficiently sized for 30-mgd design capacity; however, the current configuration includes one installed pump and a shelf-spare pump rather than installed redundancy. Due to the increased complexity of two gravity thickeners and the increased solids generation rate, the 30-mgd expansion should include installing a shelf-spare mixing pump.

6.5.11.3 Solids Transfer and Thickening

The current 60-gpm solids transfer pumps and centrifuges will have exceeded their service life at the 30-mgd capacity expansion, and the two existing transfer pumps and centrifuges must be replaced. Installing a third transfer pump and centrifuge is also recommended if five-day solids processing operations are preferable.

With two centrifuges, the five- and seven-day solids processing time will be 7.5 and 5.3 hours, respectively, assuming one unit is on standby. With a third centrifuge, the five- and seven-day solids processing times are 3.7 and 2.7 hours assuming one unit is on standby, which is consistent with current design criteria. This is recommended in lieu of increasing the transfer pump and centrifuge processing rate to ensure the WRWTP has sufficient redundancy. Based on discussions with plant operators, the centrifuges regularly require maintenance, and three centrifuges would offer welcome redundancy.

6.5.12 Chemical Storage and Metering

The following projects are recommended during the 30 mgd expansion:

- **Chemical Storage Room Modifications**: The current Chemical Storage Room configuration limits potential storage expansion. The entryway is too restricted to bring in new chemical storage tanks, chemical containments are too small to add additional tanks, and several chemical systems (such as aqueous ammonia) have been installed but never used. The 2015 MPU recommended expanding the chemical storage room, but the suggested layouts would either hinder road traffic or block access around the solids handling building. Therefore, this 2017 MPU recommends that the interior of the chemical storage room be modified as follows:
  - Replace and expand existing roll-up door.
  - Expand the alum, caustic, hypochlorite, and polymer containment areas.
  - Remove the aqueous ammonia system.
  - Consolidate chemical storage with appropriate chemical containment.
- **Dry Hypochlorite Batching System**: To supply sufficient resiliency for a regional seismic event, upgrading the hypochlorite system from a liquid to an on-site generation system is recommended. Existing hypochlorite storage is limited to approximately 14 days; in a regional seismic event chemical delivery could be hindered, making it difficult to maintain plant chemical storage. Since hypochlorite is the most important water treatment chemical, installing an onsite generation system will help ensure that at a minimum the primary chemical (salt) will have multiple suppliers and that chemical disinfection is not interrupted. Note that the electrical requirements of on-site hypochlorite generation will need to be re-evaluated as part of the 30 mgd capacity expansion project.
- **Purchase LOX Tank and Evaporators**: The WRWTP currently leases the LOX tank and evaporators from one of several chemical supply companies in the region. Though cost-effective, this arrangement prevents the plant from working with other chemical vendors. To increase chemical supplier and pricing options for the WRWTP as their LOX consumption increases, this 2017 MPU recommends purchasing the tank and evaporators as part of the 30-mgd expansion.

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures

Flow Rate	Units	Option 1	Option 2
Minimum	mgd	5.0	5.0
Average	mgd	9.6	9.6
Max (Plant Design)	mgd	30	30
	GPM	20,833	20,833
Willamette River			
Minimum River Level	FT	52.5	--
100 Year Flood Elevation	FT	91.1	--
500 Year Flood Elevation	FT	102.3	--
Intake Screens			
Type: Horizontal cylindrical			
Number	#	2	--
Capacity, total	mgd	150	--

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Diameter	IN	66	--
Screen Opening Size	mm	1.75	--
Maximum Face Velocity	FPS	0.4	--
Top of Screen Elevation	FT	42.75	--
Screen Cleaning			
Cleaning method: air burst			
Number of Compressors	#	2	--
Compressor Capacity	CFM	200	--
Air receiver volume	CF	2,200	--
Motor Size per compressor	HP	50	--
Raw Water Pumps			
Type: Vertical Turbine, Single-stage			
Number	#	4 (3+1)	--
Total capacity with stand-by	mgd	45	--
Firm capacity	mgd	30	--
Capacity (each)			
1 VFD Driven pump	mgd	7.5	--
1 VFD Driven Pump	mgd	15	--
1 VFD Driven Pump	mgd	15	--
1 Constant speed pump (Swing Pump?)	mgd	≥ 7.5	--
Total dynamic head (15 mgd)	FT	115	--
Total motor horsepower	HP	2@200 2@400	--
Initial Flash Mix			
Type: Pumped			
Number (Installed)	#	1	2 (1+1)
Mixing energy (ea)	s^{-1}	1,000	1,000
Pump capacity (ea)	gpm	1,000	1,000
Pump flow as a percentage of plant flow rate (PFR)	%	5%	5%
Total dynamic head	FT	16	16
Total motor horsepower (ea)	HP	7.5	7.5
Clarification Process			
Type: Ballasted Flocculation (Actiflo®)			
Number of Basins	#	3	--
Design flow (per basin)	mgd	10	--
Max process hydraulic flow (per basin)	mgd	15	--

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Mixing/Flocculation (per basin)			
Coagulation chamber volume	CF	2,000	--
Coagulation chamber HRT	MIN	2.2	--
Injection chamber volume	CF	2,165	--
Injection chamber HRT	MIN	2.3	--
Maturation chamber volume	CF	6,330	--
Maturation chamber HRT	MIN	6.82	--
Clarification			
Settling chamber volume	CF	7,570	--
Settling chamber HRT	MIN	8.2	--
Lamella tube settlers, surface area (ea)	SF	260	--
Maximum design surface loading rate w/ all basins	GPM/SF	--	--
Design Surface Loading Rate w/ All Basins	GPM/SF	27	--
Maximum surface loading rate	GPM/SF	40	--
Sand slurry recirculation system			
Number of sludge recirculation pumps per Basin	#	2 (2+0)	--
Pumps in operation	#	2	--
Sludge recirculation rate	%	4.8	--
Capacity per pump	GPM	165	--
Total design head	FT	75	--
Pump horsepower	HP	10	--
Number of sand hydrocyclones (per basin)	#	2	--
Average Sand Loss Rate	LB/MG	23	--
Approx. Daily Sand Loss	PPD	690	--
Ozone Contact Basins			
Type: 8-stage counter-co-counter w/ fine-bubble diffusers			
Number of basins	#	3	--
Detention time w/ all in service @ Design Flow	MIN	11.20	--
Detention time w/ one out of service @ Design Flow	MIN	7.47	--
Average water depth	FT	21	--
Inside dimensions (each basin)	FT x FT	6 x 10	--
Volume (total)	CF	31,200	--
Ozone Destruct Units	#	3	--

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Ozone Generators			
Number	#	3 (2+1)	3 (2+1)
Feed Gas	-	LOX	LOX
Capacity (ea)	ppd	300	400
% Ozone by Weight (max)	%	8	8
Design Ozone Dose	mg/L	2.4	2.4
Max Ozone Dose @ Design Flow	mg/L	3.60	4.80
Dose with one unit out of service @ Design Flow	mg/L	2.40	6.39
Liquid Oxygen (100% LOX)			
Number of tanks	#	1	--
Storage capacity, total	GAL	12,000	--
Storage (avg dose x max flow)	DAYS	17	--
Average Oxygen Dosage	mg/L	26	--
Storage Density	#/gal	9.5	--
Filters			
Type: Deep bed, dual granular media			
With influent flow splitting			
Number of filters	#	6	--
Number of bays/filter	#	1	--
Filter bay dimensions	FT x FT	20 x 23	--
Filter area (each filter)	SF	460	--
Total filter area	SF	2,760	--
Maximum filtration rate (Q/A)			
All filters on-line @ Design Flow	GPM/SF	7.5	--
One filter off-line @ Design Flow	GPM/SF	9.1	--
Hydraulic maximum	GPM/SF	12	--
Flow Rate Each Filter			
All filters on-line @ Design Flow	mgd	5.0	--
One filter off-line @ Design Flow	mgd	6.0	--
Filter media			
GAC			
Depth	IN	72	--
Effective size	mm	1.4	--
Uniformity coefficient		<1.4	--
Depth: Diameter (L:D)		1,306	--

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Minimum Empty bed contact time (EBCT)			
All filters on-line @ Design Flow	MIN	5.9	--
One filter off-line @ Design Flow	MIN	5.0	--
Sand			
Depth	IN	12	--
Effective size	mm	0.45	--
Uniformity coefficient		<1.4	--
Depth: Diameter (L:D)	MM:MM	677	--
Total media			
Depth (maximum)	IN	84	--
Depth: Diameter (L:D)	MM:MM	1,984	--
Filter wash system			
Air scour blowers			
Number	#	2	--
Air scour rate	CFM/SF	3.2	--
Blower capacity (each)	ACFM	1,500	--
Blower horsepower (each)	HP	100	--
Backwash pumps			
Number	#	2	--
Maximum backwash rate	GPM/SF	20	--
Pump capacity (each)	GPM	9,200	--
Pump horsepower (each) – constant speed	HP	150	--
Maximum Backwash Volume	mgd	6.3	--
Clearwell			
Type: Buried, reinforced concrete			
Active volume	MG	2.9	--
Max Operating Side Water Depth	FT	21.5	--
Dimensions	FT x FT	135 x 135	--
Detention Time (HRT) at Design Flow when full	HRS	2.32	--
Hydraulic Efficiency up to 9.6 mgd	T10:HRT	--	--
Hydraulic Efficiency >9.6 mgd	T10:HRT	--	--
Finished Water Pumps			
Type: Vertical turbine, Two-stage			
Number	#	4 (3+1)	5 (4+1)
Total capacity w/ stand-by	mgd	43.5	51
Firm capacity	mgd	31.5	39

Table 6.4 WRWTP 30 MGD Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Capacity each			
1 VFD Driven pump	mgd	7.5	7.5
1 VFD driven pump	mgd	12	12
1 VFD driven pump	mgd	12	12
1 Constant speed pump	mgd	12	12
1 VFD driven pump		--	7.5
Total dynamic head	FT	--	--
Motor Size	HP	1@500 3@700	2@500 3@700
Waste Washwater Equalization & Pump Station			
Equalization basins			
Type: Concrete			
Number of basins	#	1	1
Volume	GAL	244,000	244,000
Maximum Backwash Volume	mgd	6.3	11.2
Hydrocyclone Overflow @ Design Rate	mgd	1.1	0.8
Basin Hydraulic Retention Time	HRS	0.8	0.5
Washwater recycle pumps			
Type: Vertical turbine			
Number	#	4 (3+1)	3 (2+1)
Total capacity w/ stand-by	GPM	2,000	3,000
Capacity each			
1 VFD driven pump	GPM	500	1,000
1 VFD driven pump	GPM	500	1,000
1 VFD driven pump	GPM	500	--
1 constant speed pump	GPM	500	1,000
Time to empty basin w/ stand-by	HRS	2	1
Time to empty basin w/o stand-by	HRS	2.7	2.0
Total dynamic head	FT	25	25
Motor horsepower	HP	4 @ 10	3 @ 15
Solids Treatment			
Type: Gravity thickener and centrifuges			
Estimated Max Solids Production (dry) @ Design Flow	LB/DAY	4,000	4,000
Estimated Max Hydraulic Flow Rate @ Design Flow	GPM	481	481
Gravity thickener (circular)			

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Number of units (total, existing + new)	#	1	2
Diameter	FT	35	35
Side Water Depth	FT	12	12
Max solids loading rate	PPD/SF	8	8
Max hydraulic loading rate	GPM/SF	1	1
Operating solids loading rate	PPD/SF	4.2	2.1
Operating hydraulic loading rate	GPM/SF	**0.50**	0.25
Storage Capacity @ Design Rate (7-day ops)	HRS	3.0	6.0
Storage Capacity @ Design Rate (5-day ops)	HRS	2.1	4.3
Solids Storage & Mixing			
Storage Volume	GAL	33,000	--
Estimated solids flow @ 2.5%	GAL/MG	765	--
	GPD	22,950	--
Mixing Tank HRT (7-day ops)	HRS	34	--
Mixing Tank HRT (5-day ops)	HRS	24	--
Mixing Pumps	#	1	--
Pumping capacity	GPM	600	--
Pump horsepower	HP	5	--
Solids pump station			
Progressive Cavity Transfer Pumps	#	2	3
Pumping capacity (ea)	GPM	60	60
Motor Size (ea)	HP	10	10
Total dynamic head	FT	60	60
Centrifuges			
Type		Horz. Scroll	Horz. Scroll
Number of units	#	2	3
Capacity, each	GPM	60	60
Max solids loading, each	LB/HR	750	750
Maximum 8-hr Processing Capacity (ea)	PPD	6,000	6,000
Maximum 8-hr Processing Capacity (ea)	GPD	28,800	28,800
Motor horsepower-scroll, each	HP	40	40
Motor horsepower-back drive, each	HP	15	15
Centrifuge operation period (1 standby, 7-day ops)	HR/DAY	5.3	2.7
Centrifuge operation period (1 standby, 5-day ops)	HR/DAY	7.5	3.7

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Chemical Storage			
Primary coagulant (49% alum sol'n)			
Number of tanks	#	2	--
Storage capacity, total	GAL	13,000	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	18	--
Average Dosage	mg/L	15	--
Minimum volume for 21-day Storage	GAL	15,167	
Solution Strength (alum)	LB/GAL	5.4	--
Cationic polymer (dry polymer)			
Type	-	Dry Feeder	--
Feed Capacity	LB/HR	17.6	--
Required Days Storage	DAYS	14	--
% solution	%	1	--
Storage (avg dose x max flow)	DAYS	--	--
Mixing Time	min	30	--
Sodium hypochlorite (12.5% NaOCl sol'n)			
Number of tanks	#	2	--
Storage capacity, total	GAL	7,800	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	16	--
Average Dosage	mg/L	2	--
Minimum volume for 21-day Storage	GAL	10,238	
Solution Strength	LB/GAL	1.05	--
Caustic soda (25% NaOH sol'n)			
Number of tanks	#	2	--
Storage capacity, total	GAL	13,000	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	21	--
Average Dosage	mg/L	6.5	--
Minimum volume for 21-day Storage	GAL	13,000	
Solution Strength	LB/GAL	2.65	--
Aqueous ammonia (19% NH_4OH sol'n)			
Number of tanks	#	1	--
Storage capacity, total	GAL	1,400	--

Table 6.4 WRWTP 30 mgd Expansion Processes and Procedures (Continued)

Flow Rate	Units	Option 1	Option 2
Anionic polymer			
Number of tanks	#	1	--
Storage capacity, total	GAL	55	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	> 1 year	--
Average Dosage	mg/L	0.4	--
Non-ionic polymer			
Number of tanks	#	1	--
Storage capacity, total	GAL	55	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	> 1 year	--
Average Dosage	mg/L	0.4	--
Calcium Thiosulfate			
Number of tanks	#	2	--
Storage capacity, total	GAL	440	--
Required Days Storage	DAYS	14	--
Storage (avg dose x max flow)	DAYS	31	--
Minimum volume for 21-day Storage	GAL	298	
Average Dosage	mg/L	0.2	--
Solution Strength	LB/GAL	3.6	--

6.6 Repair and Replace

In addition to the seismic and life-safety CIP recommended in Chapter 5 and the capacity expansion CIP recommendations in Chapter 6, the plant requires ongoing maintenance/repair and replacement (R&R) of its existing infrastructure. Table 6.5 summarizes recommended R&R for the WRWTP across a 20-year planning horizon. The details and timing of these projects will be discussed in Chapter 7 – Implementation Plan.

Table 6.5 WRWTP Repair and Replace Projects

Repair and Replace Project	Approx. Service Year
Annual maintenance on the existing site fire alarm	Annual
Annual maintenance on the existing site sprinkler system	Annual
Replace VFDs on three finished water pumps.	2019
Replace obsolete Robocon VFDs on two raw water pumps.	2019
Replace obsolete ABB magnetic flow meters installed throughout the WRWTP and at Wilsonville Road.	2019
Replace the four hydrocyclones installed in the two existing Actiflo Basins	2020

Table 6.5 WRWTP Repair and Replace Projects (Continued)

Repair and Replace Project	Approx. Service Year
Replace lamella settling tubes in the two existing Actiflo basins, which are damaged due to UV exposure.	2020
Replace the two flash mix pumps (installed and standby)	2020
Upgrade site security monitoring system camera and computer	2020
Replace existing raw water sump pump	2020
Replace two existing sludge mixing pumps (one installed, one shelf spare)	2020
Replace three existing filter waste washwater recycle pumps	2020
Upgrade vendor PLC components in the two existing Actiflo basins	2022
Replace the six mixers installed in the two existing Actiflo Basins	2022
Replace the two sample pumps installed in the two existing Actiflo Basins	2022
Upgrade vendor PLC components in the existing dry polymer blending unit	2022
Replate two existing 300 PPD ozone generators with 400 PPD units	2022
Inspect existing alum tank and repair as needed	2022
Inspect existing caustic soda tank and repair as needed	2022
Replace existing air scour blowers and motors on existing media filtration system	2022
Replace the existing safety and warning signs throughout the site	2022
Replace sitewide fire extinguishers	2022
Replace the two existing irrigation waste pumps	2022
Replace the existing dewatered sludge screw conveyor in the Solids Handling Building	2022
Replace original dry polymer batching system	2027
PLC upgrade for Actiflo® Local Control Panels.	2027
Replace existing soft-start controller on High Service Pump 3.	2027
Replace the two existing water feature pumps	2027
Replace two existing air burst compressors.	2027
Replace existing air burst control panel PLC and local control panel.	2027
Replace two existing 60 GPM centrifuges.	2027
Replace existing PLC and local control panel for two dewatering centrifuges.	2027
Replace two existing backwash supply pumps in the wastewater equalization basin.	2032
Replace the two existing sludge mixing pumps.	2032
Replace existing streaming current analyzer on Actiflo® inlet.	2036
Replace the five solids pumps (installed and standby) on the existing Actiflo® basins.	2036
Replace the two installed flash mix pumps.	2036
Replace the six mixers installed in the two existing Actiflo® Basins.	2036
Replace the four hydrocyclones installed in the two existing Actiflo® Basins.	2036

Table 6.5 WRWTP Repair and Replace Projects (Continued)

Repair and Replace Project	Approx. Service Year
Replace the LOX evaporator equipment.	2036
Replace aging MCC in existing filter gallery.	2036
Replace air scour blowers and motors on existing media filtration system.	2036
Replace existing constant-speed 7.5 mgd pump with a VFD-controlled pump	2036
Replace two existing 60 GPM solids transfer pumps.	2036
Replace the existing gravity thickener drive.	2036

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Chapter 7

CIP APPROACH AND SCHEDULE

7.1 Introduction

This chapter summarizes the assumptions, contingencies, and classifications in the latest capital cost estimates developed for the 2017 Master Plan Update (MPU). It also summarizes the design and construction schedule outlined in the 2017 MPU.

7.2 Capital Cost Assumptions

7.2.1 Cost Estimate Classification

The expected level of accuracy for the estimates followed the Recommended Practice 18R-97 Cost Estimate Classification System for the Process Industries (Association for the Advancement of Cost Engineering, 1998) designations. For better accuracy, the 20 mgd capacity expansion, electrical upgrades, seismic retrofits, life-safety repairs, and repair and replace tasks occurring before 2027 were classified as Class 4 estimates, whereas the 30 mgd capacity expansion project and repair and replace tasks occurring in 2027 or later were classified as Class 5 estimates.

The definitions for Class 4 and Class 5 estimates are as follows:

- Class 4 estimates have an expected level of accuracy of +50 percent to -30 percent. This means that bids for these estimates are expected to fall within a range of 50 percent over the estimate or 30 percent under the estimate.
- Class 5 estimates have an expected level of accuracy of +100 percent to -50 percent. This means that bids for these estimates are expected to fall within a range of 100 percent over the estimate or 50 percent under the estimate.

Estimated project costs are escalated to 2017 dollars.

7.2.2 Opinion-of-Probable Construction Cost Estimate

To generate capital cost estimates, an opinion of probable construction cost (OPCC) was developed. An OPCC estimate provides assumptions for the labor, materials, construction, and major process equipment used to develop the total cost of work (COW) subtotal for each project in the CIP. The OPCC is included in Appendix D.

The July 2017 Means Construction Cost Indexes for Portland, Oregon, were used to develop baselines for local costs. For commodity costs, the September 2017 Engineering News Record (ENR) Construction Economics data were used.

Various cost factors were applied to create the build-up to the COW subtotal, including cost factors for insurance, bonds, profit, overhead, general conditions, and equipment and labor. Prime contractor costs, burdens, and mark-up were then added to the COW subtotal to develop the total COW. For a detailed summary of cost factors, assumptions, contingencies, and contractor factors, refer to the OPCC in Appendix D.

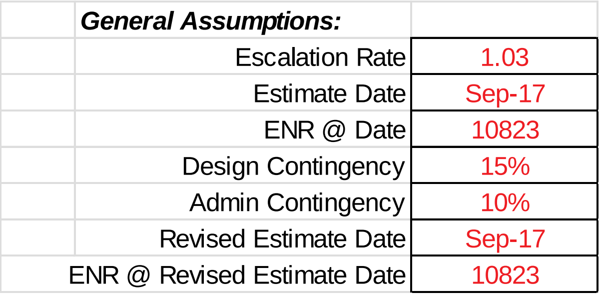
7.2.3 Cost Factoring Workbook

The cost factoring workbook outlines total COW for equipment that was not included in the OPCC. The total COW for these items includes the direct equipment cost increased by a costing factor to account for anticipated installation cost along with all applicable burdens and markups. The cost factoring workbook is included in Appendix D.

7.2.4 CIP Workbook

The WRWTP 2017 MPU CIP was generated using the cost estimates created in the OPCC. The CIP (Appendix E) is included as both a hard copy and as an electronic file. The electronic CIP workbook is an interactive tool for facilitating budget allocation efforts during the 20-year planning horizon. With this workbook, the user can modify the escalation rate, completion year, project duration, and type of cost projection calculation used. Based on the user's input, the workbook automatically updates all calculations in the financial and cost planning summaries.

The user can, for example, modify the escalation rate based on inflation, construction cost index, consumer price index, or other rates, as shown in the red cells in Figure 7.1. The user can also modify the legal and administration contingency and the design contingency added to all projects requiring engineering design.



General Assumptions:	
Escalation Rate	1.03
Estimate Date	Sep-17
ENR @ Date	10823
Design Contingency	15%
Admin Contingency	10%
Revised Estimate Date	Sep-17
ENR @ Revised Estimate Date	10823

Figure 7.1 Example Assumptions in CIP Workbook

To compare the estimated construction costs to the actual construction costs, the user can input the actual construction costs in the appropriate column, as shown in Table 7.1. The workbook contains instructions and notes to help the user. Note that the year used to estimate the future project value mentioned in Table 7.1 is not documented in the example but is included as part of the CIP summary table.

Table 7.1 Example of CIP Actual Construction Cost

Estimated Construction Cost	Design Project?	Estimated Task Cost	Future Value in Approx. Project Year	Future Value in Approx. Project Year, Using Revised Estimate Date	Actual Construction Cost
$4,147,606	Yes	$5,184,508	$5,184,508	$ -	
$180,000	Yes	$225,000	$225,000	$ -	
$285,988	Yes	$357,485	$357,485	$ -	
$4,014,088	Yes	$5,017,610	$5,017,610	$ -	
$238,323	Yes	$297,904	$297,904	$ -	

7.3 Design and Construction Schedule

For all CIP project stages, estimates for the design duration and construction duration were developed. The required project start year was calculated using each stage's project completion year and the duration of design and construction. Table 7.2 shows the design and construction schedule for the 20 mgd and 30 mgd expansion projects, electrical upgrades, seismic retrofits, life-safety repairs, and repair and replace projects.

Table 7.2 WRWTP Expansion Design and Construction Schedule

Project	Approx. Service Year	Duration (Months)			Start Date
		Design	Construction	Float	
20 MGD Capacity Expansion	2020	12	18	6	2018
Life Safety Repairs	2022	6	6	3	2020
Seismic Retrofits	2022	6	6	3	2020
30 MGD Capacity Expansion	2034	12	24	6	2032
Operations – Repair and Replace					
Year 1	2019	0	6	6	--
Year 2	2020	0	6	6	2019
Year 3	2021	0	6	6	2020
Year 4	2022	0	6	6	2021
Year 5	2023	0	6	6	2022
Year 6	2024	0	6	6	2023
Year 7	2025	0	6	6	2024
Year 8	2026	0	6	6	2025
Year 9	2027	0	6	6	2026
Year 10	2028	0	6	6	2027
Year 11	2029	0	6	6	2028
Year 12	2030	0	6	6	2029
Year 13	2031	0	6	6	2030
Year 14	2032	0	6	6	2031
Year 15	2033	0	6	6	2032
Year 16	2034	0	6	6	2033
Year 17	2035	0	6	6	2034
Year 18	2036	0	6	6	2035

7.4 Financial Summary

Table 7.3 and Figure 7.2 summarize near-term CIP costs. Capital costs are broken down by expansion projects, electrical upgrades, seismic retrofits, life-safety repairs, and repair and replace projects. For the overall 20-year CIP cost estimate summary, refer to Table 7.4 and Figure 7.3.

Design was assumed to be completed before the start of construction. As such, the design costs were allocated to the first year of the project. Construction costs were split evenly into the proceeding years based on the construction duration. The assumed financial responsibilities and fee structures for the CIP projects are listed in Table 7.5

Table 7.3 WRWTP Near-Term CIP Costs (2017 Dollars)

Project	FY	2018	2019	2020	2021	2022
20 MGD Expansion						
Design(1)		$1,885,517	--	--	--	--
Administration(2)		$419,004	$419,004	$419,004	--	--
Construction		--	$6,285,055	$6,285,055	--	--
Total		$2,304,520	$6,704,059	$6,704,059	--	--
Life Safety Repairs						
Design(1)		--	--	--	--	--
Administration(2)		--	--	$28,007	$28,007	--
Construction		--	--	--	$560,139	--
Total		--	--	$28,007	$588,146	--
Seismic Retrofits						
Design(1)				$138,224	--	
Administration(2)		--	--	$46,075	$46,075	--
Construction		--	--	--	$921,493	--
Total		--	--	$184,299	$967,568	--
Operations - Repair and Replace						
Design(1)		--	--	--	--	--
Administration(2)		--	$135,611	$144,729	$1,138	$310,899
Construction		--	$1,356,111	$1,447,291	$11,375	$3,108,994
Total		--	$1,491,722	$1,592,020	$12,513	$3,419,893
Total		**$2,304,520**	**$8,195,781**	**$8,508,384**	**$1,568,226**	**$3,419,893**

Notes:
(1) Assumes 15% contingency for engineering design.
(2) Assumes 10% contingency for legal and administration costs

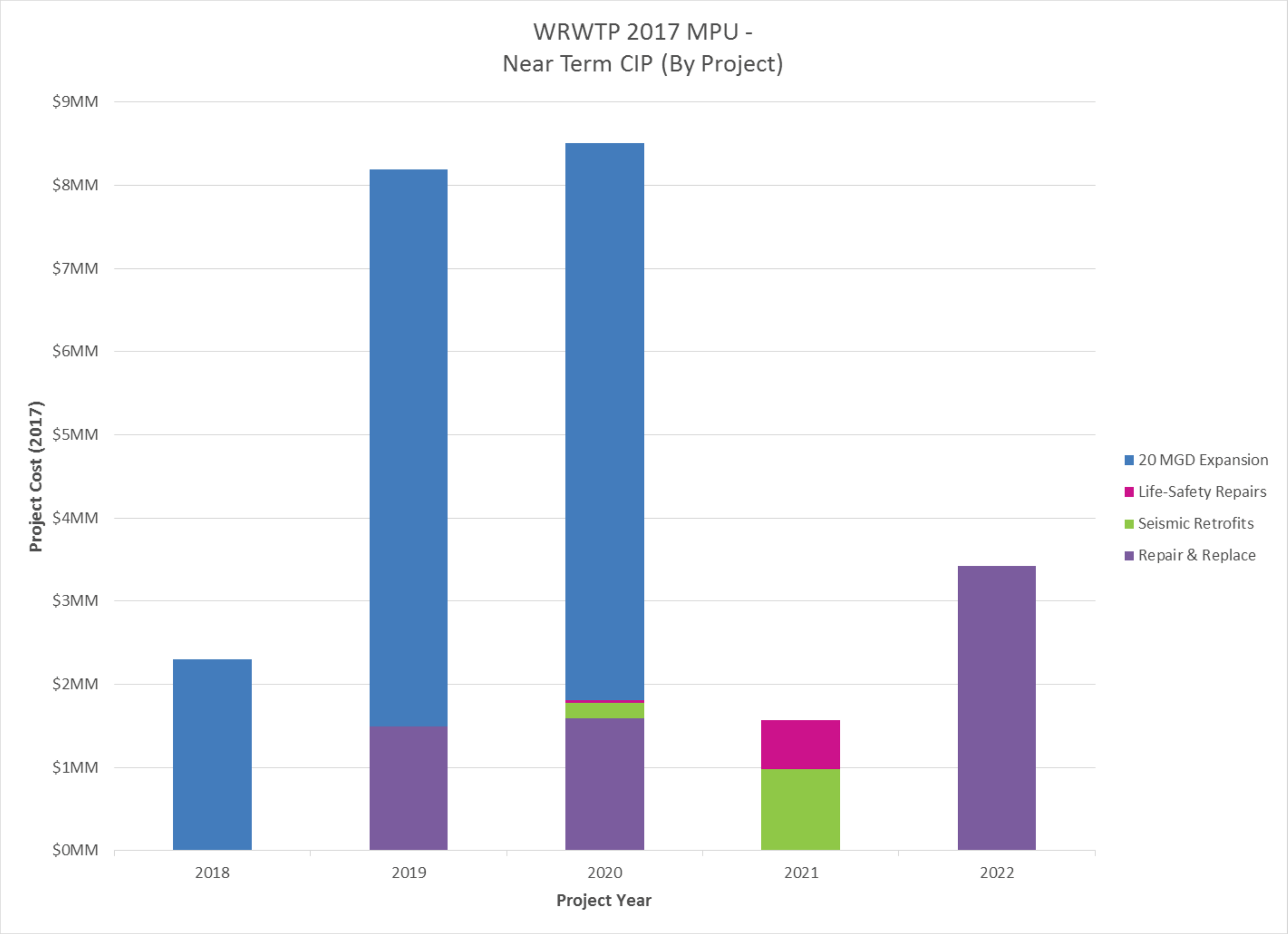


Figure 7.2 WRWTP Near-Term CIP Costs (2017 Dollars)

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Table 7.4 WRWTP Total CIP Costs (2017 Dollars)

Project	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	Total
20 MGD Expansion																				
Design(1)	$1,885,517	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$1,885,517
Administration(2)	$419,004	$419,004	$419,004	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$1,257,011
Construction	--	$6,285,055	$6,285,055	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$12,570,110
Total	$2,304,520	6,704,059	$6,704,059	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$15,712,638
Life Safety Repairs																				
Design(1)	--	--	$28,007	$28,007	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Administration(2)		--	--	$560,139																$56,014
Construction	--	--	$28,007	$588,146	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$560,139
Total	--	--	$28,007	$588,146	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$616,153
Seismic Retrofits																				
Design(1)	--	--	$138,224	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$138,224
Administration(2)		--	$46,075	$46,075																$92,149
Construction	--	--	--	$921,493	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$921,493
Total	--	--	$184,299	$ 967,568	--	--	--	--	--	--	--	--	--	--	--	--	--	--		$1,151,866
30 MGD Expansion																				
Design(1)	--	--	--	--	--	--	--	--	--	--	--	--	--	$4,636,647	--	--	--	--	--	$4,636,647
Administration(2)	--	--	--	--	--	--	--	--	--	--	--	--	--	$1,030,366	$1,030,366	$1,030,366	--	--	--	$3,091,098
Construction	--	--	--	--	--	--	--	--	--	--	--	--	--	--	$15,455,489	$15,455,489	--	--	--	$30,910,978
Total	--	--	--	--	--	--	--	--	--	--	--	--	--	$5,667,013	$16,485,855	$16,485,855	--	--	--	$38,638,723
Operations - Repair and Replace																				
Design(1)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Administration(2)	--	$135,611	$144,729	$1,138	$310,899	$ 1,138	$1,138	$1,138	$ 1,138	$473,950	$ 1,138	$ 1,138	$ 1,138	$1,138	$225,138	$1,138	$1,138	$1,138	$308,663	$1,612,641
Construction	--	$1,356,111	$1,447,291	$ 11,375	$3,108,994	$11,375	$11,375	$11,375	$11,375	$4,739,500	$11,375	$11,375	$11,375	$11,375	$2,251,375	$11,375	$ 11,375	$ 11,375	$3,086,634	$16,126,405
Total	--	$1,491,722	$1,592,020	$ 12,513	$3,419,893	$12,513	$12,513	$12,513	$12,513	$5,213,450	$12,513	$12,513	$12,513	$ 12,513	$2,476,513	$12,513	$ 12,513	$ 12,513	$3,395,297	$17,739,046
CIP TOTAL	$2,304,520	$8,195,781	$8,508,384	$1,568,226	$3,419,893	$12,513	$12,513	$12,513	$12,513	$5,213,450	$12,513	$12,513	$12,513	$5,679,525	$18,962,367	$16,498,367	$ 12,513	$ 12,513	$3,395,297	$ 73,858,425

Notes:

(1) Assuming 15% contingency for Design and 10% for legal and administration costs.

(2) All costs are rounded up to nearest $10,000.

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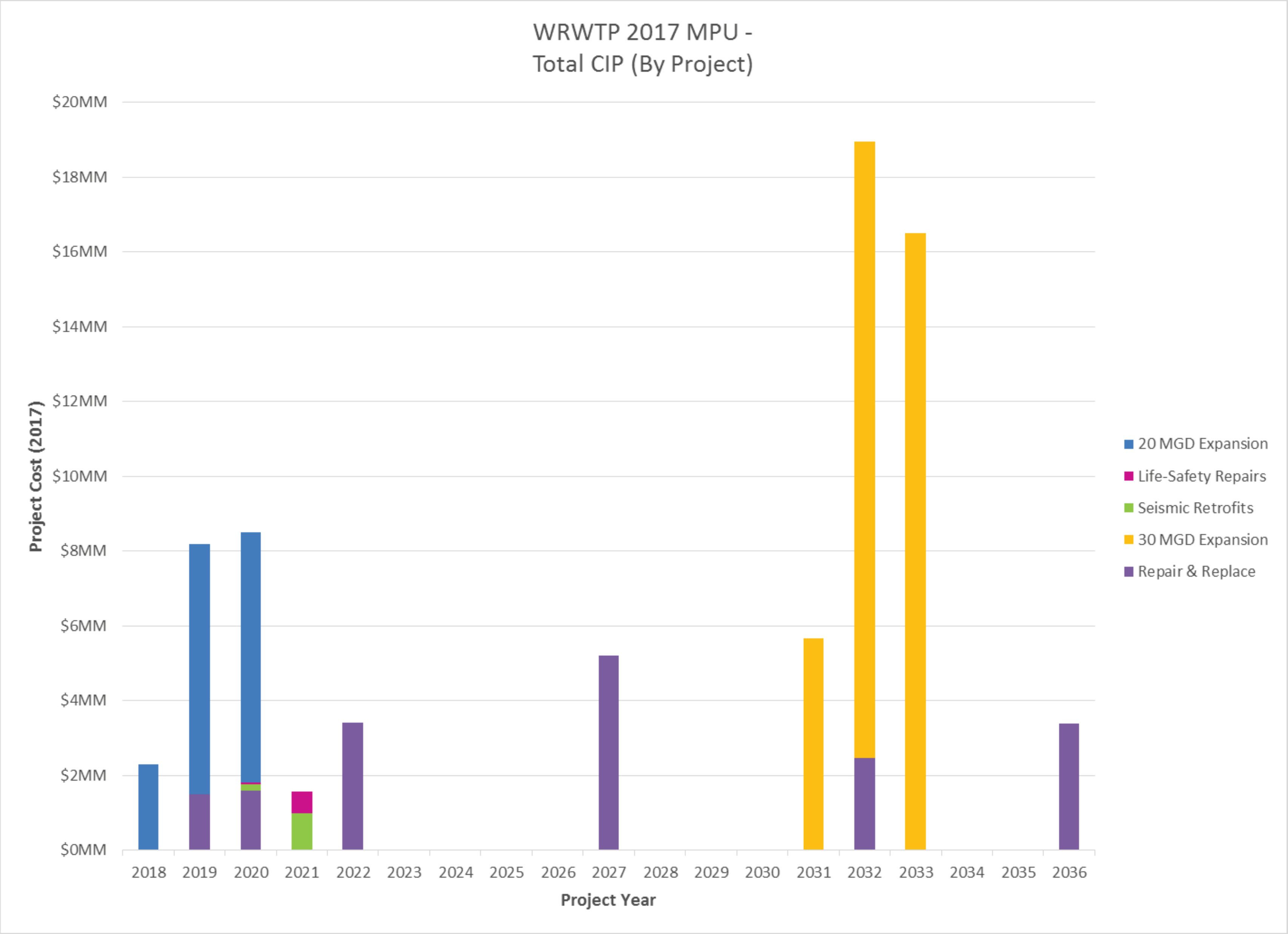

Figure 7.3 WRWTP Total CIP Costs (2017 Dollars)

Table 7.5 WRWTP 2017 MPU Stakeholder Responsibility

CIP Project	%City of Wilsonville	%City of Sherwood	%Water Operations	%SDCs
20 mgd Expansion	66.7	33.3	37	63
Life Safety Repairs	66.7	33.3	100	--
Seismic Retrofits	66.7	33.3	100	--
30 mgd Expansion	68	32	37	63
Operations – Repair and Replace	66.7	33.3	85	15

Appendix A

CONDITION ASSESSMENT CALCULATIONS

- *Hydraulic Assessment Calculations*
- *WRWTP Equipment List*
- *WRWTP Equipment Discussion Notes*
- *Electrical Assessment Calculations*
- *WRWTP 20-Year NPV Calculation*

WRWTP Hydraulics - HGL

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SECTION 2: HYDRAULIC PROFILE – 20 MGD

SUMMARY: OPERATION OF WRWTP AT 20 MGD FLOW WITH 10% INTERNAL RECYCLE FLOW. CLEARWELL/HIGH SERVICE PUMP STATION AT MAX WS EL (123.00). THREE OF FOUR FILTERS ONLINE WITH FLOW SPLIT EVENLY BETWEEN THREE FILTERS. OZONATION SPLIT EQUALLY BETWEEN TWO TREATMENT TRAINS. ACTIFLO® SPLIT EQUALLY BETWEEN TWO TREATMENT TRAINS WITH HEADLOSS PROVIDED BY KRUGER.

APPENDIX A1

PROJECT : Willamette River Water Treatment Plant 2017 MPU

JOB # : 10721A00	**REVISION:**	**CHECKED :**		**BY :**	Josh Miner
		DATE :		**DATE :**	1/22/2018

	Equation Ref.	HGL	EGL
DOWNSTREAM CONTROL			
EGL = 123.00		123.00	123.00
Flow = 15.00 mgd = 23.21 cfs			

Filter Control Weir

[STRAIGHT EDGED SHARP CRESTED WEIR]

Flow	15.00	mgd = 23.2 cfs
WSE Downstream of Weir	123.00	ft
Weir Crest Elevation	131.50	ft
Downstream head, Hd	-8.50	ft
Length of Weir, L	28.00	ft

WEIR IS FREE-DISCHARGING

Free Discharging Weir Computation { 6 }

Head on Weir, H	0.40	ft
Upstream WSE	131.90	ft

Submerged Weir Computation { 7 }

K	NA	
M	NA	
Increment	NA	ft
Upstream Head, Hu1	NA	ft
F(H1)	NA	
F'(H1)	NA	
Upstream Head, Hu2	NA	ft
Upstream WSE	NA	ft

Head over Weir *0.40 ft*

	HGL	EGL
Condition Upstream of Weir	131.90	131.90

Piping from Filters to Filter Control Weir

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow	15.0	mgd = 23.2 cfs
Pipe Diameter, D	60	inch
Pipe Length, L	50	ft
Absolute Roughness, ε	0.00040	ft
Pipe velocity, v	1.18	fps
Kinematic Viscosity	1.000E-05	ft^2/sec
Reynold's Number, R	590910	
Friction factor, f	0.0139	

Equivalent Hazen-Williams "C" = 148.8559

Friction Energy Loss, h_L 0.00 ft

MINOR PIPE LOSS HEADING

Flow, Q 15.0 mgd = 23.2 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Outlet Loss - Still Water	15.00	23.21	1.00	----	60	----	1.18	0.02	0.02
1	Tee - Thru Straight Run	15.00	23.21	0.60	60	----	1.18	----	0.02	0.01
1	Increaser	15.00	23.21	0.25	60	54	1.18	1.46	-0.01	0.00
									Sum =	0.03

Total Energy Loss = 0.03 ft

	HGL	EGL
Upstream Condition	131.93	131.93

PROJECT : Willamette River Water Treatment Plant 2017 MPU

CHECKED :
BY : Josh Miner
JOB # : 10721A00
REVISION:
DATE :
DATE : 1/22/2018

Equation Ref.	HGL	EGL

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow 15.0 mgd = 23.2 cfs

Pipe Diameter, D	54	inch
Pipe Length, L	75	ft
Absolute Roughness, ε	0.00040	ft
Pipe velocity, v	1.46	fps
Kinematic Viscosity	1.000E-05	ft^2/sec
Reynold's Number, R	656567	
Friction factor, f	0.0139	

Equivalent Hazen-Williams "C" = 148.0406

Friction Energy Loss, h_L 0.01 ft

Condition Upstream of Pipe HGL 131.94 EGL 131.94

Piping from Filter Underdrains to FW Pipe

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow 5.0 mgd = 7.7 cfs

No. of Filters in Service 3

Pipe Diameter, D	20	inch
Pipe Length, L	15	ft
Absolute Roughness, ε	0.00040	ft
Pipe velocity, v	3.55	fps
Kinematic Viscosity	1.000E-05	ft^2/sec
Reynold's Number, R	590910	
Friction factor, f	0.0156	

Equivalent Hazen-Williams "C" = 141.2289

Friction Energy Loss, h_L 0.03 ft

MINOR PIPE LOSS HEADING

Flow, Q 5.0 mgd = 7.7 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance Loss - Flush	5.00	7.74	0.50	----	20	----	3.55	0.20	0.10
1	Tee - Thru Side Outlet	5.00	7.74	1.80	20	----	3.55	----	0.20	0.35
1	90 ° Elbow - Regular Fl.	5.00	7.74	0.30	20	----	3.55	----	0.20	0.06
1	Mitre Bend - 90 ° Deflection	5.00	7.74	1.27	20	----	3.55	----	0.20	0.25
1	Entrance Loss - Flush	5.00	7.74	0.50	----	20	----	3.55	0.20	0.10
									Sum =	0.85

Total Energy Loss per Filter = 0.88 ft

Upstream Condition HGL 132.82 EGL 132.82

APPENDIX A1

PROJECT : Willamette River Water Treatment Plant 2017 MPU

			CHECKED :	**BY :**	Josh Miner
JOB # :	10721A00	**REVISION:**	**DATE :**	**DATE :**	1/22/2018

Equation Ref.	HGL	EGL

Filters (1 of 4)

[GRAVITY SAND FILTER] { 10 }

Flow	5.5	mgd	=	8.5 cfs
Area of Filter Bed	460	sf		
Superficial Velocity, Vo	0.018	fps		
Vo, SI Units	0.006	m/s		
Kinematic viscosity, v	1.1E-06	m^2/s		

GAC Layer		
Grain diameter, d	0.0014	m
Bed Porosity, E'	0.5	
Bed Foulness (% of E)	0%	
Effective Porosity, E	0.5	
Bed depth, L	6	ft
Bed depth, L - SI Units	1.83	m
Head Loss, SI Units	0.24	m
Head Loss	0.79	ft

Sand Layer		
Grain diameter, d	0.00045	m
Bed Porosity, E'	0.5	
Bed Foulness (% of E)	0%	
Effective Porosity, E	0.5	
Bed depth, L	1	ft
Bed depth, L - SI Units	0.30	m
Head Loss, SI Units	0.36	m
Head Loss	1.17	ft

Total Filter Energy Loss 1.97 ft

	HGL	EGL
Condition Upstream of Filter	134.79	*134.79*

Filter Distribution/Influent Weir

[STRAIGHT EDGED SHARP CRESTED WEIR]

Flow	5.5	mgd	=	8.5 cfs
WSE Downstream of Weir	145.65	ft		
Weir Crest Elevation	146.50	ft		
Downstream head, Hd	-0.85	ft		
Length of Weir, L	10.00	ft		

WEIR IS FREE-DISCHARGING

Free Discharging Weir Computation			{ 6 }
Head on Weir, H	0.40	ft	
Upstream WSE	146.90	ft	

Submerged Weir Computation			{ 7 }
K	NA		
M	NA		
Increment	NA	ft	
Upstream Head, Hu1	NA	ft	
F(H1)	NA		
F'(H1)	NA		
Upstream Head, Hu2	NA	ft	
Upstream WSE	NA	ft	

Head over Weir *0.40 ft*

	HGL	EGL
Condition Upstream of Weir	146.90	146.90

PROJECT : Willamette River Water Treatment Plant 2017 MPU

CHECKED :
BY : Josh Miner

JOB # : 10721A00
REVISION:
DATE :
DATE : 1/22/2018

Equation Ref.	HGL	EGL

Filter Distribution Channel

MINOR CHANNEL LOSS HEADING

Flow, Q 16.5 mgd = 25.5 cfs Channel Invert 141.5

No.	Description	Flow (mgd)	Flow (cfs)	K	Width Up (ft)	Width Down (ft)	Depth (ft)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance - Sharp Corners	16.50	25.53	0.50	10	10	5.40	0.47	0.47	0.00	0.00
1	90 Degree Bend - 0º Radius	16.50	25.53	1.30	10	----	5.40	0.47	----	0.00	0.00
										Sum =	0.00

Total Energy Loss = 0.00 ft

		Equation Ref.	HGL	EGL
Upstream Condition			146.91	146.91

Ozone to Filter Pipe

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow 16.5 mgd = 25.5 cfs

Pipe Diameter, D 60 inch
Pipe Length, L 60 ft
Absolute Roughness, ε 0.00040 ft
Pipe velocity, v 1.30 fps
Kinematic Viscosity 1.000E-05 ft^2/sec
Reynold's Number, R 650002
Friction factor, f 0.0138 Equivalent Hazen-Williams "C" = 148.6114

Friction Energy Loss, h_L 0.00 ft

MINOR PIPE LOSS HEADING

Flow, Q 16.5 mgd = 25.5 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance Loss - Flush	16.50	25.53	0.50	----	60	----	1.30	0.03	0.01
1	Outlet Loss - Still Water	16.50	25.53	1.00	60	----	1.30	----	0.03	0.03
								Sum =		0.04

Total Energy Loss = 0.04 ft

		Equation Ref.	HGL	EGL
Upstream Condition			146.95	146.95

					Equation Ref.	HGL	EGL

Ozone Contactor Effluent Weir

[STRAIGHT EDGED SHARP CRESTED WEIR]

					Equation Ref.	HGL	EGL
Flow	8.3	mgd =	12.8	cfs			
WSE Downstream of Weir	146.95	ft					
Weir Crest Elevation	148.67	ft					
Downstream head, Hd	-1.72	ft					
Length of Weir, L	10.00	ft					
WEIR IS FREE-DISCHARGING							
Free Discharging Weir Computation					{ 6 }		
Head on Weir, H	0.53	ft					
Upstream WSE	149.20	ft					
Submerged Weir Computation					{ 7 }		
K	NA						
M	NA						
Increment	NA	ft					
Upstream Head, Hu1	NA	ft					
F(H1)	NA						
F'(H1)	NA						
Upstream Head, Hu2	NA	ft					
Upstream WSE	NA	ft					
Head over Weir	*0.53*	*ft*					
				Condition Upstream of Weir		149.20	149.20

Last Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)] { 2 }

					Equation Ref.	HGL	EGL
Flow	8.3	mgd =	12.8	cfs			
Number of Ports	1						
Flow Per Port	8.3	mgd =	12.8	cfs			
Port Width	10	ft					
Port Height	3	ft					
Discharge Coefficient, C	0.61						
Velocity through port, v	0.43	fps					
Orifice Energy Loss, h_L	0.01	ft					
				Condition Upstream of Orifice		149.21	149.21

Last Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

					Equation Ref.	HGL	EGL
Flow	8.3	mgd =	12.8	cfs			
WSE Downstream of Weir	149.21	ft					
Weir Crest Elevation	146.00	ft					
Downstream head, Hd	3.21	ft					
Length of Weir, L	10.00	ft					
WEIR IS SUBMERGED							
Free Discharging Weir Computation					{ 6 }		
Head on Weir, H	NA	ft					
Upstream WSE	NA	ft					
Submerged Weir Computation					{ 7 }		
K	0.08						
M	5.74						
Increment	0.10	ft					
Upstream Head, Hu1	3.21	ft					
F(H1)	0.00						
F'(H1)	-0.47						
Upstream Head, Hu2	3.21	ft					
Upstream WSE	149.21	ft					
Head over Weir	*3.21*	*ft*					
				Condition Upstream of Weir		149.21	149.21

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	Equation Ref.	HGL	EGL

Third Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)] { 2 }

Flow	8.3	mgd =	12.8 cfs
Number of Ports	1		
Flow Per Port	8.3	mgd =	12.8 cfs
Port Width	10	ft	
Port Height	3	ft	
Discharge Coefficient, C	0.61		
Velocity through port, v	0.43	fps	
Orifice Energy Loss, h_L	0.01	ft	

	HGL	EGL
Condition Upstream of Orifice	149.21	149.21

Third Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

Flow	8.3	mgd =	12.8 cfs
WSE Downstream of Weir	149.21	ft	
Weir Crest Elevation	146.00	ft	
Downstream head, Hd	3.21	ft	
Length of Weir, L	10.00	ft	

WEIR IS SUBMERGED

Free Discharging Weir Computation { 6 }

Head on Weir, H	NA	ft
Upstream WSE	NA	ft

Submerged Weir Computation { 7 }

K	0.08	
M	5.76	
Increment	0.10	ft
Upstream Head, Hu1	3.22	ft
F(H1)	0.00	
F'(H1)	-0.47	
Upstream Head, Hu2	3.22	ft
Upstream WSE	149.22	ft
Head over Weir	*3.22*	*ft*

	HGL	EGL
Condition Upstream of Weir	149.22	149.22

Second Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)] { 2 }

Flow	8.3	mgd =	12.8 cfs
Number of Ports	1		
Flow Per Port	8.3	mgd =	12.8 cfs
Port Width	10	ft	
Port Height	3	ft	
Discharge Coefficient, C	0.61		
Velocity through port, v	0.43	fps	
Orifice Energy Loss, h_L	0.01	ft	

	HGL	EGL
Condition Upstream of Orifice	149.22	149.22

				Equation Ref.	HGL	EGL

econd Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

				Equation Ref.	HGL	EGL
Flow	8.3	mgd =	12.8 cfs			
WSE Downstream of Weir	149.22	ft				
Weir Crest Elevation	146.00	ft				
Downstream head, Hd	3.22	ft				
Length of Weir, L	10.00	ft				
WEIR IS SUBMERGED						
Free Discharging Weir Computation				{ 6 }		
Head on Weir, H	NA	ft				
Upstream WSE	NA	ft				
Submerged Weir Computation				{ 7 }		
K	0.08					
M	5.79					
Increment	0.10	ft				
Upstream Head, Hu1	3.23	ft				
F(H1)	0.00					
F'(H1)	-0.47					
Upstream Head, Hu2	3.23	ft				
Upstream WSE	149.23	ft				
Head over Weir	*3.23*	*ft*				
			Condition Upstream of Weir		149.23	149.23

First Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)] { 2 }

				Equation Ref.	HGL	EGL
Flow	8.3	mgd =	12.8 cfs			
Number of Ports	1					
Flow Per Port	8.3	mgd =	12.8 cfs			
Port Width	10	ft				
Port Height	3	ft				
Discharge Coefficient, C	0.61					
Velocity through port, v	0.43	fps				
Orifice Energy Loss, h_L	0.01	ft				
			Condition Upstream of Orifice		149.23	149.23

First Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

				Equation Ref.	HGL	EGL
Flow	8.3	mgd =	12.8 cfs			
WSE Downstream of Weir	149.23	ft				
Weir Crest Elevation	148.50	ft				
Downstream head, Hd	0.73	ft				
Length of Weir, L	10.00	ft				
WEIR IS SUBMERGED						
Free Discharging Weir Computation				{ 6 }		
Head on Weir, H	NA	ft				
Upstream WSE	NA	ft				
Submerged Weir Computation				{ 7 }		
K	0.08					
M	0.63					
Increment	0.10	ft				
Upstream Head, Hu1	0.83	ft				
F(H1)	0.00					
F'(H1)	-2.30					
Upstream Head, Hu2	0.83	ft				
Upstream WSE	149.33	ft				
Head over Weir	*0.83*	*ft*				
			Condition Upstream of Weir		149.33	149.33

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Equation Ref.	HGL	EGL

Pipe from Actiflo™ to Ozone

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow	8.3	mgd =	12.8 cfs
Pipe Diameter, D	30	inch	
Pipe Length, L	20	ft	
Absolute Roughness, ε	0.00040	ft	
Pipe velocity, v	2.60	fps	
Kinematic Viscosity	1.000E-05	ft^2/sec	
Reynold's Number, R	650002		
Friction factor, f	0.0147		Equivalent Hazen-Williams "C" = 144.1939
Friction Energy Loss, h_L	0.01	ft	

MINOR PIPE LOSS HEADING

Flow, Q 8.3 mgd = 12.8 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance Loss - Flush	8.25	12.76	0.50	----	30	----	2.60	0.10	0.05
1	Mitre Bend - 90 ° Deflection	8.25	12.76	1.27	30	----	2.60	----	0.10	0.13
1	Butterfly Valve (Open)	8.25	12.76	0.50	30	----	2.60	----	0.10	0.05
1	Outlet Loss - Still Water	8.25	12.76	1.00	30	----	2.60	----	0.10	0.10
									Sum =	0.34

Total Energy Loss = 0.36 ft

	HGL	EGL
Upstream Condition	149.69	149.69

Actiflo™ Treatment Train (Headloss provided by Kruger)

Actiflo™ Headloss **1.184** Confirm and update for each flow condition

	HGL	EGL
Upstream Condition	150.87	150.87

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Equation Ref.	HGL	EGL

Raw Water Pipe from RW Meter to Actiflo™

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow	15.0	mgd =	23.2 cfs
Pipe Diameter, D	54	inch	
Pipe Length, L	795	ft	
Absolute Roughness, ε	0.00040	ft	
Pipe velocity, v	1.46	fps	
Kinematic Viscosity	1.000E-05	ft^2/sec	
Reynold's Number, R	656567		
Friction factor, f	0.0139		Equivalent Hazen-Williams "C" = 148.0406
Friction Energy Loss, h_L	0.08	ft	

MINOR PIPE LOSS HEADING

Flow, Q 15.0 mgd = 23.2 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Outlet Loss - Still Water	15.00	23.21	1.00	54	----	1.46	----	0.03	0.03
3	Mitre Bend - 90 ° Deflection	15.00	23.21	1.27	54	----	1.46	----	0.03	0.13
1	Tee - Standard	15.00	23.21	1.50	54	----	1.46	----	0.03	0.05
1	Increaser	15.00	23.21	0.25	24	54	7.39	1.46	0.81	0.20
									Sum =	0.41

Total Energy Loss = 0.49 ft

Upstream Condition 151.36 151.36

Meter Section of RW Pipeline

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow	15.0	mgd =	23.2 cfs
Pipe Diameter, D	24	inch	
Pipe Length, L	77	ft	
Absolute Roughness, ε	0.00040	ft	
Pipe velocity, v	7.39	fps	
Kinematic Viscosity	1.000E-05	ft^2/sec	
Reynold's Number, R	1477276		
Friction factor, f	0.0144		Equivalent Hazen-Williams "C" = 136.6324
Friction Energy Loss, h_L	0.47	ft	

MINOR PIPE LOSS HEADING

Flow, Q 15.0 mgd = 23.2 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Reducer	15.00	23.21	0.25	54	24	1.46	7.39	0.85	0.21
									Sum =	0.2118

Total Energy Loss = 0.68 ft

Upstream Condition 152.04 152.04

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	Equation Ref.	HGL	EGL
DOWNSTREAM CONTROL			
EGL = 123.00		123.00	123.00
Flow = 20.00 mgd = 30.94 cfs			

Filter Control Weir

[STRAIGHT EDGED SHARP CRESTED WEIR]

Flow	20.00	mgd =	30.9	cfs
WSE Downstream of Weir	123.00	ft		
Weir Crest Elevation	131.50	ft		
Downstream head, Hd	-8.50	ft		
Length of Weir, L	28.00	ft		

WEIR IS FREE-DISCHARGING

Free Discharging Weir Computation **{ 6 }**

Head on Weir, H	0.48	ft
Upstream WSE	131.98	ft

Submerged Weir Computation **{ 7 }**

K	NA	
M	NA	
Increment	NA	ft
Upstream Head, Hu1	NA	ft
F(H1)	NA	
F'(H1)	NA	
Upstream Head, Hu2	NA	ft
Upstream WSE	NA	ft

Head over Weir *0.48 ft*

	HGL	EGL
Condition Upstream of Weir	131.98	131.98

Piping from Filters to Filter Control Weir

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] **{ 4 }**

Flow	20.0	mgd =	30.9	cfs
Pipe Diameter, D	60	inch		
Pipe Length, L	50	ft		
Absolute Roughness, ε	0.00040	ft		
Pipe velocity, v	1.58	fps		
Kinematic Viscosity	1.000E-05	ft^2/sec		
Reynold's Number, R	787881			
Friction factor, f	0.0135		Equivalent Hazen-Williams "C" =	148.0147

Friction Energy Loss, h_L 0.01 ft

MINOR PIPE LOSS HEADING

Flow, Q 20.0 mgd = 30.9 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Outlet Loss - Still Water	20.00	30.94	1.00	----	60	----	1.58	0.04	0.04
1	Tee - Thru Straight Run	20.00	30.94	0.60	60	----	1.58	----	0.04	0.02
1	Increaser	20.00	30.94	0.25	60	54	1.58	1.95	-0.02	-0.01
									Sum =	0.06

Total Energy Loss = 0.06 ft

	HGL	EGL
Upstream Condition	132.04	132.04

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	Equation Ref.	HGL	EGL
[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)]	{ 4 }		

Flow 20.0 mgd = 30.9 cfs

Pipe Diameter, D	54	inch
Pipe Length, L	75	ft
Absolute Roughness, ε	0.00040	ft
Pipe velocity, v	1.95	fps
Kinematic Viscosity	1.000E-05	ft^2/sec
Reynold's Number, R	875423	
Friction factor, f	0.0134	

Equivalent Hazen-Williams "C" = 146.9879

Friction Energy Loss, h_L 0.01 ft

	HGL	EGL
Condition Upstream of Pipe	132.05	132.05

Piping from Filter Underdrains to FW Pipe

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow 6.7 mgd = 10.3 cfs

No. of Filters in Service 3

Pipe Diameter, D	20	inch
Pipe Length, L	15	ft
Absolute Roughness, ε	0.00040	ft
Pipe velocity, v	4.73	fps
Kinematic Viscosity	1.000E-05	ft^2/sec
Reynold's Number, R	787881	
Friction factor, f	0.0153	

Equivalent Hazen-Williams "C" = 139.3849

Friction Energy Loss, h_L 0.05 ft

MINOR PIPE LOSS HEADING

Flow, Q 6.7 mgd = 10.3 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance Loss - Flush	6.67	10.31	0.50	----	20	----	4.73	0.35	0.17
1	Tee - Thru Side Outlet	6.67	10.31	1.80	20	----	4.73	----	0.35	0.62
1	90 ° Elbow - Regular Fl.	6.67	10.31	0.30	20	----	4.73	----	0.35	0.10
1	Mitre Bend - 90 ° Deflection	6.67	10.31	1.27	20	----	4.73	----	0.35	0.44
1	Entrance Loss - Flush	6.67	10.31	0.50	----	20	----	4.73	0.35	0.17
									Sum =	1.51

Total Energy Loss per Filter = 1.56 ft

	HGL	EGL
Upstream Condition	133.62	133.62

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Filters (1 of 4)

			Equation Ref.	HGL	EGL
[GRAVITY SAND FILTER]			{ 10 }		
Flow	7.3	mgd = 11.3 cfs			
Area of Filter Bed	460	sf			
Superficial Velocity, Vo	0.025	fps			
Vo, SI Units	0.008	m/s			
Kinematic viscosity, v	1.1E-06	m^2/s			
GAC Layer					
Grain diameter, d	0.0014	m			
Bed Porosity, E'	0.5				
Bed Foulness (% of E)	0%				
Effective Porosity, E	0.5				
Bed depth, L	6	ft			
Bed depth, L - SI Units	1.83	m			
Head Loss, SI Units	0.34	m			
Head Loss	1.10	ft			
Sand Layer					
Grain diameter, d	0.00045	m			
Bed Porosity, E'	0.5				
Bed Foulness (% of E)	0%				
Effective Porosity, E	0.5				
Bed depth, L	1	ft			
Bed depth, L - SI Units	0.30	m			
Head Loss, SI Units	0.48	m			
Head Loss	1.59	ft			
Total Filter Energy Loss	2.69	ft			
		Condition Upstream of Filter		136.31	*136.31*

Filter Distribution/Influent Weir

			Equation Ref.	HGL	EGL
[STRAIGHT EDGED SHARP CRESTED WEIR]					
Flow	7.3	mgd = 11.3 cfs			
WSE Downstream of Weir	145.65	ft			
Weir Crest Elevation	146.50	ft			
Downstream head, Hd	-0.85	ft			
Length of Weir, L	10.00	ft			
WEIR IS FREE-DISCHARGING					
Free Discharging Weir Computation			{ 6 }		
Head on Weir, H	0.49	ft			
Upstream WSE	146.99	ft			
Submerged Weir Computation			{ 7 }		
K	NA				
M	NA				
Increment	NA	ft			
Upstream Head, Hu1	NA	ft			
F(H1)	NA				
F'(H1)	NA				
Upstream Head, Hu2	NA	ft			
Upstream WSE	NA	ft			
Head over Weir	*0.49*	*ft*			
		Condition Upstream of Weir		146.99	146.99

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Equation Ref.	HGL	EGL

Filter Distribution Channel

MINOR CHANNEL LOSS HEADING

Flow, Q 22.0 mgd = 34.0 cfs Channel Invert 141.5

No.	Description	Flow (mgd)	Flow (cfs)	K	Width Up (ft)	Width Down (ft)	Depth (ft)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance - Sharp Corners	22.00	34.03	0.50	10	10	5.49	0.62	0.62	0.00	0.00
1	90 Degree Bend - 0º Radius	22.00	34.03	1.30	10	----	5.49	0.62	----	0.01	0.01
										Sum =	0.01

Total Energy Loss = 0.01 ft

	Upstream Condition	HGL	EGL
	Upstream Condition	147.00	147.00

Ozone to Filter Pipe

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow 22.0 mgd = 34.0 cfs

Pipe Diameter, D 60 inch
Pipe Length, L 60 ft
Absolute Roughness, ε 0.00040 ft
Pipe velocity, v 1.73 fps
Kinematic Viscosity 1.000E-05 ft^2/sec
Reynold's Number, R 866669
Friction factor, f 0.0133 Equivalent Hazen-Williams "C" = 147.668

Friction Energy Loss, h_L 0.01 ft

MINOR PIPE LOSS HEADING

Flow, Q 22.0 mgd = 34.0 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance Loss - Flush	22.00	34.03	0.50	----	60	----	1.73	0.05	0.02
1	Outlet Loss - Still Water	22.00	34.03	1.00	60	----	1.73	----	0.05	0.05
									Sum =	0.07

Total Energy Loss = 0.08 ft

	Upstream Condition	HGL	EGL
	Upstream Condition	147.07	147.07

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Ozone Contactor Effluent Weir

[STRAIGHT EDGED SHARP CRESTED WEIR]

						Equation Ref.	HGL	EGL
Flow	11.0	mgd	=	17.0	cfs			
WSE Downstream of Weir	147.07	ft						
Weir Crest Elevation	148.67	ft						
Downstream head, Hd	-1.60	ft						
Length of Weir, L	10.00	ft						
Free Discharging Weir Computation						{ 6 }		
Head on Weir, H	0.64	ft						
Upstream WSE	149.31	ft						
Submerged Weir Computation						{ 7 }		
K	NA							
M	NA							
Increment	NA	ft						
Upstream Head, Hu1	NA	ft						
F(H1)	NA							
F'(H1)	NA							
Upstream Head, Hu2	NA	ft						
Upstream WSE	NA	ft						
Head over Weir	*0.64*	*ft*						
Condition Upstream of Weir							149.31	149.31

Last Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)]

						Equation Ref.	HGL	EGL
						{ 2 }		
Flow	11.0	mgd	=	17.0	cfs			
Number of Ports	1							
Flow Per Port	11.0	mgd	=	17.0	cfs			
Port Width	10	ft						
Port Height	3	ft						
Discharge Coefficient, C	0.61							
Velocity through port, v	0.57	fps						
Orifice Energy Loss, h_L	0.01	ft						
Condition Upstream of Orifice							149.32	149.32

Last Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

						Equation Ref.	HGL	EGL
Flow	11.0	mgd	=	17.0	cfs			
WSE Downstream of Weir	149.32	ft						
Weir Crest Elevation	146.00	ft						
Downstream head, Hd	3.32	ft						
Length of Weir, L	10.00	ft						

WEIR IS SUBMERGED

						Equation Ref.	HGL	EGL
Free Discharging Weir Computation						{ 6 }		
Head on Weir, H	NA	ft						
Upstream WSE	NA	ft						
Submerged Weir Computation						{ 7 }		
K	0.17							
M	6.06							
Increment	0.10	ft						
Upstream Head, Hu1	3.33	ft						
F(H1)	0.00							
F'(H1)	-0.45							
Upstream Head, Hu2	3.33	ft						
Upstream WSE	149.33	ft						
Head over Weir	*3.33*	*ft*						
Condition Upstream of Weir							149.33	149.33

	Equation Ref.	HGL	EGL

Third Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)] { 2 }

Flow	11.0 mgd	=	17.0 cfs
Number of Ports	1		
Flow Per Port	11.0 mgd	=	17.0 cfs
Port Width	10 ft		
Port Height	3 ft		
Discharge Coefficient, C	0.61		
Velocity through port, v	0.57 fps		
Orifice Energy Loss, h_L	0.01 ft		

	HGL	EGL
Condition Upstream of Orifice	149.34	149.34

Third Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

Flow	11.0 mgd	=	17.0 cfs
WSE Downstream of Weir	149.34 ft		
Weir Crest Elevation	146.00 ft		
Downstream head, Hd	3.34 ft		
Length of Weir, L	10.00 ft		

WEIR IS SUBMERGED

Free Discharging Weir Computation { 6 }

Head on Weir, H	NA	ft
Upstream WSE	NA	ft

Submerged Weir Computation { 7 }

K	0.17	
M	6.10	
Increment	0.10	ft
Upstream Head, Hu1	3.34	ft
F(H1)	0.00	
F'(H1)	-0.45	
Upstream Head, Hu2	3.34	ft
Upstream WSE	149.34	ft

Head over Weir *3.34 ft*

	HGL	EGL
Condition Upstream of Weir	149.34	149.34

Second Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)] { 2 }

Flow	11.0 mgd	=	17.0 cfs
Number of Ports	1		
Flow Per Port	11.0 mgd	=	17.0 cfs
Port Width	10 ft		
Port Height	3 ft		
Discharge Coefficient, C	0.61		
Velocity through port, v	0.57 fps		
Orifice Energy Loss, h_L	0.01 ft		

	HGL	EGL
Condition Upstream of Orifice	149.36	149.36

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				Equation Ref.	HGL	EGL

Second Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

				Equation Ref.	HGL	EGL
Flow	11.0	mgd	= 17.0 cfs			
WSE Downstream of Weir	149.36	ft				
Weir Crest Elevation	146.00	ft				
Downstream head, Hd	3.36	ft				
Length of Weir, L	10.00	ft				
WEIR IS SUBMERGED						
Free Discharging Weir Computation				{ 6 }		
Head on Weir, H	NA	ft				
Upstream WSE	NA	ft				
Submerged Weir Computation				{ 7 }		
K	0.17					
M	6.15					
Increment	0.10	ft				
Upstream Head, Hu1	3.36	ft				
F(H1)	0.00					
F'(H1)	-0.45					
Upstream Head, Hu2	3.36	ft				
Upstream WSE	149.36	ft				
Head over Weir	*3.36*	*ft*				
			Condition Upstream of Weir		149.36	149.36

First Ozone Under Baffle

[SUBMERGED ORIFICE (RECTANGULAR)] { 2 }

				Equation Ref.	HGL	EGL
Flow	11.0	mgd	= 17.0 cfs			
Number of Ports	1					
Flow Per Port	11.0	mgd	= 17.0 cfs			
Port Width	10	ft				
Port Height	3	ft				
Discharge Coefficient, C	0.61					
Velocity through port, v	0.57	fps				
Orifice Energy Loss, h_L	0.01	ft				
			Condition Upstream of Orifice		149.37	149.37

First Ozone Contactor Weir/Over Baffle

[STRAIGHT EDGED SHARP CRESTED WEIR]

				Equation Ref.	HGL	EGL
Flow	11.0	mgd	= 17.0 cfs			
WSE Downstream of Weir	149.37	ft				
Weir Crest Elevation	148.50	ft				
Downstream head, Hd	0.87	ft				
Length of Weir, L	10.00	ft				
WEIR IS SUBMERGED						
Free Discharging Weir Computation				{ 6 }		
Head on Weir, H	NA	ft				
Upstream WSE	NA	ft				
Submerged Weir Computation				{ 7 }		
K	0.17					
M	0.82					
Increment	0.10	ft				
Upstream Head, Hu1	1.00	ft				
F(H1)	0.00					
F'(H1)	-1.94					
Upstream Head, Hu2	1.00	ft				
Upstream WSE	149.50	ft				
Head over Weir	*1.00*	*ft*				
			Condition Upstream of Weir		149.50	149.50

APPENDIX A1

PROJECT : Willamette River Water Treatment Plant 2017 MPU

			CHECKED :	**BY :**	Josh Miner
JOB # : 10721A00	**REVISION:**		**DATE :**	**DATE :**	1/22/2018

	Equation Ref.	HGL	EGL

ipe from Actiflo™ to Ozone

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] **{ 4 }**

Flow	11.0	mgd =	17.0 cfs
Pipe Diameter, D	30	inch	
Pipe Length, L	20	ft	
Absolute Roughness, ε	0.00040	ft	
Pipe velocity, v	3.47	fps	
Kinematic Viscosity	1.000E-05	ft^2/sec	
Reynold's Number, R	866669		
Friction factor, f	0.0144		Equivalent Hazen-Williams "C" = 142.603
Friction Energy Loss, h_L	0.02	ft	

MINOR PIPE LOSS HEADING

Flow, Q 11.0 mgd = 17.0 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Entrance Loss - Flush	11.00	17.02	0.50	----	30	----	3.47	0.19	0.09
1	Mitre Bend - 90 º Deflection	11.00	17.02	1.27	30	----	3.47	----	0.19	0.24
1	Butterfly Valve (Open)	11.00	17.02	0.50	30	----	3.47	----	0.19	0.09
1	Outlet Loss - Still Water	11.00	17.02	1.00	30	----	3.47	----	0.19	0.19
									Sum =	0.61

Total Energy Loss = 0.63 ft

	HGL	EGL
Upstream Condition	150.13	150.13

Actiflo™ Treatment Train (Headloss provided by Kruger)

Actiflo™ Headloss **1.184** Confirm and update for each flow condition

	HGL	EGL
Upstream Condition	151.31	151.31

APPENDIX A1

Hydraulix BY carollo

PROJECT : Willamette River Water Treatment Plant 2017 MPU

JOB # : 10721A00 **REVISION:** **CHECKED :** **DATE :**

BY : Josh Miner
DATE : 1/22/2018

Equation Ref.	HGL	EGL

Raw Water Pipe from RW Meter to Actiflo™

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow	20.0 mgd =	30.9 cfs
Pipe Diameter, D	54 inch	
Pipe Length, L	795 ft	
Absolute Roughness, ε	0.00040 ft	
Pipe velocity, v	1.95 fps	
Kinematic Viscosity	1.000E-05 ft^2/sec	
Reynold's Number, R	875423	
Friction factor, f	0.0134	Equivalent Hazen-Williams "C" = 146.9879
Friction Energy Loss, h_L	0.14 ft	

MINOR PIPE LOSS HEADING

Flow, Q 20.0 mgd = 30.9 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Outlet Loss - Still Water	20.00	30.94	1.00	54	----	1.95	----	0.06	0.06
3	Mitre Bend - 90 ° Deflection	20.00	30.94	1.27	54	----	1.95	----	0.06	0.22
1	Tee - Standard	20.00	30.94	1.50	54	----	1.95	----	0.06	0.09
1	Increaser	20.00	30.94	0.25	24	54	9.85	1.95	1.45	0.36
									Sum =	0.73

Total Energy Loss = 0.87 ft

	HGL	EGL
Upstream Condition	152.18	152.18

Meter Section of RW Pipeline

[PIPE FRICTION LOSSES (DARCY-WEISBACH / COLEBROOK)] { 4 }

Flow	20.0 mgd =	30.9 cfs
Pipe Diameter, D	24 inch	
Pipe Length, L	77 ft	
Absolute Roughness, ε	0.00040 ft	
Pipe velocity, v	9.85 fps	
Kinematic Viscosity	1.000E-05 ft^2/sec	
Reynold's Number, R	1969702	
Friction factor, f	0.0142	Equivalent Hazen-Williams "C" = 134.2704
Friction Energy Loss, h_L	0.83 ft	

MINOR PIPE LOSS HEADING

Flow, Q 20.0 mgd = 30.9 cfs

No.	Description	Flow (mgd)	Flow (cfs)	K	Dia Up (in)	Dia Down (in)	Vel Up (fps)	Vel Down (fps)	Vel Head (ft)	Minor Loss (ft)
1	Reducer	20.00	30.94	0.25	54	24	1.95	9.85	1.51	0.38
									Sum =	0.3765

Total Energy Loss = 1.20 ft

	HGL	EGL
Upstream Condition	153.38	153.38

APPENDIX A1

WRWTP EQUIPMENT LIST

ASSET ID	ASSET DESCRIPTION	HIERARCHY	HIERARCHY SYSTEM NAME	ASSET TYPE	CRITICALITY	ASSET ALIAS	IN SERVICE DATE	USEFUL LIFE	YEARS IN SERVICE	REMAINING LIFE	REPLACEMENT VALUE	Asset Group	Capacity	Capacity 2	Horsepower	Near-term Expansion Horsepower	Long-Term Expansion Horsepower	Comments	Resiliency/Redundancy
802	T-30P02 SPARE Pump, Water Feature	PTP01BGR00GRN00	Grounds System	PMPSUB	3	Not Used by Veolia	9/1/2015	20	1.657534247	18.34246575	$30,000	Mechanical							
792	T-04ME08 Mixer,Coagulation,Actiflo 2, 4050	PTP01SED00STL01	Train #1 Actiflo System	MXRFXD	3	Not Used by Veolia	6/2/2014	20	2.906849315	17.09315068	$24,000	Mechanical			7.5				
473	T-06AIT091 SPARE Analyzer, Particle Count, Counter	PTP01FLT00TSP00	Combined Filter Effluent System	MNTLQC	5	Not Used by Veolia	4/29/2002	18	15.01	2.991780822	$4,500	Electrical							
4	T-03UND03 Vault, Initial Mix	PTP01SED00PMP03	Initial Chemical Mixing and Application System	STCCNC	2	Not Used by Veolia	4/29/2002	50	15.00821918	34.99178082	$1,000	Infrastructure							
531	T-01LCP01 Panel,Local Control,Air Burst & PLC	PTP01PRE00SCR00	Raw Water Intake Screen System	CPLGEN	5	T-01LCP01	4/29/2002	25	15.01	9.991780822	$15,000	Electrical							
532	T-01ME01 Compressor,Air Burst 1	PTP01PRE00SCR00	Raw Water Intake Screen System	CMPRTR	5	T-01ME01	4/29/2002	25	15.01	9.991780822	$50,000	Mechanical	2,200 ft^3		50				
533	T-01ME02 Compressor,Air Burst 2	PTP01PRE00SCR00	Raw Water Intake Screen System	CMPRTR	5	T-01ME02	4/29/2002	25	15.01	9.991780822	$50,000	Mechanical	2,200 ft^3		50				
82	T-01ME03 Crane, 15 Ton Overhead, Raw	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HSTOVR	2	T-01ME03	4/29/2002	40	15.01	24.99178082	$25,000	Mechanical			20			(equipment schedule says 15/0.75/2/2)	
536	T-01MOV01 Valve,Control,Air Burst 1	PTP01PRE00SCR00	Raw Water Intake Screen System	VLVBTF	5	T-01MOV01	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
537	T-01MOV02 Valve,Control,Air Burst 2	PTP01PRE00SCR00	Raw Water Intake Screen System	VLVBTF	5	T-01MOV02	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
538	T-01PIPE01 Pipeline,Caisson Feed,Raw Water	PTP01PRE00SCR00	Raw Water Intake Screen System	PPGSTL	5	T-01PIPE01	4/29/2002	42	15.01	26.99178082	$200,000	Infrastructure							
539	T-01PIT001 Indicator, Pressure,Air Burst Compressor	PTP01PRE00SCR00	Raw Water Intake Screen System	MNTPRS	5	T-01PIT001	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
83	T-01RECT01 Rectifier,Cathodic Protection,Raw Water	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	CNSECT	2	T-01RECT01	4/29/2002	20	15.01	4.991780822	$5,000	Infrastructure							
540	T-01SCR01 Screen,Raw Water Intake 1	PTP01PRE00SCR00	Raw Water Intake Screen System	BSCALL	5	T-01SCR01	4/29/2002	35	15.01	19.99178082	$125,000	Mechanical	66 in	70 mgd					
541	T-01SCR02 Screen,Raw Water Intake 2	PTP01PRE00SCR00	Raw Water Intake Screen System	BSCALL	5	T-01SCR02	4/29/2002	35	15.01	19.99178082	$125,000	Mechanical	66 in	70 mgd					
542	T-01T01 Tank,Storage,Compressed Air	PTP01PRE00SCR00	Raw Water Intake Screen System	TNKPRS	5	T-01T01	4/29/2002	42	15.01	26.99178082	$10,000	Infrastructure							
84	T-02BLDG01 Raw Water Building	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	STCCNC	2	T-02BLDG01	4/29/2002	50	15.01	34.99178082	$30,000	Infrastructure							
498	T-02CV01 Valve,Check,Raw Water Pump 1	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPLG	5	T-02CV01	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
499	T-02CV02 Valve,Check,Raw Water Pump 2	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPLG	5	T-02CV02	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
500	T-02CV03 Valve,Check,Raw Water Pump 3	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPLG	5	T-02CV03	4/29/2002	33	15.00821918	17.99178082	$5,000	Mechanical							
501	T-02CV04 Valve,Check,Raw Water Pump 4	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPLG	5	T-02CV04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
85	T-02EME01 Light,Emergency,Raw Water Pumping	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	LGTGEN	2	T-02EME01	4/29/2002	20	15.01	4.991780822	$500	Electrical							
86	T-02EME02 Light,Emergency,Raw Water Elect. Room	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	LGTGEN	2	T-02EME02	4/29/2002	20	15.00821918	4.991780822	$500	Electrical							
87	T-02EME03 Light,Emergency,Raw Water Compressed Air	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	LGTGEN	2	T-02EME03	4/29/2002	20	15.00821918	4.991780822	$500	Electrical							
88	T-02F01 Fan,Exhaust, Raw Water Pump Room SE	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	FANCNT	2	T-02F01	4/29/2002	20	15.00821918	4.991780822	$1,000	Mechanical							
89	T-02F02 Fan,Exhaust, Raw Water Pump Room SW	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	FANCNT	2	T-02F02	4/29/2002	20	15.00821918	4.991780822	$1,000	Mechanical							
90	T-02F06 Fan,Exhaust, Raw Water Elect. Room N.	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	FANCNT	2	T-02F06	4/29/2002	20	15.00821918	4.991780822	$1,000	Mechanical							
91	T-02F07 Fan,Exhaust, Raw Water Elect. Room S.	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	FANCNT	2	T-02F07	4/29/2002	20	15.00821918	4.991780822	$1,000	Mechanical							
92	T-02F10 Fan,Exhaust, Raw Water Compress. Room N.	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	FANCNT	2	T-02F10	4/29/2002	20	15.00821918	4.991780822	$1,000	Mechanical							
93	T-02F11 Fan,Exhaust, Raw Water Compress. Room S.	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	FANCNT	2	T-02F11	4/29/2002	20	15.00821918	4.991780822	$1,000	Mechanical							
94	T-02H01 Heater,Raw Water Pump room, West	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02H01	4/29/2002	15	15.01	-0.008219178	$300	Mechanical							
95	T-02H02 Heater,Raw Water Pump room, East	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02H02	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
96	T-02H03 Heater,Raw Water Electrical room	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02H03	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
97	T-02H04 Heater,Air Burst room	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02H04	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
98	T-02L01 Louver,Raw Water Pump Room,small	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02L01	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
99	T-02L02 Louver,Raw Water Pump Room,large	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02L02	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
100	T-02L04 Louver,Raw Water Electrical Room,small	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02L04	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
101	T-02L05 Louver,Raw Water Electrical Room,large	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02L05	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
102	T-02L08 Louver,Raw Water Air Burst,small	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02L08	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
103	T-02L09 Louver,Raw Water Air Burst,large	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HVCGEN	2	T-02L09	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
489	T-02LIT001 Indicator,Level,Raw Water Wetwell	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	MNTLVL	3	T-02LIT001	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
502	T-02LSL001 Switch,Low Level,Raw Water Wetwell	PTP01PRE00PMP00	Raw Water Intake Pumping System	MNTLVL	5	T-02LSL001	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
544	T-02MCC-A MCC, Raw Water	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	MCCACE	5	T-02MCC-A	4/29/2002	40	15.01	24.99178082	$12,500	Electrical							
104	T-02ME05 Winch,Sump Pump,Raw Water Wetwell	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	HSTPRT	2	T-02ME05	4/29/2002	20	15.00821918	4.991780822	$250	Mechanical							
503	T-02MOV01 Valve,Control,Irrigation Supply,4 in.	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVBTF	5	T-02MOV01	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
504	T-02MOV02 Valve,Control,Raw Water Wetwell Scour,4"	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVBTF	5	T-02MOV02	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
505	T-02P01 Pump,Raw Water Intake 1	PTP01PRE00PMP00	Raw Water Intake Pumping System	PMPCNT	5	T-02P01	4/29/2002	30	15.01	14.99178082	$300,000	Mechanical	5200 gpm	107 ft TDH	200			Variable Speed	
506	T-02P02 Pump,Raw Water Intake 2	PTP01PRE00PMP00	Raw Water Intake Pumping System	PMPCNT	5	T-02P02	4/29/2002	30	15.01	14.99178082	$300,000	Mechanical	5200 gpm	107 ft TDH	200			Variable Speed	
507	T-02P03 Pump,Raw Water Intake 3	PTP01PRE00PMP00	Raw Water Intake Pumping System	PMPCNT	5	T-02P03	4/29/2002	30	15.01	14.99178082	$300,000	Mechanical	5200 gpm	107 ft TDH	200			Variable Speed, Standby	
508	T-02P04 Pump,Raw Water Intake 4	PTP01PRE00PMP00	Raw Water Intake Pumping System	PMPCNT	5	T-02P04	4/29/2002	30	15.01	14.99178082	$200,000	Mechanical	2800 gpm	106 ft TD	100			Variable Speed	
105	T-02P05 Pump,Sump,Raw Water	PTP01BGR00BLD02	Bldg 02 -- Intake Pump Sta. Building System	PMPSUB	2	T-02P05	4/29/2002	15	15.01	-0.008219178	$25,000	Mechanical	200 gpm	70 ft TDH	20				
509	T-02PIPE01 Pipeline,Discharge,RWPS	PTP01PRE00PMP00	Raw Water Intake Pumping System	PPGDST	5	T-02PIPE01	4/29/2002	42	15.01	26.99178082	$250,000	Infrastructure							
514	T-02PSH001 Switch,High Pressure,Raw Water Pump 1	PTP01PRE00PMP00	Raw Water Intake Pumping System	MNTPRS	5	T-02PSH001	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
515	T-02PSH002 Switch,High Pressure,Raw Water Pump 2	PTP01PRE00PMP00	Raw Water Intake Pumping System	MNTPRS	5	T-02PSH002	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
516	T-02PSH003 Switch,High Pressure,Raw Water Pump 3	PTP01PRE00PMP00	Raw Water Intake Pumping System	MNTPRS	5	T-02PSH003	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
517	T-02PSH004 Switch,High Pressure,Raw Water Pump 4	PTP01PRE00PMP00	Raw Water Intake Pumping System	MNTPRS	5	T-02PSH004	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
518	T-02PVFD01 VFD,Raw Water Pump 1	PTP01PRE00PMP00	Raw Water Intake Pumping System	VFDALL	5	T-02PVFD01	4/29/2002	25	15.01	9.991780822	$15,000	Electrical							
519	T-02PVFD02 VFD,Raw Water Pump 2	PTP01PRE00PMP00	Raw Water Intake Pumping System	VFDALL	5	T-02PVFD02	4/29/2002	25	15.01	9.991780822	$15,000	Electrical							
520	T-02PVFD04 VFD,Raw Water Pump 4	PTP01PRE00PMP00	Raw Water Intake Pumping System	VFDALL	5	T-02PVFD04	6/1/2010	25	6.91	18.08767123	$11,000	Electrical							
521	T-02T01 Tank, Caisson	PTP01PRE00PMP00	Raw Water Intake Pumping System	TNKCNC	5	T-02T01	4/29/2002	50	15.01	34.99178082	$300,000	Infrastructure							
522	T-02V01 Valve,Isolation,Raw Water Pump 1,16 in.	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVBTF	5	T-02V01	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
523	T-02V02 Valve,Isolation,Raw Water Pump 2,16 in.	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVBTF	5	T-02V02	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
524	T-02V03 Valve,Isolation,Raw Water Pump 3,16 in.	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVBTF	5	T-02V03	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
525	T-02V04 Valve,Isolation,Raw Water Pump 4,12 in.	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVBTF	5	T-02V04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
526	T-02V05 Valve,Drain,Raw Water Pipeline,6 in.	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVBTF	5	T-02V05	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
527	T-02VAV01 Valve,AirVac,Raw Water Pump 1	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPSI	5	T-02VAV01	4/29/2002	25	15.01	9.991780822	$750	Mechanical							
528	T-02VAV02 Valve,AirVac,Raw Water Pump 2	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPSI	5	T-02VAV02	4/29/2002	25	15.01	9.991780822	$750	Mechanical							
529	T-02VAV03 Valve,AirVac,Raw Water Pump 3	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPSI	5	T-02VAV03	4/29/2002	25	15.01	9.991780822	$750	Mechanical							
530	T-02VAV04 Valve,AirVac,Raw Water Pump 4	PTP01PRE00PMP00	Raw Water Intake Pumping System	VLVPSI	5	T-02VAV04	4/29/2002	25	15.01	9.991780822	$750	Mechanical							
490	T-03AIT001 Analyzer,Turbidity,Raw Water	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	MNTTRB	3	T-03AIT001	4/29/2002	17	15.01	1.991780822	$2,500	Electrical							
491	T-03AIT002 Analyzer,Particle Count,Raw Water	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	MNTLQC	3	T-03AIT002	4/29/2002	18	15.01	2.991780822	$4,500	Electrical							
492	T-03AIT003 Analyzer,pH/Temp,Raw Water	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	MNTLQC	3	T-03AIT003	4/29/2002	17	15.01	1.991780822	$2,000	Electrical							
493	T-03AIT004 Analyer,BTEX,Raw Water	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	MNTGAC	3	T-03AIT004	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
1	T-03AIT005 Analyzer,Streaming Current,Actiflo Inlet	PTP01SED00PMP03	Initial Chemical Mixing and Application System	MNTLQC	2	T-03AIT005	4/29/2002	18	15.01	2.991780822	$10,000	Electrical							
494	T-03FIT001 Meter,Flow,Raw Water	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	FMTMAG	3	T-03FIT001	4/29/2002	28	15.01	12.99178082	$18,000	Mechanical							
495	T-03LAD01 Ladder,Raw Water Meter Vault	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	SFTFXD	3	T-03LAD01	4/29/2002	30	15.01	14.99178082	$2,000	Infrastructure							
496	T-03MOV01 Valve,Isolation,Raw Water Meter,24 in	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	VLVBTF	3	T-03MOV01	11/1/2014	33	2.49	30.50958904	$10,000	Mechanical							
497	T-03P01 Pump,Sample,Raw Water	PTP01PRE00MNT00	Raw Water Flow Control and Monitoring System	PMPDPH	3	T-03P01	4/29/2002	15	15.01	-0.008219178	$2,500	Mechanical							
2	T-03P02 Pump,Initial Mix	PTP01SED00PMP03	Initial Chemical Mixing and Application System	PMPCNT	2	T-03P02	12/7/2001	15	15.4	-0.4	$15,000	Mechanical							
3	T-03P03 SPARE Pump,Initial Mix	PTP01SED00PMP03	Initial Chemical Mixing and Application System	PMPCNT	2	T-03P03	12/7/2001	15	15.4	-0.4	$15,000	Mechanical							
6	T-03PSH004 Switch,High Pressure,Initial Mix Pump	PTP01SED00PMP03	Initial Chemical Mixing and Application System	MNTPRS	2	T-03PSH004	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
7	T-03V01 Valve,Isolation,Initial Mix Pump,10 in.	PTP01SED00PMP03	Initial Chemical Mixing and Application System	VLVBTF	2	T-03V01	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
8	T-03V02 Valve,Isolation,Initial Mix Pump,10 in.	PTP01SED00PMP03	Initial Chemical Mixing and Application System	VLVBTF	2	T-03V02	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
10	T-04AIT001 Analyzer,pH/Temp,Settled Water,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	MNTLQC	3	T-04AIT001	4/29/2002	17	15.01	1.991780822	$2,000	Electrical							
11	T-04AIT002 Analyzer,Turb.,Settled Water,Actiflo1	PTP01SED00STL01	Train #1 Actiflo System	MNTTRB	3	T-04AIT002	5/15/2015	17	1.96	15.04383562	$2,500	Electrical							
48	T-04AIT004 Analyzer,pH/Temp,Settled Water,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	MNTLQC	3	T-04AIT004	4/29/2002	17	15.01	1.991780822	$2,000	Electrical							
49	T-04AIT005 Analyzer,Turb.,Settled Water,Actiflo2	PTP01SED00STL02	Train #2 Actiflo System	MNTTRB	3	T-04AIT005	5/15/2015	17	1.96	15.04383562	$2,500	Electrical							
9	T-04AIT203 Analyzer,pH/Temp,Streaming Current	PTP01SED00PMP03	Initial Chemical Mixing and Application System	MNTLQC	2	T-04AIT203	4/29/2002	17	15.01	1.991780822	$2,000	Electrical							
107	T-04BLDG01 Actiflo Sand Storage Area	PTP01BGR00BLD04	Bldg 04 -- Actiflo Building System	BLDCNC	2	T-04BLDG01	4/29/2002	50	15.01	34.99178082	$10,000	Infrastructure							
108	T-04BLDG02 Actiflo Sand Pump Room	PTP01BGR00BLD04	Bldg 04 -- Actiflo Building System	BLDCNC	2	T-04BLDG02	4/29/2002	50	15.01	34.99178082	$25,000	Infrastructure							
109	T-04F01 Fan,Exhaust, Actiflo Hydrocyclone Room	PTP01BGR00BLD04	Bldg 04 -- Actiflo Building System	FANCNT	2	T-04F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
12	T-04FE001 Rotameter,Flow,Polymer,Actiflo 1, West	PTP01SED00STL01	Train #1 Actiflo System	FMTRTR	3	T-04FE001	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
13	T-04FE002 Rotameter,Flow,Polymer,Actiflo 1, East	PTP01SED00STL01	Train #1 Actiflo System	FMTRTR	3	T-04FE002	4/29/2002	20	15.00821918	4.991780822	$1,000	Electrical							
50	T-04FE003 Rotameter,Flow,Polymer,Actiflo 2, West	PTP01SED00STL02	Train #2 Actiflo System	FMTRTR	3	T-04FE003	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
51	T-04FE004 Rotameter,Flow,Polymer,Actiflo 2, East	PTP01SED00STL02	Train #2 Actiflo System	FMTRTR	3	T-04FE004	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
14	T-04FSL111 Switch,Flow,Seal Water,Solids Recycle 1	PTP01SED00STL01	Train #1 Actiflo System	MNTLVL	3	T-04FSL111	4/29/2002	29	15.00821918	13.99178082	$100	Electrical							
15	T-04FSL121 Switch,Flow,Seal Water,Solids Recycle 2	PTP01SED00STL01	Train #1 Actiflo System	MNTLVL	3	T-04FSL121	4/29/2002	29	15.01	13.99178082	$100	Electrical							
52	T-04FSL131 Switch,Flow,Seal Water,Solids Recycle 3	PTP01SED00STL02	Train #2 Actiflo System	MNTLVL	3	T-04FSL131	4/29/2002	29	15.01	13.99178082	$100	Electrical							

WRWTP EQUIPMENT LIST

ASSET ID	ASSET DESCRIPTION	HIERARCHY	HIERARCHY SYSTEM NAME	ASSET TYPE	CRITICALITY	ASSET ALIAS	IN SERVICE DATE	USEFUL LIFE	YEARS IN SERVICE	REMAINING LIFE	REPLACEMENT VALUE	Asset Group	Capacity	Capacity 2	Horsepower	Near-term Expansion Horsepower	Long-Term Expansion Horsepower	Comments	Resiliency/Redundancy
53	T-04FSL141 Switch,Flow,Seal Water,Solids Recycle 4	PTP01SED00STL02	Train #2 Actiflo System	MNTLVL	3	T-04FSL141	4/29/2002	29	15.01	13.99178082	$100	Electrical							
54	T-04G01 Gate,Slide,Actiflo Isolation	PTP01SED00STL02	Train #2 Actiflo System	VLVGAT	3	T-04G01	4/29/2002	42	15.01	26.99178082	$7,500	Mechanical							
110	T-04H01 Heater,Sand Storage,Actiflo	PTP01BGR00BLD04	Bldg 04 -- Actiflo Building System	HVCGEN	2	T-04H01	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
16	T-04LCP01 Panel, Local Control,Actiflo, & PLC	PTP01SED00STL01	Train #1 Actiflo System	CPLGEN	3	T-04LCP01	4/29/2002	25	15.01	9.991780822	$15,000	Electrical							
545	T-04MCC-A MCC, Actiflo #1	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	MCCACE	5	T-04MCC-A	4/29/2002	40	15.01	24.99178082	$12,500	Electrical							
546	T-04MCC-B MCC, Actiflo #2/Emerg. Power	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	MCCACE	5	T-04MCC-B	4/29/2002	40	15.01	24.99178082	$12,500	Electrical							
18	T-04ME01-A Mixer,Coagulation,Actiflo 1, 4050	PTP01SED00STL01	Train #1 Actiflo System	MXRFXD	3	T-04ME01-A	11/1/2007	20	9.5	10.50410959	$24,000	Mechanical			7.5				
19	T-04ME02 Mixer,Injection,Actiflo 1, EW5	PTP01SED00STL01	Train #1 Actiflo System	MXRFXD	3	T-04ME02	4/29/2002	20	15.01	4.991780822	$24,000	Mechanical			7.5				
20	T-04ME03 Mixer,Maturation,Actiflo 1, 75Q	PTP01SED00STL01	Train #1 Actiflo System	MXRFXD	3	T-04ME03	10/1/2005	20	11.58	8.419178082	$24,000	Mechanical			10				
21	T-04ME04 Clarifier, Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	CLRRCT	3	T-04ME04	4/29/2002	42	15.01	26.99178082	$100,000	Mechanical			3				
22	T-04ME05 Hydrocyclone 1,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	GRCCYC	3	T-04ME05	4/29/2002	17	15.01	1.991780822	$30,000	Mechanical	155 gpm						
23	T-04ME06 Hydrocyclone 2,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	GRCCYC	3	T-04ME06	4/29/2002	17	15.01	1.991780822	$30,000	Mechanical	155 gpm						
56	T-04ME09 Mixer,Injection,Actiflo 2, EW5	PTP01SED00STL02	Train #2 Actiflo System	MXRFXD	3	T-04ME09	4/29/2002	20	15.01	4.991780822	$24,000	Mechanical			7.5				
57	T-04ME10 Mixer,Maturation,Actiflo 2, 75Q	PTP01SED00STL02	Train #2 Actiflo System	MXRFXD	3	T-04ME10	10/1/2005	20	11.58	8.419178082	$24,000	Mechanical			10				
58	T-04ME11 Clarifier, Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	CLRRCT	3	T-04ME11	4/29/2002	42	15.01	26.99178082	$100,000	Mechanical			3				
59	T-04ME12 Hydrocyclone 3,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	GRCCYC	3	T-04ME12	4/29/2002	17	15.01	1.991780822	$30,000	Mechanical	155 gpm						
60	T-04ME13 Hydrocyclone 4,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	GRCCYC	3	T-04ME13	4/29/2002	17	15.01	1.991780822	$30,000	Mechanical	155 gpm						
112	T-04ME19 Elevator Lift,Wheelchair - Outside Lab State of Oregon Elevator# WCL14790-OP	PTP01BGR00BLD04	Bldg 04 -- Actiflo Building System	ELVALL	2	T-04ME19	7/6/2007	35	9.82	25.18082192	$20,000	Infrastructure			1.4				
113	T-04ME20 Door,Overhead Rollup	PTP01BGR00BLD04	Bldg 04 -- Actiflo Building System	BLDCNC	2	T-04ME20	4/29/2002	30	15.01	14.99178082	$3,000	Infrastructure							
29	T-04MOV01 Valve,Outlet,30 in.,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	VLVBTF	3	T-04MOV01	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
65	T-04MOV02 Valve,Outlet,30 in.,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	VLVBTF	3	T-04MOV02	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
30	T-04P01 Pump 1,Solids Recycle,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	PMPCNT	3	T-04P01	4/29/2002	25	15.01	9.991780822	$40,000	Mechanical	155 gpm	70 ft TDH	10				
31	T-04P02 Pump 2,Solids Recycle,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	PMPCNT	3	T-04P02	4/29/2002	25	15.01	9.991780822	$40,000	Mechanical	155 gpm	70 ft TDH	10				
66	T-04P03 Pump 3,Solids Recycle,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	PMPCNT	3	T-04P03	4/29/2002	25	15.01	9.991780822	$40,000	Mechanical	155 gpm	70 ft TDH	10				
67	T-04P04 Pump 4,Solids Recycle,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	PMPCNT	3	T-04P04	4/29/2002	25	15.01	9.991780822	$40,000	Mechanical	155 gpm	70 ft TDH	10				
32	T-04P05,Pump,Solids Recycle,Actiflo	PTP01SED00STL01	Train #1 Actiflo System	PMPCNT	3	T-04P05	4/29/2002	25	15.01	9.991780822	$40,000	Mechanical	155 gpm	70 ft TDH	10				
33	T-04P06 Pump,Sample,Settled Water,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	PMPDPH	3	T-04P06	4/29/2002	15	15.00821918	-0.008219178	$2,500	Mechanical							
68	T-04P07 Pump,Sample,Settled Water,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	PMPDPH	3	T-04P07	4/29/2002	15	15.01	-0.008219178	$2,500	Mechanical							
37	T-04PSL110 Switch,Low Press.,Solids Recycle Pump 1	PTP01SED00STL01	Train #1 Actiflo System	MNTPRS	3	T-04PSL110	4/29/2002	15	15.00821918	-0.008219178	$2,000	Electrical							
38	T-04PSL120 Switch,Low Press.,Solids Recycle Pump 2	PTP01SED00STL01	Train #1 Actiflo System	MNTPRS	3	T-04PSL120	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
71	T-04PSL130 Switch,Low Press.,Solids Recycle Pump 3	PTP01SED00STL02	Train #2 Actiflo System	MNTPRS	3	T-04PSL130	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
72	T-04PSL140 Switch,Low Press.,Solids Recycle Pump 4	PTP01SED00STL02	Train #2 Actiflo System	MNTPRS	3	T-04PSL140	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
39	T-04T01 Tank,Coagulation,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	TNKCNC	3	T-04T01	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
40	T-04T02 Tank,Injection,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	TNKCNC	3	T-04T02	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
41	T-04T03 Tank,Maturation,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	TNKCNC	3	T-04T03	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
42	T-04T04 Tank,Clarifier,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	TNKCNC	3	T-04T04	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
73	T-04T08 Tank,Coagulation,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	TNKCNC	3	T-04T08	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
74	T-04T09 Tank,Injection, Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	TNKCNC	3	T-04T09	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
75	T-04T10 Tank,Maturation,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	TNKCNC	3	T-04T10	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
76	T-04T11 Tank,Clarifier,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	TNKCNC	3	T-04T11	4/29/2002	50	15.01	34.99178082	$100,000	Mechanical							
43	T-04V01 Valve,Drain,Coagulation,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	VLVDSC	3	T-04V01	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
44	T-04V02 Valve,Drain,Maturation,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	VLVDSC	3	T-04V02	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
77	T-04V03 Valve,Drain,Coagulation,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	VLVDSC	3	T-04V03	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
78	T-04V04 Valve,Drain,Maturation,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	VLVDSC	3	T-04V04	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
45	T-04V05 Valve,Inlet,36 in.,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	VLVBTF	3	T-04V05	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
79	T-04V06 Valve,Inlet,36 in.,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	VLVBTF	3	T-04V06	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
46	T-04VFD03 VFD,Mixer,Maturation,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	VFDALL	3	T-04VFD03	4/29/2002	25	15.01	9.991780822	$2,000	Electrical							
47	T-04VFD04 VFD,Sludge Clarifier,Actiflo 1	PTP01SED00STL01	Train #1 Actiflo System	VFDALL	3	T-04VFD04	4/29/2002	25	15.01	9.991780822	$2,000	Electrical							
80	T-04VFD10 VFD,Mixer,Maturation,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	VFDALL	3	T-04VFD10	4/29/2002	25	15.01	9.991780822	$2,000	Electrical							
81	T-04VFD11 VFD,Sludge Clarifier,Actiflo 2	PTP01SED00STL02	Train #2 Actiflo System	VFDALL	3	T-04VFD11	4/29/2002	25	15.00821918	9.991780822	$2,000	Electrical							
312	T-05AIT003 Analyzer,Dewpoint,Supplem. Nitrogen	PTP01DSF00CMA00	Ozone Generation System	MNTGAC	3	T-05AIT003	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
313	T-05AIT101 Analyzer,Ambient O3,Ozone Generator Room	PTP01DSF00CMA00	Ozone Generation System	MNTGAC	3	T-05AIT101	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
314	T-05AIT102 Analyzer,Ambient O2,Ozone Generator room	PTP01DSF00CMA00	Ozone Generation System	MNTGAC	3	T-05AIT102	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
300	T-05AIT201 Analyzer,Ozone,Residual,Position 1,C1	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT201	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
301	T-05AIT202 Analyzer,Ozone,Residual,Position 2,C1	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT202	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
302	T-05AIT203 Analyzer,Ozone,Residual,Position 3,C1	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT203	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
303	T-05AIT204 Analyzer,Ambient O2,Ozone Gallery,North	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT204	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
304	T-05AIT205 Analyzer,Ambient O3,Ozone Gallery,North	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT205	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
305	T-05AIT206 Analyzer,Ambient O2,Ozone Gallery,South	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT206	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
306	T-05AIT207 Analyzer,Ambient O3,Ozone Gallery,South	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT207	4/29/2002	15	15.00821918	-0.008219178	$3,500	Electrical							
308	T-05AIT211 Analyzer,Ozone,Residual,Position 1,C2	PTP01DSF00MNT02	Train #2 Ozone Monitoring System	MNTGAC	3	T-05AIT211	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
309	T-05AIT212 Analyzer,Ozone,Residual,Position 2,C2	PTP01DSF00MNT02	Train #2 Ozone Monitoring System	MNTGAC	3	T-05AIT212	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
310	T-05AIT213 Analyzer,Ozone,Residual,Position 3,C2	PTP01DSF00MNT02	Train #2 Ozone Monitoring System	MNTGAC	3	T-05AIT213	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
307	T-05AIT301 Analyzer,Ozone,Offgas,C1	PTP01DSF00MNT01	Train #1 Ozone Monitoring System	MNTGAC	3	T-05AIT301	4/29/2002	15	15.00821918	-0.008219178	$3,500	Electrical							
288	T-05AIT303 Analyzer,Ozone,Post Destruct Unit 1	PTP01DSF00FLT01	Train #1 Ozone Destruct System	MNTGAC	1	T-05AIT303	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
311	T-05AIT311 Analyzer,Ozone,Offgas,C2	PTP01DSF00MNT02	Train #2 Ozone Monitoring System	MNTGAC	3	T-05AIT311	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
294	T-05AIT313 Analyzer,Ozone,Post Destruct Unit 2	PTP01DSF00FLT02	Train #2 Ozone Destruct System	MNTGAC	1	T-05AIT313	4/29/2002	15	15.01	-0.008219178	$3,500	Electrical							
114	T-05F01 Fan,Exhaust, Ozone Gallery	PTP01BGR00BLD05	Bldg 05 -- Ozonation Building System	FANCNT	2	T-05F01	10/19/2005	20	11.53	8.468493151	$1,000	Mechanical							
315	T-05FIT001 Meter,Flow,Supp. Nitrogen	PTP01DSF00CMA00	Ozone Generation System	FMTTMS	3	T-05FIT001	4/29/2002	20	15.01	4.991780822	$5,000	Electrical							
316	T-05FIT101 Meter,Flow,Inlet,Ozone Generator 1	PTP01DSF00CMA00	Ozone Generation System	FMTTMS	3	T-05FIT101	4/29/2002	20	15.01	4.991780822	$5,000	Electrical							
317	T-05FIT103 Meter,Flow,Ozone	PTP01DSF00CMA00	Ozone Generation System	FMTTMS	3	T-05FIT103	4/29/2002	20	15.01	4.991780822	$5,000	Electrical							

WRWTP EQUIPMENT LIST

ASSET ID	ASSET DESCRIPTION	HIERARCHY	HIERARCHY SYSTEM NAME	ASSET TYPE	CRITICALITY	ASSET ALIAS	IN SERVICE DATE	USEFUL LIFE	YEARS IN SERVICE	REMAINING LIFE	REPLACEMENT VALUE	Asset Group	Capacity	Capacity 2	Horsepower	Near-term Expansion Horsepower	Long-Term Expansion Horsepower	Comments	Resiliency/Redundancy
333	T-05MOV01 Valve,Isolation,Evaporator 1	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV01	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
334	T-05MOV02 Valve,Isolation,Evaporator 2	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV02	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
335	T-05MOV03 Valve,Control,Air Feed,SN	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV03	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
336	T-05MOV04 Valve,Inlet,Ozone Generator 1	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV04	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
337	T-05MOV05 Valve,Outlet,Ozone Generator 1	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV05	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
338	T-05MOV06 Valve,Control,Air Inlet,SN	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV06	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
339	T-05MOV08 Valve,Isolation,Utility Water 1	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV08	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
340	T-05MOV10 Valve,Inlet,Ozone Generator 2	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV10	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
341	T-05MOV11 Valve,Outlet,Ozone Generator 2	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV11	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
342	T-05MOV13 Valve,Isolation,Utility Water 2	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05MOV13	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
343	T-05PIT003 Press. Ind. Trans,GOX Feed	PTP01DSF00CMA00	Ozone Generation System	MNTPRS	3	T-05PIT003	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
344	T-05PIT101 Press. Ind. Trans.,Generator 1 inlet,GOX	PTP01DSF00CMA00	Ozone Generation System	MNTPRS	3	T-05PIT101	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
345	T-05PIT103 Press.Ind.Trans,Ozone,Out,Generator 1&2	PTP01DSF00CMA00	Ozone Generation System	MNTPRS	3	T-05PIT103	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
346	T-05PIT106 Press. Ind. Trans,Water,In,Generator 1	PTP01DSF00CMA00	Ozone Generation System	MNTPRS	3	T-05PIT106	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
347	T-05PIT111 Press. Ind. Trans.,Generator 2 inlet,GOX	PTP01DSF00CMA00	Ozone Generation System	MNTPRS	3	T-05PIT111	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
348	T-05PIT116 Press. Ind. Trans,Water,In,Generator 2	PTP01DSF00CMA00	Ozone Generation System	MNTPRS	3	T-05PIT116	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
293	T-05PIT301 Press.Ind.Trans,Inlet,Destruct 1	PTP01DSF00FLT01	Train #1 Ozone Destruct System	MNTPRS	1	T-05PIT301	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
299	T-05PIT311 Press.Ind.Trans,Inlet,Destruct 2	PTP01DSF00FLT02	Train #2 Ozone Destruct System	MNTPRS	1	T-05PIT311	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
349	T-05SOV01 Valve,Drain,Utility Water,PSU 1	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05SOV01	4/29/2002	15	15.01	-0.008219178	$100	Mechanical							
350	T-05SOV02 Valve,Drain,Utility Water,PSU 2	PTP01DSF00CMA00	Ozone Generation System	VLVBAL	3	T-05SOV02	4/29/2002	15	15.01	-0.008219178	$100	Mechanical							
351	T-05T01 Tank,LOX Storage	PTP01DSF00CMA00	Ozone Generation System	TNKPRS	3	T-05T01	4/29/2002	30	15.01	14.99178082	$40,000	Mechanical							
352	T-05T02 Tank, Nitrogen Boost	PTP01DSF00CMA00	Ozone Generation System	TNKPRS	3	T-05T02	4/29/2002	38	15.01	22.99178082	$1,000	Infrastructure							
787	T-05T03 Contact Basin, Ozone, 1 Diffuser piping	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T03	4/29/2002	50	15.00821918	34.99178082	$90,000	Infrastructure							
785	T-05T03 Contact Basin, Ozone, 1 Diffusers	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T03	4/29/2002	30	15.00821918	14.99178082	$20,000	Mechanical							
361	T-05T03 Contact Basin, Ozone, 1	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T03	4/29/2002	50	15.01	34.99178082	$15,000	Infrastructure							
790	T-05T03 Contact Basin 1, Hatch covers	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T03	4/29/2002	50	15.00821918	34.99178082	$7,000	Infrastructure							
788	T-05T04 Contact Basin, Ozone, 2 Diffuser piping	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T04	4/29/2002	50	15.00821918	34.99178082	$90,000	Infrastructure							
786	T-05T04 Contact Basin, Ozone, 2 Diffusers	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T04	4/29/2002	30	15.00821918	14.99178082	$20,000	Mechanical							
362	T-05T04 Contact Basin, Ozone, 2	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T04	4/29/2002	50	15.01	34.99178082	$15,000	Infrastructure							
789	T-05T04 Contact Basin 2, Hatch Covers	PTP01DSF00RTK00	Ozone Contact Structure System	STCCNC	2	T-05T04	4/29/2002	50	15.00821918	34.99178082	$7,000	Infrastructure							
353	T-05TE001 Temperature Element,GOX	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE001	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
354	T-05TE101 Temp. Element,Ozone Generator 1 inlet	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE101	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
355	T-05TE102 Temp.,Ozone Outlet,Generator 1	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE102	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
356	T-05TE103 Temp.,Ozone Outlet,Generator 1&2	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE103	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
357	T-05TE105 Temp.,Water Outlet,Generator 1	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE105	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
358	T-05TE111 Temp. Element,Ozone Generator 2 inlet	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE111	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
359	T-05TE112 Temp.,Ozone Outlet,Generator 2	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE112	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
360	T-05TE115 Temp.,Water Outlet,Generator 2	PTP01DSF00CMA00	Ozone Generation System	MNTTMP	3	T-05TE115	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
420	T-06AIT001 Analyzer,Turbidity,Combined Filter Eff.	PTP01FLT00RTK00	Filter Structure Channels & Control System	MNTTRB	5	T-06AIT001	4/29/2002	17	15.00821918	1.991780822	$2,500	Electrical							
376	T-06AIT011 Analyzer,Particle Count,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	MNTLQC	2	T-06AIT011	4/29/2002	18	15.01	2.991780822	$4,500	Electrical							
377	T-06AIT012 Analyzer,Turbidity,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	MNTTRB	2	T-06AIT012	4/29/2002	17	15.01	1.991780822	$2,500	Electrical							
387	T-06AIT021 Analyzer,Particle Count,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	MNTLQC	2	T-06AIT021	4/29/2002	18	15.01	2.991780822	$4,500	Electrical							
388	T-06AIT022 Analyzer,Turbidity,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	MNTTRB	2	T-06AIT022	4/29/2002	17	15.01	1.991780822	$2,500	Electrical							
398	T-06AIT031 Analyzer,Particle Count,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	MNTLQC	2	T-06AIT031	4/29/2002	18	15.01	2.991780822	$4,500	Electrical							
399	T-06AIT032 Analyzer,Turbidity,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	MNTTRB	2	T-06AIT032	4/29/2002	17	15.01	1.991780822	$2,500	Electrical							
409	T-06AIT041 Analyzer,Particle Count,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	MNTLQC	2	T-06AIT041	4/29/2002	18	15.00821918	2.991780822	$4,500	Electrical							
410	T-06AIT042 Analyzer,Turbidity,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	MNTTRB	2	T-06AIT042	1/25/2002	17	15.26575342	1.734246575	$2,500	Electrical							
421	T-06AIT208 Analyzer,pH/Temp,Settled Water	PTP01FLT00RTK00	Filter Structure Channels & Control System	MNTLQC	5	T-06AIT208	4/29/2002	17	15.00821918	1.991780822	$2,000	Electrical							
422	T-06AIT209 Analyzer,ORP,Settled Water	PTP01FLT00RTK00	Filter Structure Channels & Control System	MNTLQC	5	T-06AIT209	4/29/2002	17	15.00821918	1.991780822	$2,000	Electrical							
423	T-06AIT210 Analyzer,Ozone,Residual,Settled Water	PTP01FLT00RTK00	Filter Structure Channels & Control System	MNTGAC	5	T-06AIT210	4/29/2002	15	15.00821918	-0.008219178	$3,500	Electrical							
372	T-06ARV01 Valve, Air Release, Back Wash line	PTP01FLT00BWS00	Backwash Water Distribution & Control System	VLVPSI	2	T-06ARV01	4/29/2002	25	15.01	9.991780822	$750	Mechanical							
363	T-06CV03 Valve,Check,Blower, Air Scour 1	PTP01FLT00AER00	Filter Air Scour & Blower System	VLVPLG	1	T-06CV03	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
364	T-06CV04 Valve,Check,Blower, Air Scour 2	PTP01FLT00AER00	Filter Air Scour & Blower System	VLVPLG	1	T-06CV04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
547	T-06DP2 Panel,Distribution,Filter Gallery	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	CPLGEN	5	T-06DP2	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
117	T-06F01 Fan,Exhaust, Filter Gallery	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	FANCNT	2	T-06F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
118	T-06F03 Fan,Exhaust, Filter Blower Room South	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	FANCNT	2	T-06F03	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
119	T-06F04 Fan,Exhaust, Filter Blower Room North	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	FANCNT	2	T-06F04	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
424	T-06FCW01 Weir,Filter Control	PTP01FLT00RTK00	Filter Structure Channels & Control System	FMTFLM	5	T-06FCW01	4/29/2002	33	15.01	17.99178082	$25,000	Electrical							
378	T-06FILT01 Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	FLTLQD	2	T-06FILT01	4/29/2002	30	15.01	14.99178082	$62,500	Mechanical							
389	T-06FILT02 Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	FLTLQD	2	T-06FILT02	4/29/2002	30	15.01	14.99178082	$62,500	Mechanical							
400	T-06FILT03 Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	FLTLQD	2	T-06FILT03	4/29/2002	30	15.01	14.99178082	$62,500	Mechanical							
411	T-06FILT04 Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	FLTLQD	2	T-06FILT04	4/29/2002	30	15.00821918	14.99178082	$62,500	Mechanical							
373	T-06FIT001 Meter,Flow,Filter to Waste	PTP01FLT00DRN00	Filter to Waste System	FMTMAG	2	T-06FIT001	4/29/2002	28	15.01	12.99178082	$18,000	Mechanical							
365	T-06FIT002 Meter,Flow,Air Scour	PTP01FLT00AER00	Filter Air Scour & Blower System	FMTTMS	1	T-06FIT002	4/29/2002	20	15.01	4.991780822	$5,000	Electrical							
120	T-06H01 Heater,East,Filter Gallery	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	HVCGEN	2	T-06H01	10/14/2005	15	11.55	3.454794521	$1,000	Mechanical							
121	T-06H02 Heater,West,Filter Gallery	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	HVCGEN	2	T-06H02	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
122	T-06HVAC01 HVAC System,Filter Deck Control Room	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	HVCGEN	2	T-06HVAC01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
123	T-06L01 Louver,Intake,Filter Gallery	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	HVCGEN	2	T-06L01	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
124	T-06L02 Louver,Intake,Filter Blower Room South	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	HVCGEN	2	T-06L02	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
125	T-06L03 Louver,Intake,Filter Blower Room North	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	HVCGEN	2	T-06L03	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
379	T-06LIT011 Indicator,Level,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	MNTLVL	2	T-06LIT011	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
390	T-06LIT021 Indicator,Level Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	MNTLVL	2	T-06LIT021	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
401	T-06LIT031 Indicator,Level,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	MNTLVL	2	T-06LIT031	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
412	T-06LIT041 Indicator,Level,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	MNTLVL	2	T-06LIT041	4/29/2002	15	15.00821918	-0.008219178	$2,500	Electrical							
548	T-06MCC-A MCC, Filter Gallery	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	MCCACE	5	T-06MCC-A	4/29/2002	40	15.01	24.99178082	$25,000	Electrical							
366	T-06ME01 Blower,Air Scour 1	PTP01FLT00AER00	Filter Air Scour & Blower System	BLWLBE	1	T-06ME01	4/29/2002	25	15.01	9.991780822	$60,000	Mechanical	1750 acfm		100				
811	T-06ME01 - 75 HP MOTOR Blower,Air Scour 1	PTP01FLT00AER00	Filter Air Scour & Blower System	BLWLBE	1	T-06ME01	4/29/2002	25	15.00821918	9.991780822		Mechanical			75				
367	T-06ME02 Blower,Air Scour 2	PTP01FLT00AER00	Filter Air Scour & Blower System	BLWLBE	1	T-06ME02	4/29/2002	25	15.01	9.991780822	$60,000	Mechanical	1750 acfm		100				
812	T-06ME02 - 75 HP MOTOR Blower,Air Scour 2	PTP01FLT00AER00	Filter Air Scour & Blower System	BLWLBE	1	T-06ME02	4/29/2002	25	15.00821918	9.991780822		Mechanical			75				
126	T-06ME12 Lift,Wheelchair - FIlter Gallery State of Oregon Elevator# WCL14788-OP	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	ELVALL	2	T-06ME12	4/29/2002	35	15.01	19.99178082	$20,000	Infrastructure			1.4				
380	T-06MOV01 Valve,Inlet,20 in.,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	VLVBTF	2	T-06MOV01	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
381	T-06MOV02 Valve,Discharge,20 in.Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	VLVBTF	2	T-06MOV02	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
382	T-06MOV03 Valve,Isolat.,Backwash,24 in.,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	VLVBTF	2	T-06MOV03	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
383	T-06MOV04 Valve,Waste Washwater,30 in,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	VLVBTF	2	T-06MOV04	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
384	T-06MOV05 Valve,Control,Air Scour,10 in.,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	VLVBTF	2	T-06MOV05	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
391	T-06MOV07 Valve,Inlet,20 in.,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	VLVBTF	2	T-06MOV07	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
392	T-06MOV08 Valve,Discharge,20 in.,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	VLVBTF	2	T-06MOV08	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
393	T-06MOV09 Valve,Isolat.,Backwash,24 in.,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	VLVBTF	2	T-06MOV09	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
394	T-06MOV10 Valve,Waste Washwater,30 in.,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	VLVBTF	2	T-06MOV10	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
395	T-06MOV11 Valve,Control,Air Scour,10 in.,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	VLVBTF	2	T-06MOV11	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
402	T-06MOV13 Valve,Inlet,20 in.,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	VLVBTF	2	T-06MOV13	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
403	T-06MOV14 Valve,Discharge,20 in.,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	VLVBTF	2	T-06MOV14	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
404	T-06MOV15 Valve,Isolat.,Backwash,24 in.,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	VLVBTF	2	T-06MOV15	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
405	T-06MOV16 Valve,Waste Washwater,30 in,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	VLVBTF	2	T-06MOV16	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
406	T-06MOV17 Valve,Control,Air Scour,10 in.,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	VLVBTF	2	T-06MOV17	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
413	T-06MOV19 Valve,Inlet,20 in.,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	VLVBTF	2	T-06MOV19	4/29/2002	33	15.00821918	17.99178082	$10,000	Mechanical							
414	T-06MOV20 Valve,Discharge,20 in.,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	VLVBTF	2	T-06MOV20	4/29/2002	33	15.00821918	17.99178082	$10,000	Mechanical							

WRWTP EQUIPMENT LIST

ASSET ID	ASSET DESCRIPTION	HIERARCHY	HIERARCHY SYSTEM NAME	ASSET TYPE	CRITICALITY	ASSET ALIAS	IN SERVICE DATE	USEFUL LIFE	YEARS IN SERVICE	REMAINING LIFE	REPLACEMENT VALUE	Asset Group	Capacity	Capacity 2	Horsepower	Near-term Expansion Horsepower	Long-Term Expansion Horsepower	Comments	Resiliency/Redundancy
415	T-06MOV21 Valve,Isolat.,Backwash,24 in.,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	VLVBTF	2	T-06MOV21	4/29/2002	33	15.00821918	17.99178082	$10,000	Mechanical							
416	T-06MOV22 Valve,Waste Washwater,30 in,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	VLVBTF	2	T-06MOV22	4/29/2002	33	15.01	17.99178082	$25,000	Mechanical							
417	T-06MOV23 Valve,Control,Air Scour,10 in.,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	VLVBTF	2	T-06MOV23	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
374	T-06MOV25 Valve, Modulating,Filter to Waste	PTP01FLT00DRN00	Filter to Waste System	VLVBTF	2	T-06MOV25	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
425	T-06P03 Pump,Sample,Comb. Filter Effluent	PTP01FLT00TSP00	Combined Filter Effluent System	PMPDPH	2	T-06P03	4/29/2002	15	15.01	-0.008219178	$2,500	Mechanical							
385	T-06PDIT011 Indicator,Pressure,Differential,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	MNTPRS	2	T-06PDIT011	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
396	T-06PDIT021 Indicator,Pressure,Differential,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	MNTPRS	2	T-06PDIT021	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
407	T-06PDIT031 Indicator,Pressure,Differential,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	MNTPRS	2	T-06PDIT031	4/29/2002	15	15.00821918	-0.008219178	$2,000	Electrical							
418	T-06PDIT041 Indicator,Pressure,Differential,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	MNTPRS	2	T-06PDIT041	4/29/2002	15	15.00821918	-0.008219178	$2,000	Electrical							
386	T-06V01 Valve,Drain,6 in.,Filter 1	PTP01FLT00FLT01	Filter #1 Media and Control System	VLVBTF	2	T-06V01	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
397	T-06V02 Valve,Drain,6 in.,Filter 2	PTP01FLT00FLT02	Filter #2 Media and Control System	VLVBTF	2	T-06V02	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
408	T-06V03 Valve,Drain,6 in.,Filter 3	PTP01FLT00FLT03	Filter #3 Media and Control System	VLVBTF	2	T-06V03	4/29/2002	33	15.00821918	17.99178082	$1,000	Mechanical							
419	T-06V04 Valve,Drain,6 in.,Filter 4	PTP01FLT00FLT04	Filter #4 Media and Control System	VLVBTF	2	T-06V04	4/29/2002	33	15.00821918	17.99178082	$1,000	Mechanical							
370	T-06V07 Valve,Isolation,Blower,12 in,Air Scour 1	PTP01FLT00AER00	Filter Air Scour & Blower System	VLVBTF	1	T-06V07	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
371	T-06V08 Valve,Isolation,Blower,12in,Air Scour 2	PTP01FLT00AER00	Filter Air Scour & Blower System	VLVBTF	1	T-06V08	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
426	T-07AIT001 Analyzer,pH/Temp,Comb. Filter Effluent	PTP01FLT00TSP00	Combined Filter Effluent System	MNTLQC	2	T-07AIT001	4/29/2002	17	15.01	1.991780822	$2,000	Electrical							
427	T-07AIT002 Analyzer,Resid.,Chlorine,Comb. Filter Effluent	PTP01FLT00TSP00	Combined Filter Effluent System	MNTLQC	2	T-07AIT002	4/29/2002	17	15.01	1.991780822	$2,500	Electrical							
458	T-07CV01 Valve,Check,Backwash Pump 1	PTP01PEF00PMP02	Backwash Pumping System	VLVPLG	1	T-07CV01	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
459	T-07CV02 Valve,Check,Backwash Pump 2	PTP01PEF00PMP02	Backwash Pumping System	VLVPLG	1	T-07CV02	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
130	T-07F01 Fan,Exhaust, H.S. Electrical Room S.	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	FANCNT	2	T-07F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
131	T-07F02 Fan,Exhaust, H.S. Electrical Room N.	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	FANCNT	2	T-07F02	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
375	T-07FIT001 Meter,Flow,Backwash	PTP01FLT00BWS00	Backwash Water Distribution & Control System	FMTMAG	2	T-07FIT001	4/29/2002	28	15.01	12.99178082	$18,000	Mechanical							
428	T-07FSL003 Switch,Low Flow,Sample Pump,Comb. Filter Effluent	PTP01FLT00TSP00	Combined Filter Effluent System	MNTLVL	2	T-07FSL003	4/29/2002	29	15.01	13.99178082	$100	Electrical							
132	T-07H01 Heater,Backwash Pump Area	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	2	T-07H01	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
133	T-07L01 Louver,Backwash Pump Area,small	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	2	T-07L01	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
134	T-07L05 Louver,Backwash Pump Area,large	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	2	T-07L05	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
429	T-07LSL001 Switch,Low Level,Clearwell	PTP01PEF00PMP01	High Service Pumping System	MNTLVL	5	T-07LSL001	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
460	T-07MOV01 Valve,Control,20 in.,Backwash Pump 1	PTP01PEF00PMP02	Backwash Pumping System	VLVBTF	1	T-07MOV01	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
461	T-07MOV02 Valve,Control,20 in.,Backwash Pump 2	PTP01PEF00PMP02	Backwash Pumping System	VLVBTF	1	T-07MOV02	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
462	T-07P01 Pump,Backwash Supply 1	PTP01PEF00PMP02	Backwash Pumping System	PMPCNT	1	T-07P01	4/29/2002	30	15.01	14.99178082	$300,000	Mechanical	9200 gpm	50 ft TDH	150			Constant Speed	
463	T-07P02 Pump,Backwash Supply 2	PTP01PEF00PMP02	Backwash Pumping System	PMPCNT	1	T-07P02	4/29/2002	30	15.01	14.99178082	$300,000	Mechanical	9200 gpm	50 ft TDH	150			Constant Speed	
468	T-07P03 Pump,Sample,Clearwell	PTP01PEF00TSP00	Finished Water Distribution & Control System	PMPDPH	5	T-07P03	4/29/2002	15	15.00821918	-0.008219178	$3,000	Mechanical							
466	T-07PSH001 Switch,High Pressure,Backwash Pump 1	PTP01PEF00PMP02	Backwash Pumping System	MNTPRS	1	T-07PSH001	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
467	T-07PSH002 Switch,High Pressure,Backwash Pump 2	PTP01PEF00PMP02	Backwash Pumping System	MNTPRS	1	T-07PSH002	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
599	T-08ARV01 Valve,Air Release,Pump.Waste Washwater 1	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVPSI	3	T-08ARV01	4/19/2007	25	10.03287671	14.96712329	$750	Mechanical							
600	T-08ARV02 Valve,Air Release,Pump.Waste Washwater 2	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVPSI	3	T-08ARV02	4/29/2002	25	15.01	9.991780822	$750	Mechanical							
601	T-08ARV03 Valve,Air Release,Pump.Waste Washwater 3	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVPSI	3	T-08ARV03	4/29/2002	25	15.00821918	9.991780822	$750	Mechanical							
602	T-08ARV04 Valve,Air Release, WW Discharge line	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVPSI	3	T-08ARV04	4/29/2002	25	15.00821918	9.991780822	$750	Mechanical							
603	T-08BAS01 Basin, Wash Water	PTP01SLL00PMP01	Washwater Equalization Pumping System	STCCNC	3	T-08BAS01	4/29/2002	50	15.00821918	34.99178082	$30,000	Infrastructure							
604	T-08CV01 Valve,Check,6 in.,Waste Washwater Pump 1	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVPLG	3	T-08CV01	4/29/2002	33	15.00821918	17.99178082	$1,000	Mechanical							
605	T-08CV02 Valve,Check,6 in.,Waste Washwater Pump 2	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVPLG	3	T-08CV02	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
606	T-08CV03 Valve,Check,6 in.,Waste Washwater Pump 3	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVPLG	3	T-08CV03	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
127	T-08F01 Fan,Exhaust,WW Building	PTP01BGR00BLD08	Bldg 08 -- Waste Washwater Building System	FANCNT	2	T-08F01	7/6/2007	20	9.82	10.18082192	$1,000	Mechanical							
607	T-08FIT001 Meter,Flow,Recovery,Waste Washwater	PTP01SLL00PMP01	Washwater Equalization Pumping System	FMTMAG	3	T-08FIT001	6/26/2007	25	9.85	15.15342466	$10,000	Electrical							
128	T-08H01 Heater,Unit,WW Building	PTP01BGR00BLD08	Bldg 08 -- Waste Washwater Building System	HVCGEN	2	T-08H01	4/29/2002	15	15.01	-0.008219178	$3,000	Mechanical							
129	T-08L01 Louver,Intake,WW Building	PTP01BGR00BLD08	Bldg 08 -- Waste Washwater Building System	HVCGEN	2	T-08L01	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
608	T-08LIT001 Indicator,Level,Waste Washwater Basin	PTP01SLL00PMP01	Washwater Equalization Pumping System	MNTLVL	3	T-08LIT001	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
549	T-08MCC-A MCC, Wash Water Recovery.	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	MCCACE	5	T-08MCC-A	4/29/2002	40	15.01	24.99178082	$12,500	Electrical							
609	T-08P01 Pump,Waste Washwater 1	PTP01SLL00PMP01	Washwater Equalization Pumping System	PMPCNT	3	T-08P01	6/26/2007	15	9.85	5.153424658	$25,000	Mechanical	500 gpm	26 ft TDH	5				
610	T-08P02 Pump,Waste Washwater 2	PTP01SLL00PMP01	Washwater Equalization Pumping System	PMPCNT	3	T-08P02	4/29/2002	15	15.01	-0.008219178	$25,000	Mechanical	500 gpm	26 ft TDH	5				
611	T-08P03 Pump,Waste Washwater 3	PTP01SLL00PMP01	Washwater Equalization Pumping System	PMPCNT	3	T-08P03	4/29/2002	15	15.01	-0.008219178	$25,000	Mechanical	500 gpm	26 ft TDH	5				
615	T-08PSH001 Switch,High Pressure, W.Washwater Pump 1	PTP01SLL00PMP01	Washwater Equalization Pumping System	MNTPRS	3	T-08PSH001	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
616	T-08PSH002 Switch,High Pressure, W.Washwater Pump 2	PTP01SLL00PMP01	Washwater Equalization Pumping System	MNTPRS	3	T-08PSH002	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
617	T-08PSH003 Switch,High Pressure, W.Washwater Pump 3	PTP01SLL00PMP01	Washwater Equalization Pumping System	MNTPRS	3	T-08PSH003	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
618	T-08V01 Valve,Isolat.,6 in.,W. Washwater Pump 1	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVBTF	3	T-08V01	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
619	T-08V02 Valve,Isolat.,6 in.,W. Washwater Pump 2	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVBTF	3	T-08V02	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
620	T-08V03 Valve,Isolat.,6 in.,W. Washwater Pump 3	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVBTF	3	T-08V03	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
621	T-08V04 Valve,Recovery,12 in,Waste Washwater	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVBTF	3	T-08V04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
622	T-08V05 Valve,Drain,8 in.,Waste Washwater Basin	PTP01SLL00PMP01	Washwater Equalization Pumping System	VLVBTF	3	T-08V05	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
135	T-09BLDG01 Building, High Service Pump Station	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	BLDCNC	2	T-09BLDG01	4/29/2002	50	15.01	34.99178082	$30,000	Infrastructure							
136	T-09BLDG02 Electrical Room, High Service P.S.	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	BLDCNC	2	T-09BLDG02	4/29/2002	50	15.01	34.99178082	$10,000	Infrastructure							
430	T-09CV01 Valve,Check,14 in.,H.S.Pump 1	PTP01PEF00PMP01	High Service Pumping System	VLVPLG	5	T-09CV01	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
431	T-09CV02 Valve,Check,14 in.,H.S.Pump 2	PTP01PEF00PMP01	High Service Pumping System	VLVPLG	5	T-09CV02	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
432	T-09CV03 Valve,Check,14 in.,H.S.Pump 1	PTP01PEF00PMP01	High Service Pumping System	VLVPLG	5	T-09CV03	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
433	T-09CV04 Valve,Check,12 in.,H.S.Pump 4	PTP01PEF00PMP01	High Service Pumping System	VLVPLG	5	T-09CV04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
137	T-09F01 Fan,Exhaust, HS Pump Room S. Small	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	FANCNT	2	T-09F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
138	T-09F02 Fan,Exhaust, HS Pump Room N. Large	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	FANCNT	2	T-09F02	4/29/2002	20	15.01	4.991780822	$2,000	Mechanical							
139	T-09H01 Heater,HS Pump Station W	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	2	T-09H01	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
140	T-09H02 Heater,HS Pump Station E	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	2	T-09H02	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
141	T-09L01 Louver,Intake,HS Pump Station 1	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	2	T-09L01	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
142	T-09L02 Louver,Intake,HS Pump Station 2	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	2	T-09L02	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
469	T-09LIT001 Indicator,Level,Clearwell	PTP01PEF00TSP00	Finished Water Distribution & Control System	MNTLVL	5	T-09LIT001	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
143	T-09ME01 Crane, 10 Ton Overhead, HS Pump Room	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HSTOVR	2	T-09ME01	4/29/2002	40	15.01	24.99178082	$25,000	Mechanical			12			(equipment schedule says 10/0.5/0.75)	
434	T-09MOV01 Valve,Discharge,14 in.,H.S.Pump 1	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09MOV01	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
435	T-09MOV02 Valve,Discharge,14 in.,H.S.Pump 2	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09MOV02	4/29/2002	33	15.00821918	17.99178082	$5,000	Mechanical							
436	T-09MOV03 Valve,Discharge,14 in.,H.S.Pump 3	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09MOV03	4/29/2002	33	15.00821918	17.99178082	$5,000	Mechanical							
437	T-09MOV04 Valve,Discharge,12 in.,H.S.Pump 4	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09MOV04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
438	T-09P01 Pump,High Service 1	PTP01PEF00PMP01	High Service Pumping System	PMPCNT	5	T-09P01	4/29/2002	35	15.01	19.99178082	$550,000	Mechanical	5200 gpm	312 ft TDH	500			Variable Speed	
439	T-09P02 Pump,High Service 2	PTP01PEF00PMP01	High Service Pumping System	PMPCNT	5	T-09P02	4/29/2002	35	15.01	19.99178082	$550,000	Mechanical	5200 gpm	312 ft TDH	500			Variable Speed	
440	T-09P03 Pump,High Service 3	PTP01PEF00PMP01	High Service Pumping System	PMPCNT	5	T-09P03	4/29/2002	35	15.01	19.99178082	$550,000	Mechanical	5200 gpm	312 ft TDH	500			Variable Speed, Standby	
441	T-09P04 Pump,High Service 4	PTP01PEF00PMP01	High Service Pumping System	PMPCNT	5	T-09P04	4/29/2002	33	15.01	17.99178082	$400,000	Mechanical	2800 gpm	312 ft TDH	300			Variable Speed	
470	T-09PIT001 Transmitter,Pressure,Finished Water Pipe	PTP01PEF00TSP00	Finished Water Distribution & Control System	MNTPRS	5	T-09PIT001	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
446	T-09PSH001 Switch,High Pressure,HS Pump 1	PTP01PEF00PMP01	High Service Pumping System	MNTPRS	5	T-09PSH001	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
447	T-09PSH002 Switch,High Pressure,HS Pump 2	PTP01PEF00PMP01	High Service Pumping System	MNTPRS	5	T-09PSH002	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
448	T-09PSH003 Switch,High Pressure,HS Pump 3	PTP01PEF00PMP01	High Service Pumping System	MNTPRS	5	T-09PSH003	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
449	T-09PSH004 Switch,High Pressure,HS Pump 4	PTP01PEF00PMP01	High Service Pumping System	MNTPRS	5	T-09PSH004	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
450	T-09V01 Valve,Isolation,14 in.,HS Pump 1	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09V01	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
451	T-09V02 Valve,Isolation,14 in.,HS Pump 2	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09V02	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
452	T-09V03 Valve,Isolation,14 in.,HS Pump 3	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09V03	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
453	T-09V04 Valve,Isolation,12 in.,HSPump 4	PTP01PEF00PMP01	High Service Pumping System	VLVBTF	5	T-09V04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
471	T-09V05 Valve,Drain,8 in.,Finished Water Pipe	PTP01PEF00TSP00	Finished Water Distribution & Control System	VLVBTF	5	T-09V05	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
454	T-09VFD01 VFD,High Service Pump 1	PTP01PEF00PMP01	High Service Pumping System	VFDALL	5	T-09VFD01	4/29/2002	25	15.01	9.991780822	$120,000	Electrical							
455	T-09VFD02 VFD,High Service Pump 2	PTP01PEF00PMP01	High Service Pumping System	VFDALL	5	T-09VFD02	4/29/2002	25	15.01	9.991780822	$120,000	Electrical							
456	T-09VFD03 - Soft Start Controller,High Service Pump 3	PTP01PEF00PMP01	High Service Pumping System	CNSECT	5	T-09VFD03	4/29/2002	25	15.01	9.991780822	$30,000	Electrical							
457	T-09VFD04 VFD,High Service Pump 4	PTP01PEF00PMP01	High Service Pumping System	VFDALL	5	T-09VFD04	4/29/2002	25	15.01	9.991780822	$30,000	Electrical							
472	T-10AIT001 Analyzer,Turbidity,Finished Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	MNTTRB	5	T-10AIT001	4/29/2002	17	15.01	1.991780822	$2,500	Electrical							
474	T-10AIT003 Analyzer,pH/Temp.,Finished Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	MNTLQC	5	T-10AIT003	4/29/2002	17	15.01	1.991780822	$2,000	Electrical							
475	T-10AIT004 Analyzer,Resid. Chlorine,Finished Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	MNTLQC	5	T-10AIT004	4/29/2002	17	15.01	1.991780822	$2,500	Electrical							

WRWTP EQUIPMENT LIST

ASSET ID	ASSET DESCRIPTION	HIERARCHY	HIERARCHY SYSTEM NAME	ASSET TYPE	CRITICALITY	ASSET ALIAS	IN SERVICE DATE	USEFUL LIFE	YEARS IN SERVICE	REMAINING LIFE	REPLACEMENT VALUE	Asset Group	Capacity	Capacity 2	Horsepower	Near-term Expansion Horsepower	Long-Term Expansion Horsepower	Comments	Resiliency/Redundancy
476	T-10FIT001 Meter,Flow,Finished Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	FMTMAG	5	T-10FIT001	4/29/2002	28	15.01	12.99178082	$18,000	Mechanical							
477	T-10FIT002 Meter,Flow,Magnetic,Utility Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	FMTMAG	5	T-10FIT002	4/29/2002	25	15.01	9.991780822	$10,000	Electrical							
478	T-10FIT003 Meter,Flow,Magnetic,Potable Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	FMTMAG	5	T-10FIT003	4/29/2002	25	15.01	9.991780822	$4,000	Electrical							
479	T-10ME05 Preventer,Backflow,Utility Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	BFPALL	5	T-10ME05	4/29/2002	25	15.01	9.991780822	$3,000	Mechanical							
480	T-10ME06 Preventer,backflow,Potable Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	BFPALL	5	T-10ME06	4/29/2002	25	15.01	9.991780822	$8,000	Mechanical							
481	T-10MOV01 Valve,Isolation,Finished Water Flow Mete	PTP01PEF00TSP00	Finished Water Distribution & Control System	VLVBTF	5	T-10MOV01	4/29/2002	33	15.01	17.99178082	$10,000	Mechanical							
482	T-10PIPE01 Pipeline,Discharge,HSPS	PTP01PEF00TSP00	Finished Water Distribution & Control System	PPGDST	5	T-10PIPE01	4/29/2002	45	15.01	29.99178082	$22,500	Infrastructure							
483	T-10V01 Valve,Pressure Reducing,Utility Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	VLVPSI	5	T-10V01	4/29/2002	35	15.01	19.99178082	$20,000	Mechanical							
484	T-10V02 Valve,Isolation,10 in.,Utility Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	VLVBTF	5	T-10V02	4/29/2002	33	15.00821918	17.99178082	$2,000	Mechanical							
485	T-10V03 Valve,Pressure Reducing,Potable Water	PTP01PEF00TSP00	Finished Water Distribution & Control System	VLVPSI	5	T-10V03	4/29/2002	33	15.01	17.99178082	$6,500	Mechanical							
486	T-10V04 Valve,Isolation,4 in.,Potable water	PTP01PEF00TSP00	Finished Water Distribution & Control System	VLVBTF	5	T-10V04	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
144	T-11F01 Fan,Exhaust, Thickener Pump Room	PTP01BGR00BLD11	Bldg 11 -- Sludge Thickening Building System	FANCNT	2	T-11F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
583	T-11FIT001 Meter,Flow,Thickened Sludge	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	FMTMAG	2	T-11FIT001	4/29/2002	25	15.01	9.991780822	$4,000	Electrical							
145	T-11H01 Heater,Thickener Pump Room	PTP01BGR00BLD11	Bldg 11 -- Sludge Thickening Building System	HVCGEN	2	T-11H01	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
146	T-11L01 Louver,Exhaust,Thickener Pump Room	PTP01BGR00BLD11	Bldg 11 -- Sludge Thickening Building System	HVCGEN	2	T-11L01	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
578	T-11LCP01 Panel,Local Control,Thickener PS	PTP01SLL00STL00	Sludge Thickener System	CPLGEN	3	T-11LCP01	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
584	T-11LIT01 Indicator,Level,TS Storage Tank	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	MNTLVL	2	T-11LIT01	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
579	T-11ME01 Drive,Thickener	PTP01SLL00STL00	Sludge Thickener System	DRVGBX	3	T-11ME01	4/29/2002	40	15.01	24.99178082	$140,000	Mechanical							
585	T-11MOV01 Valve,Control,Thickened Sludge,10 in.	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	VLVPLG	2	T-11MOV01	4/29/2002	33	15.00821918	17.99178082	$2,000	Mechanical							
586	T-11P01 Pump,Thickened Sludge 1	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	PMPPRC	2	T-11P01	4/29/2002	25	15.00821918	9.991780822	$25,000	Mechanical	60 gpm	70 ft TDH	5				
587	T-11P02 Pump,Thickened Sludge 2	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	PMPPRC	2	T-11P02	4/29/2002	25	15.01	9.991780822	$25,000	Mechanical	60 gpm	70 ft TDH	5				
588	T-11P03 Pump,Mixing,Thickened Sludge	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	PMPCNT	2	T-11P03	4/29/2002	15	15.01	-0.008219178	$15,000	Mechanical							
592	T-11PSH011 Switch,High Pressure,TS Pump 1	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	MNTPRS	2	T-11PSH011	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
593	T-11PSH012 Switch,High Pressure,TS Pump 2	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	MNTPRS	2	T-11PSH012	4/29/2002	15	15.01	-0.008219178	$2,000	Electrical							
594	T-11TANK02 Tank, Solids Storage Tank	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	TNKCNC	2	T-11TANK02	4/29/2002	38	15.00821918	22.99178082	$125,000	Infrastructure							
581	T-11THK01 Tank,Sludge Thickener	PTP01SLL00STL00	Sludge Thickener System	TNKCNC	3	T-11THK01	4/29/2002	38	15.01	22.99178082	$125,000	Infrastructure							
582	T-11V01 Valve,6 in.,Thickener Inlet	PTP01SLL00STL00	Sludge Thickener System	VLVPLG	3	T-11V01	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
595	T-11V02 Valve,Isolation,8 in.,TS Mixing Pump	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	VLVPLG	2	T-11V02	4/29/2002	33	15.00821918	17.99178082	$1,000	Mechanical							
596	T-11V03 Valve,Isolation,8 in.,TS Mixing Pump	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	VLVPLG	2	T-11V03	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
597	T-11VFD01 VFD,Thickened Sludge Transfer Pump 1	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	VFDALL	2	T-11VFD01	4/29/2002	25	15.00821918	9.991780822	$2,000	Electrical							
598	T-11VFD02 VFD,Thickened Sludge Transfer Pump 2	PTP01SLL00TSP02	Thickened Sludge Storage & Pumping System	VFDALL	2	T-11VFD02	4/29/2002	25	15.00821918	9.991780822	$2,000	Electrical							
147	T-12F01 Fan,Exhaust, Dewatering Building,North	PTP01BGR00BLD12	Bldg 12 -- Sludge Dewatering Building System	FANCNT	2	T-12F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
148	T-12F02 Fan,Exhaust, Dewatering Building,East	PTP01BGR00BLD12	Bldg 12 -- Sludge Dewatering Building System	FANCNT	2	T-12F02	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
557	T-12G01 Valve,Gate,Solids Diverter 1	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVDSC	1	T-12G01	4/29/2002	42	15.01	26.99178082	$7,500	Mechanical							
558	T-12G02 Valve,Gate,Solids Diverter 2	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVDSC	1	T-12G02	4/29/2002	42	15.01	26.99178082	$7,500	Mechanical							
149	T-12H01 Heater,Dewatering Building W.	PTP01BGR00BLD12	Bldg 12 -- Sludge Dewatering Building System	HVCGEN	2	T-12H01	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
150	T-12H02 Heater,Dewatering Building E.	PTP01BGR00BLD12	Bldg 12 -- Sludge Dewatering Building System	HVCGEN	2	T-12H02	4/29/2002	15	15.01	-0.008219178	$1,000	Mechanical							
151	T-12L01 Louver,Exhaust,Dewatering Building,small	PTP01BGR00BLD12	Bldg 12 -- Sludge Dewatering Building System	HVCGEN	2	T-12L01	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
152	T-12L02 Louver,Exhaust,Dewatering Building,large	PTP01BGR00BLD12	Bldg 12 -- Sludge Dewatering Building System	HVCGEN	2	T-12L02	4/29/2002	25	15.01	9.991780822	$500	Mechanical							
559	T-12LCP01 Panel,Local Control,Centrifuge 1, & PLC	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	CPLGEN	1	T-12LCP01	4/29/2002	25	15.01	9.991780822	$15,000	Electrical							
560	T-12LCP02 Panel,Local Control,Centrifuge 2, & PLC	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	CPLGEN	1	T-12LCP02	4/29/2002	25	15.01	9.991780822	$15,000	Electrical							
561	T-12LCP03 Panel,Local Control,Sludge Conveyor	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	CPLGEN	1	T-12LCP03	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
562	T-12ME01 Centrifuge,Dewatering 1	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	CNTHSL	1	T-12ME01	4/29/2002	25	15.01	9.991780822	$700,000	Mechanical	750 lb/hr	60 gpm	40			Mechanical Schedule says 15/40	Yes
563	T-12ME02 Centrifuge,Dewatering 2	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	CNTHSL	1	T-12ME02	4/29/2002	25	15.01	9.991780822	$700,000	Mechanical	750 lb/hr	60 gpm	40			Mechanical Schedule says 15/40	Yes
564	T-12ME03 Conveyor,Screw,Dewatered Sludge	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	CNVSCR	1	T-12ME03	4/29/2002	20	15.01	4.991780822	$30,000	Mechanical			3				
153	T-12ME04 Crane, 3 Ton Overhead, Centrifuge	PTP01BGR00BLD12	Bldg 12 -- Sludge Dewatering Building System	HSTOVR	2	T-12ME04	4/29/2002	30	15.01	14.99178082	$5,000	Mechanical			4				
570	T-12SOV Valve,Solenoid,Flushwater,Centrifuge 2	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVFLW	1	T-12SOV	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
571	T-12SOV01 Valve,Solenoid,Flushwater,Centrifuge 1	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVFLW	1	T-12SOV01	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
572	T-12SOV03 Valve,Solenoid,Flushwater,Dis. Chute 1	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVFLW	1	T-12SOV03	4/29/2002	33	15.00821918	17.99178082	$2,000	Mechanical							
573	T-12SOV04 Valve,Solenoid,Flushwater,Dis. Chute 2	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVFLW	1	T-12SOV04	4/29/2002	33	15.01	17.99178082	$2,000	Mechanical							
574	T-12V01 Valve,Isolation,Centrifuge 1	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVBAL	1	T-12V01	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
575	T-12V02 Valve,Isolation,Centrifuge 2	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VLVBAL	1	T-12V02	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
576	T-12VFD01 VFD,Centrifuge 1	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VFDALL	1	T-12VFD01	4/29/2002	18	15.01	2.991780822		Electrical							
577	T-12VFD02 VFD,Centrifuge 2	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	VFDALL	1	T-12VFD02	4/29/2002	18	15.01	2.991780822		Electrical							
657	T-13BFP01 Backflow Preventer,Fire Sprinkler System	PTP01SPS00MNT00	Fire and Security Monitoring System	BFPALL	3	T-13BFP01	4/29/2002	25	15.01	9.991780822	$1,500	Mechanical							
154	T-13BLDG01 Building,Chemical Storage	PTP01BGR00BLD13	Bldg 13 -- Chemical Storage and Metering Building	BLDCNC	2	T-13BLDG01	4/29/2002	50	15.01	34.99178082	$80,000	Infrastructure							
191	T-13BPV01a Valve, Backpressure,Chem. Room, CS 1	PTP01CHM00CHF01	Caustic Soda Feed System	VLVPSI	5	T-13BPV01a	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
192	T-13BPV01b Valve, Backpressure,CI Vault, CS 1	PTP01CHM00CHF01	Caustic Soda Feed System	VLVPSI	5	T-13BPV01b	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
193	T-13BPV03a Valve, Backpressure,Chem. Room, CS 2	PTP01CHM00CHF01	Caustic Soda Feed System	VLVPSI	5	T-13BPV03a	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
194	T-13BPV03b Valve, Backpressure,CFE, CS 2	PTP01CHM00CHF01	Caustic Soda Feed System	VLVPSI	5	T-13BPV03b	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
209	T-13BPV04a Valve, Backpressure,Chem. Room, SHC 1	PTP01CHM00CHF02	Sodium Hypochlorite System	VLVPSI	5	T-13BPV04a	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
210	T-13BPV04b Valve, Backpressure,CI Vault, SHC 1	PTP01CHM00CHF02	Sodium Hypochlorite System	VLVPSI	5	T-13BPV04b	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
211	T-13BPV05a Valve, Backpressure, Chem. Room,SHC 2	PTP01CHM00CHF02	Sodium Hypochlorite System	VLVPSI	5	T-13BPV05a	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
212	T-13BPV05b Valve, Backpressure,CFE, SHC 2	PTP01CHM00CHF02	Sodium Hypochlorite System	VLVPSI	5	T-13BPV05b	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
229	T-13BPV06a Valve, Backpressure,Chem. Room, Alum 1	PTP01CHM00CHF03	Liquid Alum System	VLVPSI	5	T-13BPV06a	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
230	T-13BPV06b Valve, Backpressure,I.M. Vault, Alum 1	PTP01CHM00CHF03	Liquid Alum System	VLVPSI	5	T-13BPV06b	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
231	T-13BPV07 Valve, Backpressure, Alum 2	PTP01CHM00CHF03	Liquid Alum System	VLVPSI	5	T-13BPV07	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
251	T-13BPV13a Valve, Backpressure, Aqueous Ammonia 1	PTP01CHM00CHF06	Aqua Ammonia Feed System	VLVPSI	1	T-13BPV13a	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
252	T-13BPV14a Valve, Backpressure, Aqueous Ammonia 2	PTP01CHM00CHF06	Aqua Ammonia Feed System	VLVPSI	1	T-13BPV14a	4/29/2002	33	15.00821918	17.99178082	$1,000	Mechanical							
262	T-13BPV19a Valve, Backpressure,Chem. Room, CTS	PTP01CHM00CHF08	Calcium Thiosulfate Feed System	VLVPSI	3	T-13BPV19a	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
263	T-13BPV19b Valve, Backpressure,Settled Water,CTS	PTP01CHM00CHF08	Calcium Thiosulfate Feed System	VLVPSI	3	T-13BPV19b	4/29/2002	33	15.01	17.99178082	$1,000	Mechanical							
155	T-13F01 Fan,Exhaust, Chemical Building North	PTP01BGR00BLD13	Bldg 13 -- Chemical Storage and Metering Building	FANCNT	2	T-13F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
156	T-13F02 Fan,Exhaust, Chemical Building South	PTP01BGR00BLD13	Bldg 13 -- Chemical Storage and Metering Building	FANCNT	2	T-13F02	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
195	T-13FD01 Pump, Chem Feed,Caustic Soda 1	PTP01CHM00CHF01	Caustic Soda Feed System	PMPDPH	5	T-13FD01	4/29/2002	14	15.01	-1.008219178	$3,750	Mechanical							
196	T-13FD03 Pump, Chem Feed, Caustic Soda 3	PTP01CHM00CHF01	Caustic Soda Feed System	PMPDPH	5	T-13FD03	4/29/2002	14	15.01	-1.008219178	$3,750	Mechanical							
213	T-13FD04 Pump, Chem Feed, Sodium Hypochlorite 1	PTP01CHM00CHF02	Sodium Hypochlorite System	PMPDPH	5	T-13FD04	4/29/2002	14	15.01	-1.008219178	$2,500	Mechanical							
214	T-13FD05 Pump, Chem Feed,Sodium Hypochlorite 2	PTP01CHM00CHF02	Sodium Hypochlorite System	PMPDPH	5	T-13FD05	4/29/2002	14	15.01	-1.008219178	$2,500	Mechanical							
232	T-13FD06 Pump, Chem Feed, Alum	PTP01CHM00CHF03	Liquid Alum System	PMPDPH	5	T-13FD06	4/29/2002	14	15.01	-1.008219178	$3,750	Mechanical							
233	T-13FD07 Pump, Chem Feed, Alum	PTP01CHM00CHF03	Liquid Alum System	PMPDPH	5	T-13FD07	4/29/2002	14	15.01	-1.008219178	$3,750	Mechanical							
241	T-13FD08 Pump, Chem Feed, Cat. poly	PTP01CHM00CHF04	Cationic Polymer Feed System	PMPDPH	3	T-13FD08	4/29/2002	14	15.01	-1.008219178	$2,500	Mechanical							
242	T-13FD09 Pump, Chem Feed, Cat. poly	PTP01CHM00CHF04	Cationic Polymer Feed System	PMPDPH	3	T-13FD09	4/29/2002	14	15.01	-1.008219178	$2,500	Mechanical							
243	T-13FD10 Pump, Chem Feed, Cat. poly	PTP01CHM00CHF04	Cationic Polymer Feed System	PMPDPH	3	T-13FD10	4/29/2002	14	15.01	-1.008219178	$2,500	Mechanical							
249	T-13FD11 Pump, Chem Feed, Anionic Poly,West	PTP01CHM00CHF05	Anionic Polymer Feed System	PMPDPH	3	T-13FD11	4/29/2002	15	15.01	-0.008219178	$2,500	Mechanical							
250	T-13FD12 Pump, Chem Feed, Anionic Poly,East	PTP01CHM00CHF05	Anionic Polymer Feed System	PMPDPH	3	T-13FD12	4/29/2002	15	15.01	-0.008219178	$2,500	Mechanical							
253	T-13FD13 Pump, Chem Feed, Aqueous Ammonia 1	PTP01CHM00CHF06	Aqua Ammonia Feed System	PMPDPH	1	T-13FD13	4/29/2002	16	15.00821918	0.991780822	$2,000	Mechanical							
254	T-13FD14 Pump, Chem Feed, Aqueous Ammonia 2	PTP01CHM00CHF06	Aqua Ammonia Feed System	PMPDPH	1	T-13FD14	4/29/2002	16	15.00821918	0.991780822	$2,000	Mechanical							
258	T-13FD17 Pump, Chem Feed, Phosphate, West	PTP01CHM00CHF07	Spare Chemical Feed System	PMPDPH	1	T-13FD17	4/29/2002	16	15.01	0.991780822	$2,000	Mechanical							
259	T-13FD18 Pump, Chem Feed, Phosphate, East	PTP01CHM00CHF07	Spare Chemical Feed System	PMPDPH	1	T-13FD18	4/29/2002	16	15.01	0.991780822	$2,000	Mechanical							
264	T-13FD19 Pump, Chem Feed, Calcium Thiosulfate 1	PTP01CHM00CHF08	Calcium Thiosulfate Feed System	PMPDPH	3	T-13FD19	4/29/2002	16	15.01	0.991780822	$2,000	Mechanical							
265	T-13FD20 Pump, Chem Feed, Calcium Thiosulfate 2	PTP01CHM00CHF08	Calcium Thiosulfate Feed System	PMPDPH	3	T-13FD20	4/29/2002	16	15.01	0.991780822	$2,000	Mechanical							
268	T-13FD21 Pump, Chem Feed, Filter Aid Polymer 1	PTP01CHM00CHF09	Filter Aid Polymer Feed System	PMPDPH	1	T-13FD21	4/29/2002	15	15.01	-0.008219178	$2,500	Mechanical							
269	T-13FD22 Pump, Chem Feed, Filter Aid Polymer 2	PTP01CHM00CHF09	Filter Aid Polymer Feed System	PMPDPH	1	T-13FD22	4/29/2002	15	15.00821918	-0.008219178	$2,500	Mechanical							
199	T-13FDSPARE01, SPARE Chem Feed,Caustic or Alum Pump	PTP01CHM00CHF01	Caustic Soda Feed System	PMPDPH	5	T-13FDspare01	4/29/2002	15	15.01	-0.008219178	$2,500	Mechanical							
200	T-13FE011 Rotameter,Carrier Water,Caustic Soda 1	PTP01CHM00CHF01	Caustic Soda Feed System	FMTRTR	5	T-13FE011	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
201	T-13FE012 Rotameter,Carrier Water,Caustic Soda 3	PTP01CHM00CHF01	Caustic Soda Feed System	FMTRTR	5	T-13FE012	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
217	T-13FE021 Rotameter,Carrier Water,SHC 1	PTP01CHM00CHF02	Sodium Hypochlorite System	FMTRTR	5	T-13FE021	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
218	T-13FE022 Rotameter,Carrier Water,SHC 2	PTP01CHM00CHF02	Sodium Hypochlorite System	FMTRTR	5	T-13FE022	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
219	T-13FE024 Rotameter,SHC Feed,Irrigation Feature	PTP01CHM00CHF02	Sodium Hypochlorite System	FMTRTR	5	T-13FE024	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							

WRWTP EQUIPMENT LIST

ASSET ID	ASSET DESCRIPTION	HIERARCHY	HIERARCHY SYSTEM NAME	ASSET TYPE	CRITICALITY	ASSET ALIAS	IN SERVICE DATE	USEFUL LIFE	YEARS IN SERVICE	REMAINING LIFE	REPLACEMENT VALUE	Asset Group	Capacity	Capacity 2	Horsepower	Near-term Expansion Horsepower	Long-Term Expansion Horsepower	Comments	Resiliency/Redundancy
202	T-13LCP01 LCP,Chemical Feed,Caustic Soda	PTP01CHM00CHF01	Caustic Soda Feed System	CPLGEN	5	T-13LCP01	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
793	T-13LCP-04 Polyelectrolyte Dry Polymer	PTP01CHM00CHF02	Sodium Hypochlorite System	CPLGEN	5	T-13LCP02	4/29/2002	30	15.00821918	14.99178082	$15,000	Infrastructure							
220	T-13LCP02 LCP,Chemical Feed,SHC	PTP01CHM00CHF02	Sodium Hypochlorite System	CPLGEN	5	T-13LCP02	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
236	T-13LCP03 LCP,Chemical Feed,Liquid Alum	PTP01CHM00CHF03	Liquid Alum System	CPLGEN	5	T-13LCP03	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
203	T-13LCP20 LCP,Truck Loading Station	PTP01CHM00CHF01	Caustic Soda Feed System	CPLGEN	5	T-13LCP20	4/29/2002	25	15.00821918	9.991780822	$5,000	Electrical							
204	T-13LIT001 Indicator,Level,Caustic Soda	PTP01CHM00CHF01	Caustic Soda Feed System	MNTLVL	5	T-13LIT001	4/29/2002	15	15.00821918	-0.008219178	$2,500	Electrical							
221	T-13LIT002 Indicator,Level,SHC Tank 1	PTP01CHM00CHF02	Sodium Hypochlorite System	MNTLVL	5	T-13LIT002	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
222	T-13LIT003 Indicator,Level,SHC Tank 2	PTP01CHM00CHF02	Sodium Hypochlorite System	MNTLVL	5	T-13LIT003	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
237	T-13LIT004 Indicator,Level,Alum Tank 4	PTP01CHM00CHF03	Liquid Alum System	MNTLVL	5	T-13LIT004	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
238	T-13LIT005 Indicator,Level,AlumTank 5	PTP01CHM00CHF03	Liquid Alum System	MNTLVL	5	T-13LIT005	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
257	T-13LIT008 Indicator,Level,AA	PTP01CHM00CHF06	Aqua Ammonia Feed System	MNTLVL	1	T-13LIT008	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
223	T-13LIT009 Indicator,Level, Drain SHC Tank	PTP01CHM00CHF02	Sodium Hypochlorite System	MNTLVL	5	T-13LIT009	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
157	T-13MAU01 Make-Up Air, Rooftop, Chemical Building	PTP01BGR00BLD13	Bldg 13 -- Chemical Storage and Metering Building	FANCNT	2	T-13MAU01	4/29/2002	25	15.01	9.991780822	$5,000	Mechanical							
247	T-13ME01 Dry polymer batching system	PTP01CHM00CHF04	Cationic Polymer Feed System	FDRLQD	3	T-13ME01	4/29/2002	25	15.01	9.991780822	$50,000	Mechanical							
158	T-13ME02 Door,Overhead Rollup,Chemical Building	PTP01BGR00BLD13	Bldg 13 -- Chemical Storage and Metering Building	BLDCNC	2	T-13ME02	4/29/2002	30	15.01	14.99178082	$3,000	Infrastructure							
205	T-13MOV01 Valve,Tank Fill,Caustic Soda	PTP01CHM00CHF01	Caustic Soda Feed System	VLVBAL	5	T-13MOV01	4/29/2002	33	15.00821918	17.99178082	$875	Mechanical							
224	T-13MOV02 Valve,Tank Fill,Sodium Hypochlorite 1	PTP01CHM00CHF02	Sodium Hypochlorite System	VLVBAL	5	T-13MOV02	4/29/2002	33	15.01	17.99178082	$875	Mechanical							
225	T-13MOV03 Valve,Tank Fill,Sodium Hypochlorite 2	PTP01CHM00CHF02	Sodium Hypochlorite System	VLVBAL	5	T-13MOV03	4/29/2002	33	15.01	17.99178082	$875	Mechanical							
159	T-13Safety01 Safety Shower/Eye Wash Station, Inside	PTP01BGR00BLD13	Bldg 13 -- Chemical Storage and Metering Building	SFTFXD	2	T-13Safety01	4/29/2002	25	15.01	9.991780822	$2,000	Infrastructure							
160	T-13Safety02 Safety Shower/Eye Wash Station, Outside	PTP01BGR00BLD13	Bldg 13 -- Chemical Storage and Metering Building	SFTFXD	2	T-13Safety02	4/29/2002	25	15.01	9.991780822	$2,000	Infrastructure							
206	T-13SOV01 Valve,Control,Carrier Water,CS 1	PTP01CHM00CHF01	Caustic Soda Feed System	VLVFLW	5	T-13SOV01	4/29/2002	33	15.01	17.99178082	$875	Mechanical							
207	T-13SOV02 Valve,Control,Carrier Water,CS 3	PTP01CHM00CHF01	Caustic Soda Feed System	VLVFLW	5	T-13SOV02	4/29/2002	33	15.00821918	17.99178082	$875	Mechanical							
208	T-13T01 Tank,Caustic Soda	PTP01CHM00CHF01	Caustic Soda Feed System	TNKHDP	5	T-13T01	4/29/2002	20	15.01	4.991780822	$15,000	Infrastructure							
226	T-13T02 Tank,Sodium Hypochlorite 1	PTP01CHM00CHF02	Sodium Hypochlorite System	TNKHDP	5	T-13T02	9/1/2010	20	6.66	13.33972603	$15,000	Infrastructure							
227	T-13T03 Tank,Sodium Hypochlorite 2	PTP01CHM00CHF02	Sodium Hypochlorite System	TNKHDP	5	T-13T03	4/29/2002	20	15.01	4.991780822	$15,000	Infrastructure							
239	T-13T04 Tank,Liquid Alum 4	PTP01CHM00CHF03	Liquid Alum System	TNKHDP	5	T-13T04	4/29/2002	20	15.01	4.991780822	$15,000	Infrastructure							
240	T-13T05 Tank,Liquid Alum 5	PTP01CHM00CHF03	Liquid Alum System	TNKHDP	5	T-13T05	4/29/2002	20	15.01	4.991780822	$15,000	Infrastructure							
228	T-13T09 Tank,Waste Holding,Sodium Hypochlorite	PTP01CHM00CHF02	Sodium Hypochlorite System	TNKHDP	5	T-13T09	4/29/2002	20	15.01	4.991780822	$500	Infrastructure							
550	T-15MCC-A MCC, HSPS	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	MCCACE	5	T-15MCC-A	4/29/2002	40	15.01	24.99178082	$75,000	Electrical							
551	T-15SWBD-B SWBD, HSPS, Emerg. Power	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	CPLGEN	5	T-15SWBD-B	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
161	T-16F01 Fan,Exhaust, Emerg. Gen Building E.	PTP01BGR00BLD16	Bldg 16 -- Standby Power Building System	FANCNT	2	T-16F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
162	T-16F02 Fan,Exhaust, Emerg. Gen Building W.	PTP01BGR00BLD16	Bldg 16 -- Standby Power Building System	FANCNT	2	T-16F02	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
554	T-16ME01 Generator,Standby Caterpillar 3508 1000 KW Standby Diesel Engine Generator Set M/N SR4B	PTP01PWR00GNR00	Emergency Power System	GENDSL	5	T-16ME01	4/29/2002	33	15.01	17.99178082	$58,500	Electrical	1000 kW						
555	T-16TANK01 Tank, Storage, Diesel Fuel	PTP01PWR00GNR00	Emergency Power System	TNKSTL	5	T-16TANK01	4/29/2002	42	15.01	26.99178082	$7,500	Infrastructure							
553	T-17MVSWT001 Switchgear,Medium Voltage 12.5 kV	PTP01PWR00ELE02	Medium Voltage MCC and Wiring System	MCCACE	5	T-17MVSWT001	4/29/2002	40	15.00821918	24.99178082	$300,000	Electrical							
556	T-17SUBST001 Substation, 12.5 kV	PTP01PWR00TNS00	12.5 KVA Service and Substation System	MCCACE	5	T-17SUBST001	4/29/2002	40	15.01	24.99178082	$200,000	Electrical							
163	T-18BLDG01 Building,Administration	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	BLDCNC	2	T-18BLDG01	4/29/2002	50	15.01	34.99178082	$50,000	Infrastructure							
552	T-18DPLAB Electrical - Distrib. Panel, Elect. Room	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	CPLGEN	5	T-18DPLAB	4/29/2002	25	15.01	9.991780822	$5,000	Electrical							
164	T-18F-03 Exhaust Fan, Admin. Building	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	FANCNT	2	T-18F-03	4/29/2002	20	15.00821918	4.991780822	$1,000	Mechanical							
165	T-18F-04 Exhaust Fan, Hood, Laboratory	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	FANCNT	2	T-18F-04	4/29/2002	20	15.00821918	4.991780822	$2,000	Mechanical							
166	T-18F-05 Exhaust Fan, Hood, Laboratory, Backup	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	FANCNT	2	T-18F-05	4/29/2002	20	15.01	4.991780822	$2,000	Mechanical							
658	T-18FACP01 Fire Alarm System	PTP01SPS00MNT00	Fire and Security Monitoring System	SECFIR	3	T-18FACP01	4/29/2002	15	15.01	-0.008219178	$10,000	Infrastructure							
659	T-18FASS01 Sprinkler System, Fire Alarm	PTP01SPS00MNT00	Fire and Security Monitoring System	SECFIR	3	T-18FASS01	4/29/2002	15	15.01	-0.008219178	$10,000	Infrastructure							
167	T-18Fume01 West Lab Fume Hood	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	LABFXD	2	T-18Fume01	4/29/2002	30	15.01	14.99178082	$3,000	Infrastructure							
168	T-18Fume02 East Lab Fume Hood	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	LABFXD	2	T-18Fume02	4/29/2002	30	15.01	14.99178082	$3,000	Infrastructure							
169	T-18HVAC01 HVAC Unit #1, Rooftop,Admin, Confer.Rm	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	HVCGEN	2	T-18HVAC01	4/29/2002	25	15.01	9.991780822	$20,000	Mechanical							
170	T-18HVAC02 HVAC Unit #2, Rooftop,Admin, Control Rm	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	HVCGEN	2	T-18HVAC02	4/29/2002	25	15.01	9.991780822	$20,000	Mechanical							
171	T-18HVAC03 HVAC Unit #3, Rooftop,Admin, Lab	PTP01BGR00BLD18	Bldg 18 -- Administration Building System	HVCGEN	2	T-18HVAC03	4/29/2002	25	15.01	9.991780822	$15,000	Mechanical							
639	T-18LAB02 Deionized Water System, Ozone Gen Room	PTP01SPS00LAB00	Laboratory Equipment System	BLDCNC	1	T-18LAB02	4/29/2002	38	15.00821918	22.99178082	$1,000	Infrastructure							
640	T-18LAB03 PH Meter, Orion Benchtop	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB03	2/6/2014	8	3.224657534	4.775342466	$1,500	Infrastructure							
641	T-18LAB04 Turbidimeter, Hach 2100 N, Benchtop	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB04	4/29/2002	20	15.00821918	4.991780822	$3,000	Infrastructure							
642	T-18LAB05 Spectrophotometer, Hach	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB05	4/29/2002	20	15.01	4.991780822	$3,000	Infrastructure							
643	T-18LAB06 Incubator, Precision	PTP01SPS00LAB00	Laboratory Equipment System	LABFXD	1	T-18LAB06	4/29/2002	25	15.00821918	9.991780822	$1,500	Infrastructure							
644	T-18LAB07 Oven, Precision	PTP01SPS00LAB00	Laboratory Equipment System	LABFXD	1	T-18LAB07	4/29/2002	17	15.00821918	1.991780822	$600	Infrastructure							
645	T-18LAB08 Conductivity meter, VWR Benchtop	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB08	4/29/2002	20	15.00821918	4.991780822	$3,000	Infrastructure							
646	T-18LAB08-A Conductivity meter, Hach Sension7	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB08-A	5/1/2009	20	7.997260274	12.00273973	$3,000	Infrastructure							
647	T-18LAB09 Autoclave, Harvey SterileMax	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB09	4/29/2002	20	15.00821918	4.991780822	$2,500	Infrastructure							
648	T-18LAB10 Balance, Ohaus	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB10	4/29/2002	29	15.00821918	13.99178082	$2,000	Infrastructure							
649	T-18LAB11 Balance, Sartorious	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB11	4/29/2002	29	15.00821918	13.99178082	$2,000	Infrastructure							
650	T-18LAB12 PH Meter, Portable	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB12	2/6/2014	20	3.224657534	16.77534247	$3,000	Infrastructure							
651	T-18LAB13 Ozone Pocket Colorimeter	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB13	4/29/2002	20	15.00821918	4.991780822	$3,000	Infrastructure							
652	T-18LAB14 Cl2 Pocket Colorimeter	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB14	4/29/2002	20	15.00821918	4.991780822	$3,000	Infrastructure							
653	T-18LAB15 Lab Refrigerator	PTP01SPS00LAB00	Laboratory Equipment System	APLPRT	1	T-18LAB15	4/29/2002	23	15.00821918	7.991780822	$800	Infrastructure							
654	T-18LAB16 Ozone Pocket Colorimeter DR/850	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB16	4/29/2002	20	15.00821918	4.991780822	$3,000	Infrastructure							
655	T-18LAB17 Traceable Thermometer, portable	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB17	4/29/2002	20	15.01	4.991780822	$3,000	Infrastructure							
656	T-18LAB18 Refrigerator Thermometer	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1	T-18LAB18	4/29/2002	20	15.01	4.991780822	$3,000	Infrastructure							
623	T-18PHON01 Telephone System	PTP01SPS00CMM00	Telephone/Intercom/Paging System	CMMTEL	1	T-18PHON01	4/29/2002	15	15.01	-0.008219178	$2,500	Electrical							
660	T-18SECUR01 Security Monitoring System	PTP01SPS00MNT00	Fire and Security Monitoring System	SECALM	3	T-18SECUR01	4/29/2002	15	15.01	-0.008219178	$10,000	Infrastructure							
172	T-19BLDG01 Building, Ozone Generator	PTP01BGR00BLD19	Bldg 19 -- Ozone Generation Building System	BLDCNC	2	T-19BLDG01	4/29/2002	50	15.01	34.99178082	$40,000	Infrastructure							
173	T-19F01 Exhaust, Fan, Ozone Gen Building	PTP01BGR00BLD19	Bldg 19 -- Ozone Generation Building System	FANCNT	2	T-19F01	4/29/2002	20	15.01	4.991780822	$1,000	Mechanical							
174	T-19MAU01 Make-Up Air, Rooftop, Ozone Gen Building	PTP01BGR00BLD19	Bldg 19 -- Ozone Generation Building System	FANCNT	2	T-19MAU01	4/29/2002	25	15.01	9.991780822	$5,000	Mechanical							
543	T-19MCC-A MCC, Ozone Generation	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	MCCACE	5	T-19MCC-A	4/29/2002	40	15.01	24.99178082	$12,500	Electrical							
175	T-19ME01 Door,Overhead Rollup,Ozone Gen Building	PTP01BGR00BLD19	Bldg 19 -- Ozone Generation Building System	BLDCNC	2	T-19ME01	4/29/2002	30	15.01	14.99178082	$3,000	Infrastructure							
177	T-20P01-A Pump, Submersible, Sanitary Sewer	PTP01BGR00GRN00	Grounds System	PMPSUB	3	T-20P01-A	4/29/2002	15	15.01	-0.008219178	$5,000	Mechanical							
179	T-20P02-A Pump, Submersible, Sanitary Sewer	PTP01BGR00GRN00	Grounds System	PMPSUB	3	T-20P02-A	4/29/2002	15	15.01	-0.008219178	$5,000	Mechanical							
487	T-30FIT01 Meter, Wilsonville Road Turnout	PTP01PEF00TSP00	Finished Water Distribution & Control System	FMTMAG	5	T-30FIT01	4/29/2002	28	15.01	12.99178082	$18,000	Mechanical							
488	T-30FIT02 Meter, Brockway	PTP01PEF00TSP00	Finished Water Distribution & Control System	FMTRTR	5	T-30FIT02	4/29/2002	20	15.01	4.991780822	$1,000	Electrical							
180	T-30P01 Pump, Water Feature	PTP01BGR00GRN00	Grounds System	PMPSUB	3	T-30P01	4/29/2002	22	15.01	6.991780822	$50,000	Mechanical							
181	T-30P02 Pump #1,Waste,Irrigation	PTP01BGR00GRN00	Grounds System	PMPSUB	3	T-30P02	4/29/2002	20	15.01	4.991780822	$30,000	Mechanical							
182	T-30P03 Pump #2,Waste,Irrigation	PTP01BGR00GRN00	Grounds System	PMPSUB	3	T-30P03	4/29/2002	20	15.00821918	4.991780822	$30,000	Mechanical							
183	T-31UND001 Vaults, Underground	PTP01BGR00GRN00	Grounds System	STCCNC	3	T-31UND001	4/29/2002	50	15.00821918	34.99178082	$7,500	Infrastructure							
184	T-31YARD001 Indoor and Outdoor Lighting	PTP01BGR00GRN00	Grounds System	LGTGEN	3	T-31YARD001	4/29/2002	20	15.01	4.991780822	$5,000	Electrical							
185	T-31YARD002 Fire Hydrants	PTP01BGR00GRN00	Grounds System	VLVFRP	3	T-31YARD002	4/29/2002	33	15.01	17.99178082	$5,000	Mechanical							
186	T-31YARD003 Gate, Aluminum Handrailing	PTP01BGR00GRN00	Grounds System	SFTFXD	3	T-31YARD003	4/29/2002	25	15.01	9.991780822	$4,000	Infrastructure							
745	T-32YARD001 Company Truck	PTP01SPS00RSK00	Support Vehicles System	VEHGAS	1	T-32YARD001	4/29/2002	18	15.01	2.991780822	$25,000	Vehicle							
746	T-32YARD002 Mule Kawasaki 550	PTP01SPS00RSK00	Support Vehicles System	VEHGAS	1	T-32YARD002	4/29/2002	15	15.00821918	-0.008219178	$10,000	Vehicle							
747	T-32YARD003 Forklift Truck,Caterpillar	PTP01SPS00RSK00	Support Vehicles System	VEHGAS	1	T-32YARD003	4/29/2002	29	15.00821918	13.99178082	$60,000	Vehicle	1750 acfm						
187	T-32YARD004 Gate, Plant Access	PTP01BGR00GRN00	Grounds System	SECFEN	3	T-32YARD004	4/29/2002	25	15.01	9.991780822	$6,000	Infrastructure							
188	T-32YARD005 Gate, Park Access Bridge	PTP01BGR00GRN00	Grounds System	SECFEN	3	T-32YARD005	4/29/2002	25	15.01	9.991780822	$6,000	Infrastructure							
625	T-32YARD007 Irrigator, Portable Reel	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	HTLGEN	1	T-32YARD007	3/30/2004	15	13.08767123	1.912328767	$1,500	Infrastructure							
626	T-32YARD008 Pressure Washer, Portable	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	HTLGEN	1	T-32YARD008	6/1/2002	15	14.92	0.082191781	$1,000	Infrastructure							
661	T-32YARD009 Motion Sensor	PTP01SPS00MNT00	Fire and Security Monitoring System	SECALM	3	T-32YARD009	8/1/2002	15	14.75068493	0.249315068	$1,000	Infrastructure							
662	T-32YARD010 Wall Photo Beam, Actiflo	PTP01SPS00MNT00	Fire and Security Monitoring System	SECALM	3	T-32YARD010	4/29/2002	15	15.00821918	-0.008219178	$1,000	Infrastructure							
663	T-32YARD011 Wall Photo Beam, Wash Water	PTP01SPS00MNT00	Fire and Security Monitoring System	SECALM	3	T-32YARD011	4/29/2002	15	15.00821918	-0.008219178	$1,000	Infrastructure							
664	T-32YARD012 Wall Photo Beam, S. Filter #2	PTP01SPS00MNT00	Fire and Security Monitoring System	SECALM	3	T-32YARD012	4/29/2002	15	15.00821918	-0.008219178	$1,000	Infrastructure							
665	T-32YARD013 Wall Photo Beam, Filter Control Weir	PTP01SPS00MNT00	Fire and Security Monitoring System	SECALM	3	T-32YARD013	4/29/2002	15	15.01	-0.008219178	$1,000	Infrastructure							

WRWTP EQUIPMENT LIST

ASSET ID	ASSET DESCRIPTION	HIERARCHY	HIERARCHY SYSTEM NAME	ASSET TYPE	CRITICALITY	ASSET ALIAS	IN SERVICE DATE	USEFUL LIFE	YEARS IN SERVICE	REMAINING LIFE	REPLACEMENT VALUE	Asset Group	Capacity	Capacity 2	Horsepower	Near-term Expansion Horsepower	Long-Term Expansion Horsepower	Comments	Resiliency/Redundancy
666	T-32YARD014 Wall Photo Beam, Raw and H.S.	PTP01SPS00MNT00	Fire and Security Monitoring System	SECALM	3	T-32YARD014	4/29/2002	15	15.00821918	-0.008219178	$1,000	Infrastructure							
189	T-32YARD015 Signs, Safety and Warning	PTP01BGR00GRN00	Grounds System	SFTFXD	3	T-32YARD015	4/29/2002	15	15.01	-0.008219178	$10,000	Infrastructure							
629	T-33TOOLS01 Portable Air Compressor	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	HTLGEN	1	T-33TOOLS01	4/29/2002	15	15.01	-0.008219178	$1,500	Infrastructure							
748	T-33TOOLS02 Portable Retrieval Hoist	PTP01SPS00SAF00	Safety Equipment System	HSTPRT	3	T-33TOOLS02	4/29/2002	25	15.00821918	9.991780822	$5,000	Mechanical							
749	T-33TOOLS03 6 portable Motorola XPR6100 radios and chargers	PTP01SPS00SAF00	Safety Equipment System	CMMTEL	3	T-33TOOLS03	5/8/2009	20	7.978082192	12.02191781	$5,000	Electrical							
630	T-33TOOLS04 Detector,Gas,Portable	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	SFTFXD	1	T-33TOOLS04	4/29/2002	15	15.00821918	-0.008219178	$5,000	Infrastructure							
631	T-33TOOLS05 Grinder,Bench	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	HTLGEN	1	T-33TOOLS05	4/29/2002	20	15.00821918	4.991780822	$250	Infrastructure							
632	T-33TOOLS06 Vacuum, Wet/Dry	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	HTLGEN	1	T-33TOOLS06	4/29/2002	15	15.00821918	-0.008219178	$250	Infrastructure							
750	T-33TOOLS08 Fire Extinguishers	PTP01SPS00SAF00	Safety Equipment System	FREEXT	3	T-33TOOLS08	4/29/2002	20	15.00821918	4.991780822	$10,000	Infrastructure							
634	T-33TOOLS09 800 MHz Radio	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	CMMTEL	1	T-33TOOLS09	4/29/2002	20	15.00821918	4.991780822	$5,000	Electrical							
635	T-33TOOLS10 Ham Radio	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	CMMTEL	1	T-33TOOLS10	4/29/2002	20	15.00821918	4.991780822	$5,000	Electrical							
636	T-33TOOLS11 Portable Sump Pump	PTP01SPS00HTL00	Maintenance Hand/Shop Tools System	HTLGEN	1	T-33TOOLS11	4/29/2002	15	15.00821918	-0.008219178	$1,000	Infrastructure							
190	T-33YARD010 1.25 Acre Lawn Areas	PTP01BGR00GRN00	Grounds System	GRDALL	3	T-33YARD010	4/29/2002	50	15.01	34.99178082	$125,000	Infrastructure							
270	T-99FILTERPLCB PCM 5 PLC B	PTP01CST00CTR00	Industrial Programmable Logic Controller(PLC) System	PLCGEN	3	T-99FILTERPLCB	4/29/2002	15	15.01	-0.008219178	$15,000	Electrical							
271	T-99FILTERPLCC PCM 5 PLC C	PTP01CST00CTR00	Industrial Programmable Logic Controller(PLC) System	PLCGEN	3	T-99FILTERPLCC	4/29/2002	15	15.01	-0.008219178	$15,000	Electrical							
667	T-99Officeprinter Printer, Xerox, Phaser 7300	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99Officeprinter	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
282	T-99OI1 Work Station, Control Room,South,OI1	PTP01CST00SCA00	Industrial Control Workstation (SCADA) System	CMTWKS	5	T-99OI1	4/29/2002	7	15.01	-8.008219178	$1,500	Electrical							
283	T-99OI2 Work Station, Control Room, North,OI2	PTP01CST00SCA00	Industrial Control Workstation (SCADA) System	CMTWKS	5	T-99OI2	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
284	T-99OI3 Work Station, Lab, East,OI3	PTP01CST00SCA00	Industrial Control Workstation (SCADA) System	CMTWKS	5	T-99OI3	4/29/2002	7	15.01	-8.008219178	$1,500	Electrical							
274	T-99PCM01 PCM01,Admin Panel Rm 103A	PTP01CST00NET00	Industrial Control Network System	PLCGEN	5	T-99PCM01	4/29/2002	15	15.01	-0.008219178	$30,000	Electrical							
275	T-99PCM02 PCM02,Admin Electrical Room 106	PTP01CST00NET00	Industrial Control Network System	PLCGEN	5	T-99PCM02	4/3/2002	15	15.08	-0.079452055	$30,000	Electrical							
276	T-99PCM03 PCM03,Ozone Gallery	PTP01CST00NET00	Industrial Control Network System	PLCGEN	5	T-99PCM03	4/29/2002	15	15.01	-0.008219178	$15,000	Electrical							
277	T-99PCM04 PCM04,WW Recovery	PTP01CST00NET00	Industrial Control Network System	PLCGEN	5	T-99PCM04	4/29/2002	15	15.00821918	-0.008219178	$15,000	Electrical							
278	T-99PCM05 PCM05,Filter Gallery	PTP01CST00NET00	Industrial Control Network System	PLCGEN	5	T-99PCM05	4/29/2002	15	15.01	-0.008219178	$15,000	Electrical							
279	T-99PCM06 PCM06,High Service Elec Room	PTP01CST00NET00	Industrial Control Network System	PLCGEN	5	T-99PCM06	4/29/2002	15	15.01	-0.008219178	$15,000	Electrical							
285	T-99PCM3CLIENT Work Station,Ozone Gallery	PTP01CST00SCA00	Industrial Control Workstation (SCADA) System	CMTWKS	5	T-99PCM3CLIENT	4/29/2002	7	15.01	-8.008219178	$1,500	Electrical							
286	T-99PCM5CLIENT Work Station,Filter Control Bldg.	PTP01CST00SCA00	Industrial Control Workstation (SCADA) System	CMTWKS	5	T-99PCM5CLIENT	4/29/2002	7	15.01	-8.008219178	$1,500	Electrical							
287	T-99PCM6CLIENT Work Station,High Service Elec Room	PTP01CST00SCA00	Industrial Control Workstation (SCADA) System	CMTWKS	5	T-99PCM6CLIENT	4/29/2002	7	15.01	-8.008219178	$1,500	Electrical							
272	T-99PLCA PCM 1 PLC A	PTP01CST00CTR00	Industrial Programmable Logic Controller(PLC) System	PLCGEN	3	T-99PLCA	4/29/2002	15	15.01	-0.008219178	$15,000	Electrical							
273	T-99PLCA Backup PCM 1 PLC Back-up	PTP01CST00CTR00	Industrial Programmable Logic Controller(PLC) System	PLCGEN	3	T-99PLCA Backup	4/29/2002	15	15.01	-0.008219178	$15,000	Electrical							
280	T-99SCADAPRINTER Printer,Xerox,SCADA,Control Room	PTP01CST00NET00	Industrial Control Network System	CMTWKS	5	T-99SCADAPRINTER	4/29/2002	7	15.01	-8.008219178	$1,500	Electrical							
281	T-99SERVER Server for OI1 and OI2.	PTP01CST00NET00	Industrial Control Network System	CMTWKS	5	T-99SERVER	4/29/2002	7	15.01	-8.008219178	$1,500	Electrical							
668	T-99SERVER2 Office Server	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99SERVER2	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
669	T-99WTP1127 Control Room, Dell Computer (old)	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99WTP1127	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
670	T-99WTP1129 Admin. secretary, Dell Computer (old)	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99WTP1129	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
671	T-99WTP1130 Lab, Dell Computer (same, new Eq.#)	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99WTP1130	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
672	T-99WTPADM1 Admin. secretary, Computer	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99WTPADM1	10/15/2008	7	8.539726027	-1.539726027	$1,500	Electrical							
673	T-99WTPCR1 Control Room, Computer	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99WTPCR1	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
674	T-99WTPLAB1 Lab, S.W., Computer	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99WTPLAB1	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
675	T-99WTPLAB2 Lab, E. Island, Computer	PTP01SPS00NET00	Administrative Computing & Networking System	CMTWKS	1	T-99WTPLAB2	4/29/2002	7	15.00821918	-8.008219178	$1,500	Electrical							
777	T-09T01 Tank, Clearwell	PTP01PEF00PMP01	High Service Pumping System	TNKCNC	5		4/29/2002	50	15.00821918	34.99178082	$3,900,000	Infrastructure	2.9MG						
753	T-18PIPE01 Potable Water Piping System	PTP01PEF00TSP00	Finished Water Distribution & Control System	PPGAPP	1		4/29/2002	42	15.01	26.99178082	$250,000	Infrastructure							
771	T-17DISCONN-T1, Disconnect for T-1	PTP01PWR00TNS00	12.5 KVA Service and Substation System	MCCACE	5		4/29/2002	40	15.00821918	24.99178082	$200,000	Electrical							
772	T-17DISCONN-T2, Disconnect for T-2	PTP01PWR00TNS00	12.5 KVA Service and Substation System	MCCACE	5		4/29/2002	40	15.00821918	24.99178082	$200,000	Electrical							
759	T-17MVMCC-A, 4160 kV	PTP01PWR00TNS00	12.5 KVA Service and Substation System	MCCACE	5		4/29/2002	40	15.00821918	24.99178082	$200,000	Electrical							
769	T-17XFMR-T1, 12.5 kV to 4160 V Transformer	PTP01PWR00TNS00	12.5 KVA Service and Substation System	MCCACE	5		4/29/2002	40	15.00821918	24.99178082	$100,000	Electrical							
760	T-17SWBD-A, 480 V	PTP01PWR00TNS00	12.5 KVA Service and Substation System	MCCACE	5		4/29/2002	40	15.00821918	24.99178082	$75,000	Electrical							
770	T-17XFMR-T2, 12.5 kV to 480 V Transformer	PTP01PWR00TNS00	12.5 KVA Service and Substation System	MCCACE	5		4/29/2002	40	15.00821918	24.99178082	$50,000	Electrical							
776	T-05BLDG01 Building and Gallery, Ozone	PTP01BGR00BLD05	Bldg 05 -- Ozonation Building System	STCCNC	2		4/29/2002	50	15.00821918	34.99178082	$30,000	Infrastructure							
779	Water Feature and related wet well, piping, valves and structures	PTP01BGR00GRN00	Grounds System	TNKCNC	1		4/29/2002	50	15.00821918	34.99178082	$30,000	Mechanical							
795	Distribution Transformer - Lower Level Rack Mount 18-XFMR-B Fed from 13-DP-B	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
794	Distribution Transformer - Upper Level Rack Mount 18-XFMR-LAB Fed from 13-DP-B	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
796	Distribution Transformer -13-XFMR-1 Location, mounted up above 13-LP-B	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
797	Distribution Transformer 4-XFMR-B Location, Actiflo Sand Room	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
800	Distribution Transformer, 15-SWBD-B	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
799	Distribution Transformer, Filter Gallery	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
801	Distribution Transformer, Raw Water Building	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
798	T-04LP-Panel, Location, Actiflo Sand Room	PTP01PWR00TNS00	12.5 KVA Service and Substation System	TRFACE	5		4/29/2002	30	15.00821918	14.99178082	$15,000	Electrical							
775	T-06BLDG01 Building and Gallery, Filtration	PTP01BGR00BLD06	Bldg 06 --Filtration Building System	BLDCNC	2		4/29/2002	50	15.00821918	34.99178082	$10,000	Infrastructure							
751	T-08BLDG01 Building, Waste Washwater Recovery	PTP01SLL00PMP01	Washwater Equalization Pumping System	BLDCNC	2		4/29/2002	50	15.01	34.99178082	$10,000	Infrastructure							
752	T-12BLDG01 Building, Centrifuge	PTP01SLL00DWT00	Sludge Dewatering (Centrifuge) System	BLDCNC	2		4/29/2002	50	15.01	34.99178082	$10,000	Infrastructure							
756	T-02-DP-B Panel, Distribution	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	CPLGEN	5		4/29/2002	25	15.00821918	9.991780822	$5,000	Electrical							
757	T-03LCP02 Panel, Local Control, Initial Mix	PTP01SED00PMP03	Initial Chemical Mixing and Application System	CPLGEN	2		4/29/2002	25	15	10	$5,000	Electrical							
754	T-13-DPA-A Panel, Distribution	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	CPLGEN	5		4/29/2002	25	15.00821918	9.991780822	$5,000	Electrical							
755	T-13-DPA-B Panel, Distribution	PTP01PWR00ELE01	Low Voltage Electrical MCC's & Wiring System	CPLGEN	5		4/29/2002	25	15.00821918	9.991780822	$5,000	Electrical							
758	T-20LCP01 Panel, Local Control, Sanitary Sewer	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	25	15.00821918	9.991780822	$5,000	Electrical							
768	T-02LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
774	T-04LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
764	T-06LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
763	T-08LPA Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
766	T-09LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
767	T-11LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
765	T-12LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
762	T-13LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
773	T-17MVMCC-A Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
791	T-18LAB12A PH Meter, Portable	PTP01SPS00LAB00	Laboratory Equipment System	LABBCH	1		4/29/2002	20	15.00821918	4.991780822	$3,000	Infrastructure							
761	T-18LPB Panel, Lighting	PTP01BGR00GRN00	Grounds System	CPLGEN	3		4/29/2002	40	15.00821918	24.99178082	$3,000	Electrical							
778	T-06MOV28 Valve, Air Scour Vent, 10 in.	PTP01FLT00AER00	Filter Air Scour & Blower System	VLVBTF	2		4/29/2002	33	15.00821918	17.99178082	$2,000	Mechanical							
783	Ozone Contact Train 1 Drain Valve	PTP01DSF00AER01	Train #1 Ozone Distribution System	VLVPLG	2		6/1/2013	33	3.909589041	29.09041096	$1,000	Mechanical							
784	Ozone Contact Train 2 Drain Valve	PTP01DSF00AER01	Train #1 Ozone Distribution System	VLVPLG	2		6/1/2013	33	3.909589041	29.09041096	$1,000	Mechanical							
5	T-03UND02 Vault, Chemical Injection	PTP01SED00PMP03	Initial Chemical Mixing and Application System	STCCNC	2		4/29/2002	50	15.01	34.99178082	$1,000	Infrastructure							
780	T-09H01 Heater, HS Electrical room, N	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	1		4/29/2002	15	15.00821918	-0.008219178	$1,000	Mechanical							
781	T-09H02 Heater, HS Electrical room, S	PTP01BGR00BLD09	Bldg 09 -- High Service Pump Building System	HVCGEN	1		4/29/2002	15	15.00821918	-0.008219178	$1,000	Mechanical							
807	T-02PM01 - Motor, Raw Water Pump, 2-P-1 - 200 HP	PTP01PRE00PMP00	Raw Water Intake Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			200				
808	T-02PM02 - Motor, Raw Water Pump, 2-P-2 - 200 HP	PTP01PRE00PMP00	Raw Water Intake Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			200				
809	T-02PM03 - Motor, Raw Water Pump, 2-P-3 - 200 HP	PTP01PRE00PMP00	Raw Water Intake Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			200				
810	T-02PM04 - Motor, Raw Water Pump, 2-P-4 - 100 HP	PTP01PRE00PMP00	Raw Water Intake Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			100				
803	T-09PM01, Motor, High Service Pump 9-P-1 - 500 HP	PTP01PEF00PMP01	High Service Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			500				
804	T-09PM02, Motor, High Service Pump 9-P-2 - 500 HP	PTP01PEF00PMP01	High Service Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			500				
805	T-09PM03, Motor, High Service Pump 9-P-3 - 500 HP	PTP01PEF00PMP01	High Service Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			500				
806	T-09PM04, Motor, High Service Pump 9-P-4 - 300 HP	PTP01PEF00PMP01	High Service Pumping System	MTRELE	5		4/29/2002	25	15.00821918	9.991780822		Electrical			300				
782	WONDERWARE SOFTWARE CONTRACT 40182	PTP01SPS00NET00	Administrative Computing & Networking System	CNSECT	1		4/29/2002	20	15.00821918	4.991780822		Infrastructure							

MEETING MEMORANDUM (Rev 1)

Project: Willamette River Water Treatment Plant 2017 Master Plan Update

Conf. Date: August 15, 2017

Client: City of Wilsonville, City of Sherwood

Issue Date: September 5, 2017

Location: City of Wilsonville Conference Room

Project No.: 10721A00

Purpose: The goals of this meeting was to: discuss equipment and instrumentation status to support the on-going CIP evaluation.

Attendees: **Veolia:** Kim Reid, Shane Wyer

Portland Engineering: Carl Serpa

Carollo: Meghann Chell

Distribution: Attendees, Eric Mende (City of Wilsonville), Mike Green (Veolia), Jude Grounds (Carollo)

Discussion:
The following is our understanding of the subject matter covered in this conference. If this differs from your understanding, please notify us.

1) Confirm HP sizes attached to MCC-19
    a) Estimate total loads at 15 HP
        i) Seven of the loads are exhaust fans, estimated at 1.5 HP each
        ii) Booster pumps for aqueous ammonia system estimated at 7.5 HP but are not used
    b) Carollo will follow up if more information needed

2) Request for daily electrical loads and plant flow rates from SCADA historian
    a) Veolia emailed requested information to Carollo on Tuesday August 15th

3) Electrical and mechanical equipment discussion:
    a) Concerned about insufficient redundancy for raw and finished water pump stations, which primarily operate on the 4 MGD pumps
    b) Plant-wide PLC upgrade taking place before end of 2017 fiscal year. Recommend vendor PLC upgrade within next five years. Plant PLCs should be able to supply spare parts for vendor PLC maintenance during that period.
    c) Robocon VFDs on finished water pumps 9-P-1 and 9-P-2 are obsolete and no longer supported. On CIP for replacement of one each year in next two fiscal years.
    d) ABB flow meters are obsolete and no longer supported. Transmitters are failing and cannot be replaced. Primary concern is meter on the intake vault, which controls all downstream processes. This meter recently failed and required manual plant control until transmitter was temporarily replaced with transmitter from finished water unit. This also impacts the meter on Wilsonville Road.
    e) Currently only two Actiflo solids pumps in service, one standing by but not connected, and two pending service by Mather&Sons. May require additional shelf spare pumps for higher flow rates due to some lag in pump service.

   f) Actiflo troughs over the lamella tubes are becoming brittle, so operators no longer walk on them. If replaced would recommend upgrading to stainless steel. Priority is Actiflo train #2 since that it is connected to emergency generator.
   g) Several IQ Analyzers on MCCs are burned out or broken
   h) CIP evaluation should review analyzers (e.g., turbidimeters, ozone sensors, etc.) for replacement of obsolete and unserviceable units
   i) Recommend sparge valves added to the washwater basin near pump bells to prevent solids uptake
   j) During intake pipe screen upgrade, recommended extending the sparge system to the intake pipe improve solids/sediment removal.
   k) Plant is currently utilizing all chemical pipe capacity, so will need to take this into consideration for CIP. This is a larger concern than chemical pumps since those are low dollar value.

4) Life safety and security discussion:
   a) Exterior lighting system is a concern now that plant is operating 24-hours. Initial design utilized sodium vapor lamps and was concerned with off-site spillage. Nighttime operator cannot see into process units on the Actiflo deck and the lighting by the thickener is not functional. Temporary spotlights are currently required when working in these areas.
   b) Plant security system is becoming unreliable. Nighttime operator cannot see who is at the front door.
   c) Adding connection points for temporary safety barriers at centrifuges and other equipment

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	SWGR-MAIN 'MS'		
DESCRIPTION		**PHASE, WIRE, KASC**	3PH, 3W, 14 KASC
LOCATION	OUTDOOR MAIN MS	**LARGEST MOTOR**	500HP
VOLTAGE	12470	**COMMENTS**	OWNED BY THE CITY OF WILSONVILLE300 MVA PER ASBUIT
BUS AMPS	600		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
3627.4	167.9

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
4534.3	209.9

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
3868.1	179.1

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

SUBFED EQUIPMENT

TAG	DESCRIPTION	EQUIPMENT SIZE	EQUIPMENT UNITS	STATUS	OPERATING KVA	OPERATING AMPS	BUS COMMENTS
XFMR T1		1,500.0	KVA	EXISTING	1513.1	70.1	
XFMR T2		2,000.0	KVA	EXISTING	2114.3	97.9	
				OPERATING LOAD SUBFED SUBTOTAL	3627.4	167.9	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT CITY OF WILSONWILLE
PROJECT NUMBER 10002A60
REPORT BY JAMSHID DORAFSHA
REPORT DATE 1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG 17-MVMCC-A
DESCRIPTION WALKIN
LOCATION OUTDOOR MAIN MS
VOLTAGE 4160
BUS AMPS 3000
PHASE, WIRE, KASC 3PH, 3W, 14 KASC
LARGEST MOTOR 500HP
COMMENTS 350 MVA PER AS BUILT

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
1513.1	210.0

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
1891.4	262.5

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
1639.2	227.5

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
9-P-1	FINISHED WATER PUMP	500	HP	VFD-18	DUTY / CONTINUOUS	EXISTING	504.4	70.0	
9-P-2	FINISHED WATER PUMP	500	HP	VFD-18	DUTY / CONTINUOUS	EXISTING	504.4	70.0	
9-P-3	FINISHED WATER PUMP	500	HP	RVSS	DUTY / CONTINUOUS	EXISTING	504.4	70.0	
					OPERATING LOAD SUBTOTAL		1513.1	210.0	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT CITY OF WILSONWILLE
PROJECT NUMBER 10002A60
REPORT BY JAMSHID DORAFSHA
REPORT DATE 1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG 17-SWBD-A
DESCRIPTION
LOCATION OUTDOOR MAIN MS
VOLTAGE 480
BUS AMPS 3000

PHASE, WIRE, KASC 3PH, 3W, 65 KAIC KASC
LARGEST MOTOR 300HP
COMMENTS

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
2114.3	2543.1

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
2642.9	3178.9

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
2303.9	2771.2

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

SUBFED EQUIPMENT

TAG	DESCRIPTION	EQUIPMENT SIZE	EQUIPMENT UNITS	STATUS	OPERATING KVA	OPERATING AMPS	BUS COMMENTS
15-MCC-A	TO HSPS	1,200.0	AMPS	EXISTING	408.0	490.8	
4-MCC-A	TO ACTIFLO BLDG	600.0	AMPS	EXISTING	51.4	61.8	
6-MCC-A	TO FILTER GALLERY	600.0	AMPS	EXISTING	113.6	136.7	
8-MCC-A	TO WASTE WASH. EQ.	600.0	AMPS	EXISTING	29.5	35.5	
15-SWBD-B	TO HSPS (STDBY)	2,000.0	AMPS	EXISTING	1015.9	1221.9	
13-DP-A	TO CHEM BUILDING	800.0	AMPS	EXISTING	96.8	116.4	
				OPERATING LOAD SUBFED SUBTOTAL	1715.2	2063.1	

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
2-P-1	RAW WATER PUMP	200	HP	VFD-18	DUTY / CONTINUOUS	EXISTING	199.5	240.0	
2-P-2	RAW WATER PUMP	200	HP	VFD-18	DUTY / CONTINUOUS	EXISTING	199.5	240.0	
						OPERATING LOAD SUBTOTAL	399.1	480.0	

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	13-DP-A		
DESCRIPTION	TO CHEM BUILDING	**PHASE, WIRE, KASC**	3PH, 3W, 42 KAIC KASC
LOCATION		**LARGEST MOTOR**	55HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	800		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
96.8	116.4

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
121.0	145.5

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
120.3	144.8

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
12-ME-1	CENTRIFUGE #1	55	HP	RVSS	DUTY / CONTINUOUS	EXISTING	0.0	0.0	
12-ME-2	CENTRIFUGE #2	55	HP		STANDBY	EXISTING	0.0	0.0	
12-ME-3	CENTRIFUGE SOLIDS CONVEYOR	2	HP		DUTY / CONTINUOUS	EXISTING	2.8	3.4	
12-ME-4	CENTRIFUGE HOIST	5	HP		STANDBY	EXISTING	0.0	0.0	
13-MAU-1	CHEM BLDG. FAN	1.50	HP		DUTY / CONTINUOUS	EXISTING	2.5	3.0	
19-ME-1	OZONE GENERATOR 1	100	KW		STANDBY	EXISTING	0.0	0.0	
RTU-1	ADMIN KITCHEN	27	AMP		DUTY / CONTINUOUS	EXISTING	22.4	27.0	
RTU-3	ADMIN-LAB	23	AMP		DUTY / CONTINUOUS	EXISTING	19.1	23.0	
SPARE	XX	40	AMP		DUTY / CONTINUOUS	EXISTING	33.3	40.0	
SPARES	(TYP OF 7)	20	AMP		DUTY / CONTINUOUS	EXISTING	16.6	20.0	
					OPERATING LOAD SUBTOTAL		96.8	116.4	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	15-MCC-A		
DESCRIPTION	TO HSPS	**PHASE, WIRE, KASC**	3PH, 3W, 65 KAIC KASC
LOCATION		**LARGEST MOTOR**	200HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	1200		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
408.0	490.8

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
510.1	613.5

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
457.9	550.8

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
07-MOV-1	MOV	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
07-MOV-2	MOV	1	HP		STANDBY	EXISTING	0.0	0.0	
07-P-1	BACKWASH PUMP	150	HP	FVNR	DUTY / CONTINUOUS	EXISTING	149.6	180.0	
07-P-2	BACKWASH PUMP	150	HP	FVNR	STANDBY	EXISTING	0.0	0.0	
09-MOV-1	MOV	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
09-MOV-2	MOV	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
09-MOV-3	MOV	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
16-F-2	ELECTRICAL RM FAN	3	HP	FVNR	DUTY / CONTINUOUS	EXISTING	4.0	4.8	
1-ME-2	INTAKE SCREEN COMPRESSOR	50	HP	RVSS	STANDBY	EXISTING	0.0	0.0	
2-P-3	RAW WATER PUMP	200	HP	FVNR	DUTY / CONTINUOUS	EXISTING	199.5	240.0	
30-P-1	IRRIGATION RECIRC PUMP	40	HP		DUTY / CONTINUOUS	EXISTING	43.2	52.0	
7-F-2	ELECTRICAL RM FAN	2	HP	FVNR	DUTY / CONTINUOUS	EXISTING	2.8	3.4	
9-F-1	ELECTRICAL RM FAN	1/4	HP	FVNR	DUTY / CONTINUOUS	EXISTING	0.9	1.1	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	15-MCC-A		
DESCRIPTION	TO HSPS	**PHASE, WIRE, KASC**	3PH, 3W, 65 KAIC KASC
LOCATION		**LARGEST MOTOR**	200HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	1200		

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
9-F-2	ELECTRICAL RM FAN	1/2	HP	FVNR	DUTY / CONTINUOUS	EXISTING	0.9	1.1	
BRIDGE CRANE-15-MCC-A	HSPS	20	HP		STANDBY	EXISTING	0.0	0.0	
					OPERATING LOAD SUBTOTAL		408.0	490.8	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	15-SWBD-B		
DESCRIPTION	TO HSPS (STDBY)	**PHASE, WIRE, KASC**	3PH, 3W, 65 KAIC KASC
LOCATION		**LARGEST MOTOR**	300HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	2000		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
1015.9	1221.9

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
1269.9	1527.4

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
1180.9	1420.4

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

SUBFED EQUIPMENT

TAG	DESCRIPTION	EQUIPMENT SIZE	EQUIPMENT UNITS	STATUS	OPERATING KVA	OPERATING AMPS	BUS COMMENTS
4-MCC-B	TO ACTI FLD BLDG.	600.0	AMPS	EXISTING	139.7	168.0	
13-DP-B	TO CHEM BLDG.	800.0	AMPS	EXISTING	364.8	438.8	
17-MVMCC-A-LP	LIGHTING PANEL	100.0	AMPS	EXISTING	0.0	0.0	
2-DP-B	INTAKE PS DISTR PANEL	100.0	AMPS	EXISTING	47.7	57.3	
6-DP-B	FILTER GALLERY DISTER PANEL	100.0	AMPS	EXISTING	0.0	0.0	
XFMR-8-LP-B		30.0	KVA	EXISTING	15.0	18.0	
XFMR-9-LP-B	TRANSFORMER	30.0	KVA	EXISTING	15.0	18.0	
				OPERATING LOAD SUBFED SUBTOTAL	582.2	700.2	

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
1-ME-1	INTAKE SCREEN COMPRESSOR	50	HP	RVSS	STANDBY	EXISTING	0.0	0.0	
20-P-1	SANITARY SEWER PUMP 1	5	HP		DUTY / CONTINUOUS	EXISTING	6.3	7.6	
20-P-2	SANITARY SEWER PUMP 2	5	HP		STANDBY	EXISTING	0.0	0.0	
2-P-4	RAW WATER PUMP	100	HP	VFD-18	DUTY / CONTINUOUS	EXISTING	103.1	124.0	
30-P-2	IRRIGATION WASTE PUMPS	20	HP		DUTY / CONTINUOUS	EXISTING	22.4	27.0	
30-P-3	IRRIGATION WASTE PUMPS	20	HP		STANDBY	EXISTING	0.0	0.0	

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	15-SWBD-B		
DESCRIPTION	TO HSPS (STDBY)	**PHASE, WIRE, KASC**	3PH, 3W, 65 KAIC KASC
LOCATION		**LARGEST MOTOR**	300HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	2000		

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
9-MOV-4	MOV	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
9-P-4	FINISHED WATER PUMP	300	HP	VFD-18	DUTY / CONTINUOUS	EXISTING	300.1	361.0	
						OPERATING LOAD SUBTOTAL	433.7	521.7	

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PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	13-DP-B		
DESCRIPTION	TO CHEM BLDG.	**PHASE, WIRE, KASC**	3PH, 3W, 42 KAIC KASC
LOCATION		**LARGEST MOTOR**	125HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	800		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
364.8	438.8

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
456.0	548.4

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
450.5	541.9

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

SUBFED EQUIPMENT

TAG	DESCRIPTION	EQUIPMENT SIZE	EQUIPMENT UNITS	STATUS	OPERATING KVA	OPERATING AMPS	BUS COMMENTS
19-MCC-A		600.0	AMPS	EXISTING	129.7	156.0	
13-XFMR-LP-B	CHEMICAL BUILDING	30.0	KVA	EXISTING	15.0	18.0	
18-XFMR-LAB	TRANSFORMER	45.0	KVA	EXISTING	22.5	27.1	
18-XFMR-LP-B		30.0	KVA	EXISTING	15.0	18.0	
				OPERATING LOAD SUBFED SUBTOTAL	182.2	219.1	

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
10-MOV-1	FINISH WATER VAULT	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
19-MAU-1	OZONE GEN	10	AMP		DUTY / CONTINUOUS	EXISTING	8.3	10.0	
19-ME-2	OZONE GENERATOR 2	100	KW		DUTY / CONTINUOUS	EXISTING	117.6	141.5	
5-ME-3&4	NITROGEN BOOST CP	15	HP		DUTY / CONTINUOUS	EXISTING	17.5	21.0	
BRIDGE ONLY GATES POWER	XX	10	AMP		DUTY / CONTINUOUS	EXISTING	8.3	10.0	
EF-4	ADMIN EXHAUST FAN	1.50	HP		DUTY / CONTINUOUS	EXISTING	2.5	3.0	
RTU-2	ADMIN HAVC	22	AMP		DUTY / CONTINUOUS	EXISTING	18.3	22.0	

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	13-DP-B		
DESCRIPTION	TO CHEM BLDG.	**PHASE, WIRE, KASC**	3PH, 3W, 42 KAIC KASC
LOCATION		**LARGEST MOTOR**	125HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	800		

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
SITE LIGHT CONTACTOR	XX	10	AMP		DUTY / CONTINUOUS	EXISTING	8.3	10.0	
					OPERATING LOAD SUBTOTAL		182.6	219.6	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONVILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	13-LP-B		
DESCRIPTION	CHEMICAL BUILDING	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	208	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
15.0	41.6

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
	13-LP-B LOAD	15	KVA		DUTY / CONTINUOUS	EXISTING	15.0	41.6	
					OPERATING LOAD SUBTOTAL		15.0	41.6	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONVILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	18-LP-LAB		
DESCRIPTION	ADMIN LAB PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	208	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
22.5	62.5

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
28.1	78.1

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
28.1	78.1

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
	18-LP-LAB-LOAD	22.50	KVA		DUTY / CONTINUOUS	EXISTING	22.5	62.5	
					OPERATING LOAD SUBTOTAL		22.5	62.5	

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LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	18-LP-B		
DESCRIPTION	ADMIN BUILDING PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	208	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
15.0	41.6

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
	18-LP-B-LOAD	15	KVA		DUTY / CONTINUOUS	EXISTING	15.0	41.6	
					OPERATING LOAD SUBTOTAL		15.0	41.6	

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LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	19-MCC-A		
DESCRIPTION		**PHASE, WIRE, KASC**	3PH, 3W, 65 KAIC KASC
LOCATION		**LARGEST MOTOR**	125HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	600		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
129.7	156.0

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
162.1	195.0

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
162.1	195.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
13-EF-1	CHEMICAL NORTH	0			DUTY / CONTINUOUS	EXISTING	0.0	0.0	
13-EF-2	CHEMICAL SOUTH	0			DUTY / CONTINUOUS	EXISTING	0.0	0.0	
18-EF-4	ADMIN	0			DUTY / CONTINUOUS	EXISTING	0.0	0.0	
18-EF-5	ADMIN	0			DUTY / CONTINUOUS	EXISTING	0.0	0.0	
19-F-1	OZONE GEN	125	HP	RVSS	DUTY / CONTINUOUS	EXISTING	129.7	156.0	LOAD HP IS ASSUMED AND IS FOR THE ENTIRE MCC
BOOSTER PUMP 1	CHEMICAL BUILDING	0			DUTY / CONTINUOUS	EXISTING	0.0	0.0	
BOOSTER PUMP 2	CHEMICAL BUILDING	0			DUTY / CONTINUOUS	EXISTING	0.0	0.0	
SPARE-19-MCC-A	TYP OF 2	0			DUTY / CONTINUOUS	EXISTING	0.0	0.0	
					OPERATING LOAD SUBTOTAL		129.7	156.0	

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	17-MVMCC-A-LP		
DESCRIPTION	LIGHTING PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS		NEC 215 EQUIPMENT SIZING		NEC 430 EQUIPMENT SIZING	
OPERATING KVA	**OPERATING AMPS**	**EQUIPMENT KVA**	**EQUIPMENT AMPS**	**EQUIPMENT KVA**	**EQUIPMENT AMPS**
0.0	0.0	0.0	0.0	0.0	0.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

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LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	2-DP-B		
DESCRIPTION	INTAKE PS DISTR PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	2HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
47.7	57.3

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
59.6	71.7

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
56.3	67.7

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

SUBFED EQUIPMENT

TAG	DESCRIPTION	EQUIPMENT SIZE	EQUIPMENT UNITS	STATUS	OPERATING KVA	OPERATING AMPS	BUS COMMENTS
2-MCC-A	INTAKE PUMP STATION	600.0	AMPS	EXISTING	9.1	10.9	
2-XFMR	TRANSFORMER	30.0	KVA	EXISTING	15.0	18.0	
				OPERATING LOAD SUBFED SUBTOTAL	24.1	28.9	

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
2-MOV-1	MOV	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
2-P-6	CASSION DEWATERING PUMP	10	HP		STANDBY	EXISTING	0.0	0.0	
3-MOV-1	MOV	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
AIR COMPRESSOR ROOM HEATER	XX	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
BRIDGE CRANE	XX	1	HP		STANDBY	EXISTING	0.0	0.0	
SANITARY SEWAGE CP	CONTROL PANEL	20	AMP		DUTY / CONTINUOUS	EXISTING	16.6	20.0	
SUMP PUMP	XX	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
						OPERATING LOAD SUBTOTAL	23.6	28.4	

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	2-MCC-A		
DESCRIPTION	INTAKE PUMP STATION	**PHASE, WIRE, KASC**	3PH, 3W, 65 KAIC KASC
LOCATION		**LARGEST MOTOR**	2HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	600		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
9.1	10.9

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
11.3	13.6

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
9.8	11.8

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
2-F-1	VENTILATION FAN	1/4	HP		DUTY / CONTINUOUS	EXISTING	0.9	1.1	
2-F-11	COMPRESSOR ROOM COOLING FAN	2	HP		DUTY / CONTINUOUS	EXISTING	2.8	3.4	
2-F-2	PUMP ROOM COOLING FAN	2	HP		DUTY / CONTINUOUS	EXISTING	2.8	3.4	
2-F-7	ELECTRICAL ROOM COOLING FAN	1.50	HP		DUTY / CONTINUOUS	EXISTING	2.5	3.0	
					OPERATING LOAD SUBTOTAL		9.1	10.9	

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LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONVILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	2-LP-13		
DESCRIPTION	LIGHTING PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	208	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
15.0	41.6

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
	2-LP-13-LOAD	15	KVA		DUTY / CONTINUOUS	NEW	15.0	41.6	
					OPERATING LOAD SUBTOTAL		15.0	41.6	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	4-MCC-B		
DESCRIPTION	TO ACTI FLD BLDG.	**PHASE, WIRE, KASC**	3PH, 3W, 42 KAIC KASC
LOCATION		**LARGEST MOTOR**	15HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	600		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
139.7	168.0

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
174.6	210.1

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
165.3	198.8

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

SUBFED EQUIPMENT

TAG	DESCRIPTION	EQUIPMENT SIZE	EQUIPMENT UNITS	STATUS	OPERATING KVA	OPERATING AMPS	BUS COMMENTS
XFMR-4-LP-B		30.0	KVA	NEW	15.0	18.0	
				OPERATING LOAD SUBFED SUBTOTAL	15.0	18.0	

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
04-ME-10	MECHANICAL MIXER	10	HP	VFD-6	DUTY / CONTINUOUS	EXISTING	11.6	14.0	
04-ME-11	SLUDGE SCRAPPER (SETTLING TANK)	3	HP	VFD-6	DUTY / CONTINUOUS	EXISTING	4.0	4.8	
04-ME-8	MECHANICAL MIXER	7.50	HP		DUTY / CONTINUOUS	EXISTING	9.1	11.0	
04-ME-9	MECHANICAL MIXER	7.50	HP		DUTY / CONTINUOUS	EXISTING	9.1	11.0	
04-MOV-1	XX	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
04-MOV-2	XX	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
04-P-3	RECIRC. PUMP	15	HP		DUTY / CONTINUOUS	EXISTING	17.5	21.0	
04-P-4	RECIRC. PUMP MICROSAND	15	HP		STANDBY	EXISTING	0.0	0.0	
05-LCP-4	TO DESTRUCT BUILDING	14	AMP		DUTY / CONTINUOUS	EXISTING	11.6	14.0	
5-F-1	XX	50	AMP		DUTY / CONTINUOUS	EXISTING	41.6	50.0	
5-MAU-1	XX	20	AMP		DUTY / CONTINUOUS	EXISTING	16.6	20.0	
						OPERATING LOAD SUBTOTAL	124.7	150.0	

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PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	4-LP-B		
DESCRIPTION	ACTIIFLO BLDG LIGHTING PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	208	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
15.0	41.6

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
	4-LP-B-LOAD	15	KVA		DUTY / CONTINUOUS	EXISTING	15.0	41.6	
					OPERATING LOAD SUBTOTAL		15.0	41.6	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	6-DP-B		
DESCRIPTION	FILTER GALLERY DISTER PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS		NEC 215 EQUIPMENT SIZING		NEC 430 EQUIPMENT SIZING	
OPERATING KVA	OPERATING AMPS	EQUIPMENT KVA	EQUIPMENT AMPS	EQUIPMENT KVA	EQUIPMENT AMPS
0.0	0.0	0.0	0.0	0.0	0.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

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PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	8-LP-B		
DESCRIPTION	WWPS LIGHTING PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	208	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
15.0	41.6

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
	8-LP-B-LOAD	15	KVA		DUTY / CONTINUOUS	EXISTING	15.0	41.6	
					OPERATING LOAD SUBTOTAL		15.0	41.6	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	9-LP-B		
DESCRIPTION	HSPS LIGHTING PANEL	**PHASE, WIRE, KASC**	3PH, 3W, 22 KAIC KASC
LOCATION		**LARGEST MOTOR**	0HP
VOLTAGE	208	**COMMENTS**	
BUS AMPS	100		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
15.0	41.6

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
18.8	52.0

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
	9-LP-B-LOAD	15	KVA		DUTY / CONTINUOUS	EXISTING	15.0	41.6	
					OPERATING LOAD SUBTOTAL		15.0	41.6	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	4-MCC-A		
DESCRIPTION	TO ACTIFLO BLDG	**PHASE, WIRE, KASC**	3PH, 3W, 42 KAIC KASC
LOCATION		**LARGEST MOTOR**	15HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	600		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
51.4	61.8

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
64.2	77.3

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
55.7	67.1

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
04-ME-1	MECHANICAL MIXER	7.50	HP	FVNR	DUTY / CONTINUOUS	EXISTING	9.1	11.0	
04-ME-2	MECHANICAL MIXER	7.50	HP	FVNR	DUTY / CONTINUOUS	EXISTING	9.1	11.0	
04-ME-3	MECHANICAL MIXER	10	HP	VFD-6	DUTY / CONTINUOUS	EXISTING	11.6	14.0	
04-ME-4	SLUDGE SCRAPPER (SETTLING TANK)	3	HP	VFD-6	DUTY / CONTINUOUS	EXISTING	4.0	4.8	
04-P-1	RECIRC. PUMP (MICROSAND)	15	HP	FVNR	DUTY / CONTINUOUS	EXISTING	17.5	21.0	
04-P-2	RECIRC. PUMP (MICROSAND)	15	HP	FVNR	STANDBY	EXISTING	0.0	0.0	
					OPERATING LOAD SUBTOTAL		51.4	61.8	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	6-MCC-A		
DESCRIPTION	TO FILTER GALLERY	**PHASE, WIRE, KASC**	3PH, 3W, 42 KAIC KASC
LOCATION		**LARGEST MOTOR**	100HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	600		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
113.6	136.7

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
142.1	170.9

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
141.2	169.8

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
06-ME-1	AIR SCOUR BLOWER	100	HP	FVNR	DUTY / CONTINUOUS	EXISTING	103.1	124.0	
06-ME-2	AIR SCOUR BLOWER	100	HP	FVNR	STANDBY	EXISTING	0.0	0.0	
6-F-3	AIR SCOUR RM FAN	1	HP	FVNR	DUTY / CONTINUOUS	EXISTING	1.7	2.1	
6-F-4	AIR SCOUR RM FAN	1	HP	FVNR	DUTY / CONTINUOUS	EXISTING	1.7	2.1	
HEATER EAST	XX	3	KW		DUTY / CONTINUOUS	EXISTING	3.5	4.2	
HEATER WEST	XX	3	KW		DUTY / CONTINUOUS	EXISTING	3.5	4.2	
					OPERATING LOAD SUBTOTAL		113.6	136.7	

Date/Time displayed in this report reflect time in PST

LOAD STUDY REPORT

PROJECT INFORMATION

PROJECT	WILLAMETTE RIVER WATER TREATMENT PLANT-15 MGD
CLIENT	CITY OF WILSONWILLE
PROJECT NUMBER	10002A60
REPORT BY	JAMSHID DORAFSHA
REPORT DATE	1/3/2018 12:03 PM

EQUIPMENT INFORMATION

TAG	8-MCC-A		
DESCRIPTION	TO WASTE WASH. EQ.	**PHASE, WIRE, KASC**	3PH, 3W, 42 KAIC KASC
LOCATION		**LARGEST MOTOR**	5HP
VOLTAGE	480	**COMMENTS**	
BUS AMPS	600		

LOAD TOTALS

OPERATING KVA	OPERATING AMPS
29.5	35.5

NEC 215 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
36.9	44.4

NEC 430 EQUIPMENT SIZING

EQUIPMENT KVA	EQUIPMENT AMPS
31.1	37.4

DEFINITIONS

OPERATING = CONTINUOUS + INTERMITTENT

NEC 215 EQUIPMENT SIZING = 1.25 x CONTINUOUS + 1.0 x INTERMITTENT (BASED ON NEC ARTICLE 215)

NEC 430 EQUIPMENT SIZING = 1.25 x LARGEST MOTOR + 1.0 x ALL OTHER MOTORS + 1.25 x CONTINUOUS NON-MOTOR + 1.0 x INTERMITTENT NON-MOTOR (BASED ON NEC ARTICLE 430)

EQUIPMENT SIZING IS BASED ON THE LARGER OF NEC 215 AND NEC 430 CALCULATIONS (LARGER IS HIGHLIGHTED WHEN APPLICABLE)

Note: For 3-phase busses that feed single -phase loads, the amp summation under loads will not match the bus amps due to the difference in voltage.

Note: The values in this report are rounded from higher precision numbers. Manually summing the values shown may yield slightly varied results due to rounding error.

LOADS

TAG	DESCRIPTION	LOAD VALUE	LOAD UNITS	STARTING METHOD	LOAD DESIGNATION	LOAD STATUS	OPERATING KVA	OPERATING AMPS	COMMENTS
11-ME-1	THICKENER MECHANISM	1.50	HP		DUTY / CONTINUOUS	EXISTING	2.5	3.0	
11-MOV-1	MOTOR OPERATED VALVE	1	HP		DUTY / CONTINUOUS	EXISTING	1.7	2.1	
11-P-1	THICKENED SOLIDS PUMP	5	HP		DUTY / CONTINUOUS	EXISTING	6.3	7.6	
11-P-2	THICKENED SOLIDS PUMP	5	HP		STANDBY	EXISTING	0.0	0.0	
11-P-3	RECYCLED SOLIDS MIXING PUMP	5	HP	FVNR	DUTY / CONTINUOUS	EXISTING	6.3	7.6	
8-P-1	WASH WATER RECYCLE PUMP	5	HP		DUTY / CONTINUOUS	EXISTING	6.3	7.6	
8-P-2	WASH WATER RECYCLE PUMP	5	HP		DUTY / CONTINUOUS	EXISTING	6.3	7.6	
8-P-3	WASH WATER RECYCLE PUMP	5	HP	FVNR	STANDBY	EXISTING	0.0	0.0	
					OPERATING LOAD SUBTOTAL		29.5	35.5	

Date/Time displayed in this report reflect time in PST

WRWTP 20-Year NPV Summary

	Alternative A Baseline	Alternative B Modified	Alternative C Compliance
20-Year NPV	$ 88,400,000	$ 81,200,000	$ 76,700,000
Cost Comparison ($)			
Alternative A	--	$ (7,200,000)	$ (11,700,000)
Alternative B	$ 7,200,000	--	$ (4,500,000)
Alternative C	$ 11,700,000	$ 4,500,000	--
Cost Comparison (%)			
Alternative A	--	-9%	-15%
Alternative B	8%	--	-6%
Alternative C	13%	6%	--

This sheet provides the references used for the NPV calculation sheets. In most cases, this sheet references the cost summary tables.

Summarized A Cost Data (for NPV Use)		Year Applied
Lower Site Interim Expansions	$20,550,870	2020
Lower Site Expansion	$19,487,928	2034
Lower Site Fixed Costs	$1,891,405	2015
Lower Site Variable Costs (per MG)	$412	2015

Summarized B Cost Data (for NPV Use)		Year Applied
Lower Site Interim Expansions	$10,663,463	2020
Lower Site Expansion	$22,487,442	2034
Lower Site Fixed Costs	$1,881,405	2015
Lower Site Variable Costs (per MG)	$410	2015

Summarized C Cost Data (for NPV Use)		Year Applied
Lower Site Interim Expansions	$8,441,300	2020
Lower Site Expansion	$21,650,443	2034
Lower Site Fixed Costs	$1,881,405	2015
Lower Site Variable Costs (per MG)	$374	2015

Constants	
Discount Rate	5.50%
Inflation	4.00%
Real Rate	1.500%

NPV: Alternative A

Total Net Present Value	LOWER SITE
	$88,328,940.04

Construction and Maintenance Costs							
Year	Year No.	Non-Program (Lower Site) WTP Capital Cost	Lower Site Average Flow, mgd	Lower Site Variable O&M Costs	Lower Site Fixed O&M Costs	Non-Program (Lower Site) Total Cost	Non-Program WTP Present Value
2015	0	$0.00	5.67	$853,094	$1,891,405	$2,744,499	$2,744,499
2016	1	$0.00	5.86	$881,065	$1,891,405	$2,772,469	$2,731,497
2017	2	$0.00	6.05	$909,035	$1,891,405	$2,800,440	$2,718,280
2018	3	$0.00	6.23	$937,005	$1,891,405	$2,828,410	$2,704,856
2019	4	$0.00	6.42	$964,975	$1,891,405	$2,856,380	$2,691,236
2020	5	$20,550,870.00	6.61	$993,645	$1,891,405	$23,435,920	$21,754,634
2021	6	$0.00	6.82	$1,025,112	$1,891,405	$2,916,516	$2,667,277
2022	7	$0.00	7.03	$1,056,578	$1,891,405	$2,947,983	$2,656,212
2023	8	$0.00	7.24	$1,088,045	$1,891,405	$2,979,450	$2,644,890
2024	9	$0.00	7.44	$1,119,511	$1,891,405	$3,010,916	$2,633,324
2025	10	$0.00	7.66	$1,151,677	$1,891,405	$3,043,082	$2,622,124
2026	11	$0.00	7.78	$1,169,858	$1,891,405	$3,061,263	$2,598,808
2027	12	$0.00	7.90	$1,187,339	$1,891,405	$3,078,744	$2,575,023
2028	13	$0.00	8.02	$1,205,520	$1,891,405	$3,096,925	$2,551,950
2029	14	$0.00	8.14	$1,223,701	$1,891,405	$3,115,106	$2,528,996
2030	15	$0.00	8.26	$1,242,581	$1,891,405	$3,133,985	$2,506,723
2031	16	$0.00	8.45	$1,270,551	$1,891,405	$3,161,956	$2,491,719
2032	17	$0.00	8.64	$1,299,221	$1,891,405	$3,190,625	$2,477,154
2033	18	$0.00	8.83	$1,327,890	$1,891,405	$3,219,295	$2,462,476
2034	19	$19,487,927.50	9.02	$1,356,560	$1,891,405	$22,735,892	$17,133,938
2035	20	$0.00	9.22	$1,385,929	$1,891,405	$3,277,333	$2,433,323

Constants	
Discount Rate	5.50%
Inflation	4.00%
Interest Rate	1.500%

NPV: Alternative B

Total Net Present Value	LOWER SITE
	$81,131,664.88

Construction and Maintenance Costs							
Year	Year No.	Non-Program (Lower Site) WTP Capital Cost	Lower Site Average Flow, mgd	Lower Site Variable O&M Costs	Lower Site Fixed O&M Costs	Non-Program (Lower Site) Total Cost	Lower Site Present Value
2015	0	$0.00	5.67	$848,958	$1,881,405	$2,730,362	$2,730,362
2016	1	$0.00	5.86	$876,792	$1,881,405	$2,758,197	$2,717,436
2017	2	$0.00	6.05	$904,627	$1,881,405	$2,786,032	$2,704,294
2018	3	$0.00	6.23	$932,462	$1,881,405	$2,813,866	$2,690,948
2019	4	$0.00	6.42	$960,296	$1,881,405	$2,841,701	$2,677,406
2020	5	$10,663,462.50	6.61	$988,827	$1,881,405	$13,533,694	$12,562,791
2021	6	$0.00	6.82	$1,020,141	$1,881,405	$2,901,546	$2,653,586
2022	7	$0.00	7.03	$1,051,455	$1,881,405	$2,932,860	$2,642,585
2023	8	$0.00	7.24	$1,082,769	$1,881,405	$2,964,174	$2,631,330
2024	9	$0.00	7.44	$1,114,083	$1,881,405	$2,995,488	$2,619,830
2025	10	$0.00	7.66	$1,146,093	$1,881,405	$3,027,498	$2,608,695
2026	11	$0.00	7.78	$1,164,185	$1,881,405	$3,045,590	$2,585,503
2027	12	$0.00	7.90	$1,181,582	$1,881,405	$3,062,987	$2,561,844
2028	13	$0.00	8.02	$1,199,675	$1,881,405	$3,081,079	$2,538,893
2029	14	$0.00	8.14	$1,217,767	$1,881,405	$3,099,172	$2,516,060
2030	15	$0.00	8.26	$1,236,556	$1,881,405	$3,117,960	$2,493,905
2031	16	$0.00	8.45	$1,264,390	$1,881,405	$3,145,795	$2,478,984
2032	17	$0.00	8.64	$1,292,921	$1,881,405	$3,174,326	$2,464,500
2033	18	$0.00	8.83	$1,321,451	$1,881,405	$3,202,856	$2,449,902
2034	19	$22,487,441.67	9.02	$1,349,982	$1,881,405	$25,718,828	$19,381,901
2035	20	$0.00	9.22	$1,379,208	$1,881,405	$3,260,613	$2,420,909

Constants	
Discount Rate	5.50%
Inflation	4.00%
Interest Rate	1.500%

NPV: Alternative C

Total Net Present Value	LOWER SITE
	$76,648,629.51

Construction and Maintenance Costs

Year	Year No.	Non-Program (Lower Site) WTP Capital Cost	Lower Site Average Flow, mgd	Lower Site Variable O&M Costs	Lower Site Fixed O&M Costs	Non-Program (Lower Site) Total Cost	Lower Site Present Value
2015	0	$0.00	5.67	$773,389	$1,881,405	$2,654,794	$2,654,794
2016	1	$0.00	5.86	$798,746	$1,881,405	$2,680,151	$2,640,543
2017	2	$0.00	6.05	$824,103	$1,881,405	$2,705,508	$2,626,133
2018	3	$0.00	6.23	$849,460	$1,881,405	$2,730,865	$2,611,572
2019	4	$0.00	6.42	$874,817	$1,881,405	$2,756,222	$2,596,869
2020	5	$8,441,300.00	6.61	$900,808	$1,881,405	$11,223,513	$10,418,342
2021	6	$0.00	6.82	$929,335	$1,881,405	$2,810,739	$2,570,540
2022	7	$0.00	7.03	$957,861	$1,881,405	$2,839,266	$2,558,255
2023	8	$0.00	7.24	$986,388	$1,881,405	$2,867,793	$2,545,771
2024	9	$0.00	7.44	$1,014,915	$1,881,405	$2,896,319	$2,533,098
2025	10	$0.00	7.66	$1,044,075	$1,881,405	$2,925,480	$2,520,790
2026	11	$0.00	7.78	$1,060,557	$1,881,405	$2,941,962	$2,497,529
2027	12	$0.00	7.90	$1,076,405	$1,881,405	$2,957,810	$2,473,875
2028	13	$0.00	8.02	$1,092,887	$1,881,405	$2,974,292	$2,450,897
2029	14	$0.00	8.14	$1,109,369	$1,881,405	$2,990,774	$2,428,058
2030	15	$0.00	8.26	$1,126,485	$1,881,405	$3,007,890	$2,405,865
2031	16	$0.00	8.45	$1,151,842	$1,881,405	$3,033,247	$2,390,293
2032	17	$0.00	8.64	$1,177,833	$1,881,405	$3,059,238	$2,375,147
2033	18	$0.00	8.83	$1,203,824	$1,881,405	$3,085,229	$2,359,927
2034	19	$21,650,443.33	9.02	$1,229,815	$1,881,405	$24,761,663	$18,660,575
2035	20	$0.00	9.22	$1,256,440	$1,881,405	$3,137,845	$2,329,757

Multiplicative Factors		Year Applies (and beyond)
Peaking Factor (avg day from peak day)	0.465	ALL

Year	Wilsonville	Sherwood	Combined Demands	Lower Site Peak Demands	Lower Site Average Demands
2010	6.70	3.53	10.23	10.23	4.76
2011	7.02	3.60	10.62	10.62	4.94
2012	7.34	3.67	11.01	11.01	5.12
2013	7.66	3.74	11.40	11.40	5.30
2014	7.98	3.82	11.80	11.80	5.49
2015	8.30	3.90	12.20	12.20	5.67
2016	8.62	3.98	12.60	12.60	5.86
2017	8.94	4.06	13.00	13.00	6.05
2018	9.26	4.14	13.40	13.40	6.23
2019	9.58	4.22	13.80	13.80	6.42
2020	9.90	4.31	14.21	14.21	6.61
2021	10.26	4.40	14.66	14.66	6.82
2022	10.62	4.49	15.11	15.11	7.03
2023	10.98	4.58	15.56	15.56	7.24
2024	11.34	4.67	16.01	16.01	7.44
2025	11.70	4.77	16.47	16.47	7.66
2026	11.86	4.87	65.07	16.73	7.78
2027	12.02	4.96	67.21	16.98	7.90
2028	12.18	5.06	69.36	17.24	8.02
2029	12.34	5.16	71.51	17.50	8.14
2030	12.50	5.27	72.44	17.77	8.26
2031	12.80	5.37	74.02	18.17	8.45
2032	13.10	5.48	75.62	18.58	8.64
2033	13.40	5.59	77.21	18.99	8.83
2034	13.70	5.70	78.81	19.40	9.02
2035	14.00	5.82	81.34	19.82	9.22
2036	14.30	5.98	82.70	20.28	9.43
2037	14.60	6.05	83.98	20.65	9.60
2038	14.90	6.17	85.31	21.07	9.80
2039	15.20	6.30	86.64	21.50	10.00
2040	15.50	6.42	88.98	21.92	10.19
2041	15.80	6.55	100.32	22.35	10.39
2042	16.10	6.68	101.66	22.78	10.59
2043	16.40	6.82	103.02	23.22	10.80
2044	16.70	6.95	104.36	23.65	11.00
2045	17.00	7.09	106.72	24.09	11.20
2046	17.30	7.23	108.01	24.53	11.41
2047	17.60	7.38	109.31	24.98	11.62
2048	17.90	7.53	110.61	25.43	11.82
2049	18.20	7.68	111.91	25.88	12.03
2050	18.50	7.83	114.22	26.33	12.24

Appendix B

LIFE SAFETY AND SEISMIC ASSESSMENT TECHNICAL MEMORANDUM

City of Wilsonville

Willamette River Water Treatment Plant 2017 Master Plan Update

TECHNICAL MEMORANDUM LIFE SAFETY AND SEISMIC ASSESSMENT

Final | January 2018

CITY OF WILSONVILLE

WILLAMETTE RIVER WATER TREATMENT PLANT 2017 MASTER PLAN UPDATE

TECHNICAL MEMORANDUM

LIFE SAFETY AND SEISMIC ASSESSMENT

Digitally signed by James A. Doering
Contact Info: Carollo Engineers, Inc.
Date: 2018.01.31 13:56:20-08'00'

REGISTERED PROFESSIONAL
ENGINEER
78514
OREGON
SEPT. 19, 2006
JAMES A. DOERING
EXPIRES: 12/31/19

Contents

Attachments

Tables

Figures

Abbreviations

ACI	American Concrete Institute
amps	amperes
ASCE	American Society of Civil Engineers
BPOE	Basic Performance Objective for Existing Buildings
BSE-1E	basic safety earthquake 1
Carollo	Carollo Engineers, Inc.
DCR	demand-to-capacity ratio
ft	feet
GFCI	ground fault circuit interrupter
lb	pounds
mgd	million gallons per day
MWH	Montgomery Watson Harza
NFPA	National Fire Protection Association
oc	on center
OFC	Oregon Fire Code
OSHA	Occupational Safety and Health Administration
OSSC	Oregon Structural Specialty Code
pcf	pounds per cubic foot
psf	pounds per square foot
psi	pounds per square inch
S&W	Shannon & Wilson
sec	second
Sherwood	City of Sherwood
TVWD	Tualatin Valley Water District
UBC	Uniform Building Code
USGS	United States Geological Survey
Wilsonville	City of Wilsonville
WRWTP	Willamette River Water Treatment Plant

Technical Memorandum 1

LIFE SAFETY AND SEISMIC ASSESSMENT

1.1 Introduction

The City of Wilsonville (Wilsonville) and Tualatin Valley Water District (TVWD) share joint ownership of the Willamette River Water Treatment Plant (WRWTP) located in Wilsonville, Oregon. Construction of the WRWTP began in 2000 and was commissioned in 2002. The WRWTP provides potable drinking water to Wilsonville and the City of Sherwood (Sherwood) with a current production capacity of approximately 15 million gallons per day (mgd) and future production capacity of approximately 60 MGD. The WRWTP is situated on the north bank of the Willamette River at approximately River Mile 39. Water is drawn into the WRWTP through a raw water intake structure located within the river. The water then flows through an intake pipe into the raw water concrete caisson, where it is then pumped into the plant at the raw water pump station.

In 2015, Tualatin Valley Water District (TVWD) updated their master plan for their water supply system, which includes a substantial increase in potable water production at the site of the WRWTP. To meet the increased requirements, additional treatment facilities located off of the current WRWTP site have been planned to augment the capacity, but a number of WRWTP facilities have been determined to be common to the new facilities and will be relied upon to meet the long-term water production requirements. As a part of the 2015 TVWD Master Plan Update, a seismic evaluation was prepared for these “common” facilities, which included the raw water caisson, the raw water pump station, high service pump station, finished water reservoir, and operations/administration building.

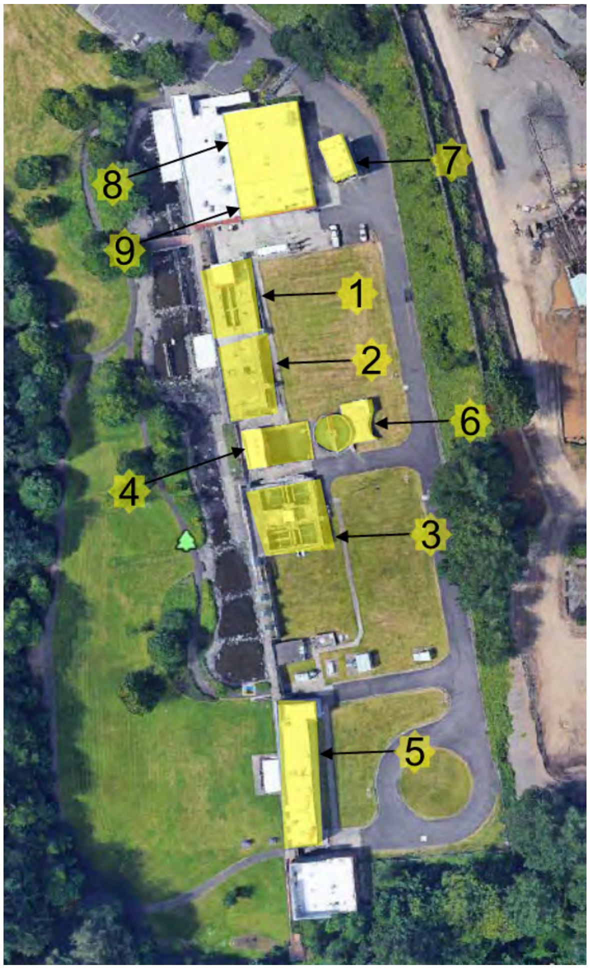
Similar to TVWD, Wilsonville is planning future upgrades and/or modifications to the WRWTP, which likewise provides an opportunity to simultaneously address any life safety and/or seismic vulnerabilities. To identify what potential vulnerabilities exist, Carollo Engineers, Inc., (Carollo) has been tasked to prepare a life safety and seismic assessment of the balance of the WRWTP facilities that were not included in the 2015 TVWD Master Plan Update. Although the plant was constructed approximately 17 years ago, seismic ground accelerations used in design and evaluation have generally increased in the Pacific Northwest, design detailing requirements in adopted building codes have become more stringent and focused, and in particular, geo-seismic hazard analyses for liquefaction and lateral spread have more well-defined methods prescribed by current building codes and evaluation standards. Therefore, in the interest of helping to ensure that the WRWTP facilities are resilient, a life safety and seismic assessment of the remaining WRWTP facilities that are not common to TVWD’s planned expansion was requested by Wilsonville. These facilities and their associated support systems and structural and architectural components, include the following (see Figure 1.1):

- Actiflo® (Ballasted Flocculation)
- Ozonation
- Filters

- Waste Washwater Equalization
- High Service Pump Station (Switchgear and Generator Rooms)
- Sludge Thickening
- Sludge Dewatering
- Chemical Storage
- Ozone Generation

This life safety and seismic assessment is a two-fold effort to both identify potential life safety deficiencies that may exist in the structural connections, equipment anchors, mechanical and electrical systems, and other ancillary components, and to identify potential seismic performance deficiencies that can jeopardize the safe and reliable operation of the WRWTP. Planning level mitigation strategies/measures to address identified deficiencies were then developed. Subsequent studies or planning adjustments may be prudent if findings at this stage suggest large-scale mitigation efforts are required.

The balance of this chapter provides a brief description of the structures, procedures, criteria, findings, and recommendations derived from the onsite walk-down and the seismic evaluation of the facilities.



1. Actiflo™
2. Ozonation
3. Filters
4. Waste Washwater
5. High Service PS
6. Sludge Thickening
7. Sludge Dewatering
8. Chemical Storage
9. Ozone Generation

Figure 1.1 WRWTP Facilities Included in the 2017 Life Safety and Seismic Assessment

1.2 Life Safety Assessment

In conjunction with the seismic assessment, Wilsonville requested that Carollo assess life safety deficiencies at the WRWTP. Carollo conducted a site visit on Tuesday, July 25, 2017, for the purpose of identifying potential life safety issues and for the purpose of fulfilling the seismic evaluation requirements of the scope of work.

The site visit was performed by James Doering, an Oregon licensed structural engineer. The site visit included both interior and exterior inspections. Interior access was limited to portions of the structures that were readily accessible and did not include entry into tanks, onto roofs, or into confined space. The plant was in full operation at the time of the site visit.

1.2.1 Findings and Recommendations

Life safety assessment findings were presented in a workshop with Wilsonville and Sherwood, held at the WRWTP on Friday, August 18, 2017. These life safety findings are summarized in Table 1.1 and include those seismic vulnerabilities that are also a potential life safety hazard. Additionally, each issue has been assigned a priority of high (H), medium (M), or low (L), which can be used to facilitate integration of any mitigation measures into separate projects or in a phased implementation over time. Where building code provisions and standards are applicable, the relevant sections have been noted. Photographs are provided in Appendix A to assist with the description of the issues that were identified.

Table 1.1 Summary of Life Safety Findings

Issue #	Location	Description	Code Reference	Recommendation	Cost(1)(2)(3)	Priority(4)
LS1	Various	Tread plate hatches do not typically have any provisions for installing temporary fall protection barriers when in use.	OSHA 1910.23	Install sleeves or other hardware for temporary fall protection systems around hatches.	$12,000	H
LS2	Various	Color coded chemical safety warning signs at exterior locations are faded so that colors are not clear any longer.	2014 OFC (NFPA 704)	Replace safety signs throughout the plant as required.	< $2,000	H
LS3	Actiflo® / Ozonation / Filters	Exterior stair guardrail height is less than 42 inches above the stair tread and has no dedicated handrail. Installation met 1997 UBC provisions, but not current code.	2014 OSSC, Chapter 10	Replace guardrail with current code-compliant installation.	$17,000	M
LS4	Actiflo® / Higher Service PS / Chemical Storage	Doors exiting rooms that have rated electrical service that is 1,200 amps or greater do not have panic hardware.	2014 OSSC, Chapter 10	Provide panic door hardware on 4 affected doors.	$7,000	H
LS5	Ozone Generation / Chemical Storage	Doors serving occupancy Group H are lacking panic hardware. Also, the door that connects the Ozone Generation Room to the Administration Building swings into the Ozone Generation Room, which is a Group H occupancy.	2014 OSSC, Chapter 10	Provide panic door hardware on 3 doors and replace the door between the Ozone Generation Room and the Administration Building to reverse the door swing direction.	$9,500	H
LS6	Ozone Generation / Chemical Storage	Chemical piping passes directly over exit egress routes at the southwest door of the Ozone Generation Room, the east door of the Chemical Room, and the west door of the Chemical Room.		Add secondary containment pans below the chemical piping over exit routes.	< $2,000	M
LS7	Various	Doors were found propped open during the site visit, which may suggest that the ventilation in the rooms may not be operating effectively and/or efficiently.		Verify that the ventilation system is operating as intended.	N/A	L
LS8	Actiflo® / Filters	The west guardrail on the top deck of the Actiflo® Basin and the top side of the ladder pit at the filters lack kick plates.		Install new kickplates at these locations.	< $2,000	L

Table 1.1 Summary of Life Safety Findings (Continued)

Issue #	Location	Description	Code Reference	Recommendation	Cost$^{(1)(2)(3)}$	Priority$^{(4)}$
LS9	Actiflo® / Ozonation / Filters	The below-grade galleries have active weeping leaks that are coming from cracks in the tank walls and through expansion joints leaving the floor wet and potentially slippery.		Pressure inject a hydrophobic sealant into active leaks to seal them. Apply an exterior (negative side) waterstop on the surface of the joint.	$20,000 (100 lineal foot allowance)	M
LS10	Actiflo® / Ozonation / Filters	The below-grade galleries typically have wet floors due to leaking walls and leaking pipes/equipment. The electrical receptacles do not appear to have any GFCI protection.		Remove and replace the electrical receptacles with ones that are GFCI protected.	< $2,000	M
LS11	Ozonation	The south stairwell does not have a dedicated ventilation system that serves it directly.		Investigate if ventilation is sufficient and provide as required.	N/A	M
LS12	Filters	The maximum distance of travel to exit the north door is approximately 85 feet. The maximum distance to a single exit per the building code is 75 feet. The doors at the east end of the Filter Gallery exit to a ladder pit, which is not considered to be an exit for egress determination.	2014 OSSC, Chapter 10	Add a fire-rated door at the bottom of the stairs and add signage to the existing ladder pit door to clarify that it is not an exit. This may also require revision to the ventilation of the existing stair.	$8,000	M
LS13	Waste Washwater	The ladder into the basin does not have any permanent tie-off points for a fall restraint system.		Verify how fall restraint is provided when using the ladder and provide additional hardware as required.	< $2,000	M
LS14	Sludge Dewatering	The building roof does not appear to have any overflow scuppers.	2014 OSSC, Chapter 15	Saw-cut out a notch in the parapet wall and install a scupper and downspout.	$6,000	L
LS15	Ozone Generation Room	The emergency shut-off switch for the ozone generation equipment is located between the sensor and the generation equipment.		Install emergency shut-off switch at two other exits from the building.	$10,000	M
LS16 (S4)	High Service Pump Station	The roof diaphragm shear capacity is exceeded at approximately 50% of the roof deck area with DCR's that vary from 1.82 to 2.25. Refer to Figure 1.7.	ASCE 41-13, Tier 1	Replace existing deficient deck sections with 16 GA corrugated steel decking.	$85,000	H

Issue #	Location	Description	Code Reference	Recommendation	Cost$^{(1)(2)(3)}$	Priority$^{(4)}$
LS17 (S6)	High Service Pump Station	Roof deck shear transfer to the interior wall ledger bolts have DCR's of 3.20 to 3.90. Refer to Figure 1.10.	ASCE 41-13, Tier 1	Add a new top plate over the interior shear walls and install epoxied anchors as required. Refer to Figure 1.11.	\$20,000$^{(5)}$	H
LS18 (S7)	Solids Dewatering Building	The building has no lateral load resisting system in the transverse direction at the first floor level. The existing concrete joint at the elevated slab to the east and west walls does not have any seismic detailing to establish any concrete moment frame.	ASCE 41-13, Tier 1	Provide steel braced frames at the exterior of the building at the east side that braces the building at the second floor level. This system is anticipated to include three braces, each with their own concrete grade beam. It is assumed that the existing stair will need to be relocated to the west side of the building. Refer to Figure 1.12.	\$210,000	H
LS19 (S10)	Various (estimated at 8 locations)	The space heaters at all facilities are laterally braced above their center of gravity, which allows the heaters to sway during an earthquake. The space heaters at the Switchgear Room at the High Service Pump Station are not braced at all.	ASCE 41-13, Tier 1	Provide seismic bracing.	\$5,000	H
LS20 (S13)	Chemical Storage / Ozone Generation Room	The chemical pipes that run through the center of the Chemical Storage Room are not seismically braced. The balance of the chemical pipes in the Chemical Storage Room and Ozone Generation Room lack longitudinal seismic bracing.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	\$10,000	M
LS21 (S14)	Ozone Generation Room	The ozone and LOX piping is not seismically braced.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	\$5,000	M

Notes:
1. Cost estimate includes an indirect cost multiplier of 2.0, which is meant to account for contingency, overhead, profit, taxes, etc...
2. The cost threshold is considered to be \$2,000. Anything less than this amount will be indicated as such.
3. Soft costs, such as, engineering services, inspection, permitting, etc..., are not included in the cost estimate.
4. H = High, M = Medium, L = Low.
5. Assumes that vulnerability S4 is addressed simultaneously, otherwise the cost will need to include removal/replacement of the roofing.

1.3 Seismic Evaluation

The seismic evaluation of the WRWTP facilities consisted of both analytical and visual assessments. The analytical review is a quantitative estimate of the potential material stresses of the structural members when subjected to estimated loads due to self-weight, soils, water, seismic, and other potential loads that may be present during an earthquake. The visual condition assessment is a qualitative evaluation of the structural conditions, which can have a significant bearing on the available structural capacity and the ability of the structure to remain serviceable for a period of time. The goal of this evaluation is to identify those structural vulnerabilities and conditions, whether by analytical or visual assessment methods, that have the potential to have a significant impact on the ability of the facility to remain serviceable during and after an earthquake, or that pose life safety risks. Initially, the evaluation is comprised of data gathering, establishment of a seismic evaluation and acceptance criteria, assumptions regarding material properties, and mathematical analyses of the structural systems and members. The results of this evaluation include both quantitative and qualitative findings, which may serve as a basis for the development of mitigation strategies.

1.3.1 Structural Description

The subject facilities were constructed between 2000 and 2002 under a design-build contract. Construction is generally comprised of cast-in-place concrete, masonry, and steel materials. Refer to Figure 1.1 for a map of the facilities included in the scope of work.

1.3.1.1 Actiflo® (Ballasted Flocculation)

The Actiflo® facility is a partially buried process basin constructed of cast-in-place concrete construction and includes a small single-story masonry building that houses equipment to support the process. The footprint of the basin is approximately 40 feet wide and 70 feet long with a height of 22 feet from the top of the roof deck to the top of the bottom slab. The top of the basin is located approximately 6 feet above the surrounding grade, which slopes downward toward the river to the south. The basin includes a small gallery that is located below grade at the south side of the structure. The basin has numerous interior concrete walls that form the cells and channels for the water treatment process. The basin abuts the north end of the Ozonation basin, but is separated by an expansion joint. The single-story masonry building on top of the Actiflo® basin has a floor area of approximately 400 square feet and has a steel-framed roof with light gauge corrugated steel deck diaphragm and open-web steel joists. The building roof is located approximately 11 feet above the floor.

The facility also includes electrical equipment, pumps, and piping that are supported off of the structure. The Actiflo® building is also equipped with a space heater that is suspended from the roof framing.

1.3.1.2 Ozonation

The Ozonation facility is a partially buried process basin that is constructed of cast-in-place concrete construction. The footprint of the basin is approximately 40 feet wide by 70 feet long with a height of 25 feet from the top of the roof deck to the top of the bottom slab. The top of the basin is located approximately 14 feet above the surrounding grade at the south side of the structure. The basin includes a gallery located below grade that is interconnected to the Actiflo®

gallery. The basin has numerous interior concrete walls and slabs that form the cells and channels of the water treatment process.

The facility also includes mechanical equipment and piping that is supported from the structure. Ozone destruct pipes are located on the roof deck.

1.3.1.3 Filters

The Filter facility is a partially buried process basin that is constructed of cast-in-place concrete construction and includes a small steel-framed control house supported on the top deck of the structure. The footprint of the basin is approximately 70 feet wide by 70 feet long with a height of 19 feet from the top of the roof deck to the top of the bottom slab. The top of the basin is located approximately 10 feet above grade at the north side of the structure. The basin includes a gallery located below grade and traverses the middle of the structure from east to west. The basin has numerous interior concrete walls and slabs that form the cells and channels of the water treatment process.

The facility also includes large diameter piping and blower equipment that is located in the gallery below grade. The filters are also equipped with braced/stiffened launders.

1.3.1.4 Waste Washwater Equalization

The Waste Washwater Equalization facility includes a basin that is constructed of cast-in-place concrete construction and includes an 18 feet by 36 feet, single-story masonry building supported on top of the basin walls at the west end of the structure. The footprint of the basin is approximately 36 feet wide by 63 feet long with a height of 21 feet from the top of the wall to the top of the bottom slab. The basin is open to the atmosphere to the east of the building and covered by the building floor slab at the west side. The building has an approximate floor area of 600 square feet and has a steel-framed roof constructed with a light gauge corrugated steel deck diaphragm and open-web steel joists. The building roof is located approximately 11 feet above the floor.

The building houses vertical turbine pumps, electrical equipment, and a space heater that is suspended from the roof framing.

1.3.1.5 High Service Pump Station (Switchgear and Generator Rooms)

The pump station is constructed over the top of the east side of the clearwell and is a single-story building that has a footprint of approximately 32 feet by 138 feet. The interior and exterior walls are constructed of cast-in-place concrete and the roof is constructed with a light gauge corrugated steel deck with open-web steel joists. The building roof is located approximately 22 feet above the floor. The building has a generator room, switchgear room, and a pump station room that are all separated by full-height interior concrete walls.

The generator room houses a diesel engine generator along with associated exhaust piping. The switchgear room houses electrical equipment along with numerous suspended cable tray runs that distribute cable/wiring to the equipment. The pump station includes vertical turbine pumps, more electrical cable tray, and a bridge crane. The switchgear and pump station rooms include space heaters that are suspended from the roof framing.

1.3.1.6 Sludge Thickening

The sludge thickening facility is comprised of a 35-foot diameter circular thickener with a side water depth of 12 feet and a small pump station located below grade. The structures are constructed with cast-in-place concrete construction. The thickener is partially buried with the top of the perimeter wall located approximately 6.5 feet above the surrounding grade. The pump station has a wet well section and a dry area where the pumps reside. The pump station has an area of approximately 800 square feet and the bottom slab is located approximately 16 feet below the finished grade.

The pump station room houses pumps that are mounted on the bottom slab.

1.3.1.7 Sludge Dewatering

The Sludge Dewatering facility is comprised of a two-story building that is constructed of cast-in-place concrete construction. The building has a footprint that is approximately 22 feet wide by 34 feet long. The building is located entirely above grade and has first and second floor heights of approximately 16 and 14 feet, respectively. The first floor serves as a truck bay and is completely open at the north and south ends. The second floor houses sludge dewatering equipment and is enclosed by cast-in-place concrete walls on all four sides. The roof is framed with a light gauge corrugated steel deck diaphragm and open web steel joists. The building is founded on shallow concrete spread footings below the east and west walls.

The equipment room, located at the second floor, houses dewatering equipment and associated electrical equipment. The room also includes a space heater that is suspended from the roof framing. The truck bay also includes process piping and conveying equipment that is suspended from the bottom side of the second floor concrete deck.

1.3.1.8 Chemical Storage Room

The Chemical Storage Room is located within a building that houses the Administration Facility and the Ozone Generation Room. The Chemical Storage Room is situated at the northeast corner of the building and is separated from the Administration Facility to the west and the Ozone Generation Room to the south by interior reinforced masonry walls. The Chemical Storage Room has an approximate footprint measuring 48 feet by 70 feet. The building has one story and is founded on shallow spread footings. The roof structure is comprised of open-web steel joists with a light gauge corrugated steel deck diaphragm. The roof framing is supported down to the foundation by tube steel columns and masonry bearing walls.

The Chemical Storage Room houses several chemical tanks that have their own secondary containment. The room also has an abundance of small diameter chemical piping that traverses the room and is suspended from the roof framing.

1.3.1.9 Ozone Generation

The Ozone Generation Room is located within a building that houses the Administration Facility and the Chemical Storage Room. The Ozone Generation Room is situated at the southeast corner of the building and is separated from the Administration Facility to the west and the Chemical Storage Room to the north by interior reinforced masonry walls. The Ozone Generation Room has an approximate footprint measuring 30 feet by 70 feet. The building has one story and is founded on shallow spread footings. The roof structure is comprised of open-web steel joists with a light gauge corrugated steel deck diaphragm. The roof framing is supported down to the foundation by the masonry bearing walls.

The Ozone Generation Room houses ozone generation equipment along with the associated ozone and LOX piping. Chemical pipes are also suspended from the roof framing and traverse the room at the west end.

1.3.2 Structural Conditions

Based on our review of the available documentation and visual inspection during the site visit, the buildings appear to be in good condition with no obvious signs of deterioration, corrosion, or damage that would be considered to reduce the capacity of the structural members.

1.3.3 Seismic Evaluation Approach

Numerous standards and guidelines have been published by professional organizations and government agencies to assist the public with the seismic evaluation and retrofit of existing structures. To date, most of these publications have been developed for buildings, with a focus on commercial buildings. American Society of Civil Engineers (ASCE) 41-13, "Seismic Evaluation and Retrofit of Existing Buildings," is the most current seismic evaluation standard, which is intended to be applied to buildings. Since many of the structures included in the scope of work are non-building structures with structural systems and load paths that are not similar to buildings, for the seismic evaluation we chose to apply the relevant design standard, which is American Concrete Institute (ACI) 350.3-06, "Seismic Design of Liquid-Containing Concrete Structures and Commentary," recognizing that no relevant seismic evaluation guides or standards are available for concrete tanks. The balance of the buildings and non-structural contents were evaluated using ASCE 41-13.

In general, the seismic evaluation process is comprised of the following steps when using ASCE 41-13:

- Establish the seismic evaluation criteria:
  - Selection of a performance objective
  - Define the building performance levels
  - Define the seismic hazard level
- Collect and review as-built information.
- Perform seismic/structural analyses:
  - Tier 1 level
  - Tier 2 level as required
- Identify vulnerabilities.
- Recommend mitigation measures.

The seismic evaluation of the water-bearing structures made use of ACI 350.3-06, which does not have a formal seismic evaluation process. In this case, the structure is evaluated against design standards for new structures, except that the load combinations were adjusted to more accurately reflect the actual load scenarios.

The seismic evaluation for the building structures using ASCE 41-13 is multi-tiered, with Tier 1, referred to as the screening procedure, and Tier 2, referred to as the deficiency based evaluation procedure. Tier 1 is a rapid evaluation procedure that involves completion of checklists that include a list of potential deficiencies. Each checklist item requires the evaluator to select a status of compliant (C), non-compliant (NC), not applicable (N/A), and unknown (U). Overall, the Tier 1 screening procedure checklists include one for the basic configuration, one for the structural systems of the particular building type, and one for non-structural elements. Checklists are completed by the combination of a physical reconnaissance of the building and by performing quick-check calculations that are intended to allow the evaluator to make a rapid assessment.

When a checklist item is determined to be non-compliant or where a potential vulnerability not included in the checklists is to be evaluated, the seismic evaluation continues onto Tier 2. The Tier 2 evaluation requires a more in-depth analysis for the item being considered and may include a complete building analysis that may involve linear static or linear dynamic modeling depending on the Tier 1 deficiency. The Tier 2 evaluation involves checking the structural member for strength or deformation capacity against the seismic load. Where a member is found to have a demand-capacity ratio (DCR) less than 1.0, the member is identified as being non-compliant.

1.3.4 Seismic Evaluation Criteria

Defining the seismic evaluation criteria is the first step in the evaluation process. It sets the stage for the execution of the evaluation work. This step involves the selection of a performance objective, definition of building performance levels, and the definition of the seismic hazard level.

1.3.4.1 Performance Objectives

The performance objective is typically a two-fold objective that establishes building performance levels for different seismic hazards. For example, a typical performance objective for a non-essential building might be meeting the life safety performance level when subjected to an earthquake having a return period of 225 years and meeting the collapse prevention performance level when subjected to an earthquake having a return period of 975 years. The scope of work indicates that the structures are to be evaluated for a life safety performance for a seismic event having a return period of 500 years, which is an objective that is typically associated with new construction for non-essential buildings. The performance objective for existing building structures has been adjusted to consider that the existing structures require an increased level of seismic performance due to their inherent use importance. However, to apply this increased performance objective against the 500-year and 2500-year event hazard levels can result in exceedingly conservative findings for existing buildings. Typically, it is acceptable to tolerate a slightly reduced hazard level when seeking to identify seismic deficiencies in an existing building. Therefore the hazard level has been adjusted downward for the existing buildings, but the performance requirements have been elevated above that of the life safety level. This is consistent with the approach used for the evaluation of the common facilities under the 2015 TVWD Master Plan Update.

It is the prevailing practice to assign Risk Category III classification to water treatment plant structures and assign Risk Category IV classification to essential facilities, such as fire stations and emergency response centers, and more critical components of water treatment plants, such as, reservoirs, pump stations, and intake structures. Risk Category III/IV structures are evaluated with a more stringent performance objective, since an interruption in the operation of these facilities can result in a significant and immediate hazard to the general public.

Non-structural components, such as equipment anchorage, piping, and architectural features are evaluated on a qualitative basis in accordance with ASCE 41-13 checklists.

1.3.4.2 Building Performance Levels

Basic Performance Objective for Existing Buildings (BPOE) levels include both structural and non-structural performance levels. The structural performance levels defined in ASCE 41-13 are as follows:

- S-1: Immediate Occupancy
- S-2: Damage Control
- S-3: Life Safety
- S-4: Limited Safety
- S-5: Collapse Prevention

Non-structural performance levels defined in ASCE 41-13 are as follows:

- N-A: Operational
- N-B: Position Retention
- N-C: Life Safety

The BPOE for Risk Category III structures establishes a structural performance level of S-2 (Damage Control) and a non-structural performance level of N-B (Position Retention). While that for Risk Category IV structures establishes a structural performance level of S-1 (Immediate Occupancy) and a non-structural performance level of N-A (Operational). These performance levels are evaluated against the basic seismic hazard level for existing buildings. Refer to Table 1.2 for a summary of the structural and non-structural performance levels assigned to the facilities in this evaluation. Tanks, while not explicitly covered by ASCE 41-13, have similar performance levels that are achieved by following the seismic design provisions of ACI 350.3-06.

Table 1.2 Summary of Performance Levels

Structure	Risk Category	Structural Performance Level	Non-structural Performance Level
Actiflo®	III	S-2	N-B
Ozonation	III	S-2	N-B
Filters	III	S-2	N-B
Waste Washwater Equalization	III	S-2	N-B
High Service Pump Station	IV	S-1	N-A
Sludge Thickening	III	S-2	N-B
Sludge Dewatering	III	S-2	N-B
Chemical Storage	III	S-2	N-B
Ozone Generation	III	S-2	N-B

1.3.4.3 Seismic Hazard Level

The BPOE for existing buildings requires that the Tier 1 and Tier 2 evaluations be performed using a seismic hazard level input referred to as the basic safety earthquake-1 or BSE-1E, which is the ground motion level associated with an earthquake that has a 20 percent probability of being exceeded in a 50-year period. The ground accelerations associated with this hazard level have been derived from the 2008 United States Geological Survey (USGS) seismic data available at https://earthquake.usgs.gov/designmaps/us/application.php.

The seismic hazard level used for the evaluation of the tanks is consistent with an earthquake that has a 10 percent probability of being exceeded in a 50-year period. The ground accelerations associated with this hazard level have been derived from the 2008 USGS seismic data available at https://earthquake.usgs.gov/designmaps/us/application.php.

1.3.4.4 Seismic Evaluation Parameters

The seismic evaluation parameters are set forth in Table 1.3.

Table 1.3 Seismic Evaluation Parameters

Parameter	Value
Risk Category	III / IV
Structural Performance Level	S-2 / S-1
Non-Structural Performance Level	N-B / N-A
Soil Site Class	D
Seismic Hazard Level for Buildings	ASCE 41-13 / BSE-1E
S_{XS}	0.445
S_{X1}	0.254
Seismic Hazard Level for Tanks	ACI 350.3 / ASCE 7-10
S_{DS}	0.696
S_{D1}	0.435
T_L	16 sec

1.3.5 Data Collection and Review

To obtain data and information necessary for use in the evaluation of the facilities, we reviewed the following documents and media:

- Record drawings for the Willamette River Water Treatment Plant, prepared by Montgomery Watson Harza (MWH), dated December 2002.
- Geotechnical Analyses and Recommendations in Support of 30 Percent Design Effort, prepared by Squier Associates, dated March 2000.
- Geotechnical Report for the WRWTP Lower Site and Upper Site, prepared by Shannon & Wilson (S&W), dated November 2016.

Based on a review of these documents, the material properties used in this evaluation are summarized in Table 1.4.

Table 1.4 Material Properties

Material	Property
Concrete compressive strength	f'_c = 4,000 psi
Masonry compressive strength	f'_m = 1,500 psi
Reinforcing steel yield strength	f_y = 60,000 psi
Wide-flange steel yield strength	f_y = 36,000 psi
Steel shape yield strength	f_y = 36,000 psi
Steel deck yield strength	f_y = 38,000 psi

1.3.6 Analysis Procedures

Analysis procedures followed the requirements set forth in ASCE 41-13. For the most part, the structures did not have any significant irregularities that prohibited the use of linear static procedures and two-dimensional mathematical models.

Two-dimensional linear static analyses were advanced using a combination of calculation tools. Where required by ASCE 41-13 and where structural framing systems and load paths were sufficiently complicated, we used three-dimensional mathematical models, which were performed using STAADPro v8i, a finite element structural analysis software package. Where inclusion of hydrostatic and hydrodynamic loads were necessary, Carollo's proprietary, in-house spreadsheets tailored for analysis of water-bearing structures were used.

The analyses include the structure above grade and those portions of the structure below grade that are within the seismic load path for load resistance. Loads applied to the structures include dead loads, live loads, surcharge loads, active earth pressure, soil seismic pressures, fluid loads, hydrodynamic loads, and inertial seismic loads. Load combinations analyzed were limited to those that include seismic loads. Load intensities and material weights assumed for the evaluation are presented in Table 1.5.

Refer to Appendix B for the Tier 1 checklists and Appendix C for the supporting calculations for both the Tier 1 and Tier 2 level seismic evaluations.

Table 1.5 Load Intensities

Material	Property
Unit weight of concrete	150 pcf
Unit weight of water	62.4 pcf
Unit weight of steel	490 pcf
Unit weight of soil	110 pcf
Active earth pressure	55 psf/ft
Soil seismic pressure(1)	35 psf/ft

Notes:

1. Applied as in inverted triangular load distribution. See Squier 2000.

1.3.7 Acceptance Criteria

The analysis involves the estimation of seismic load and deformation demands placed upon structural members. These demands are compared against their estimated capacity, which is a function of the member proportions, material properties, and desired performance level. The metric used in this evaluation to quantify the degree of distress of an existing member or connection is referred to as the "demand-capacity ratio" or DCR.

$$\mathrm{DCR} = \frac{\text{Load Demand}}{\text{Available Capacity}}$$

DCR values that exceed 1.0 are typically considered to have exceeded their capacity for the evaluated performance level.

The estimated capacity is a function of the material properties. For this evaluation, the material properties have been obtained from the record construction documents. For Tier 2 investigations and beyond, ASCE 41-13 requires that a knowledge factor be applied to the material property depending on what type of construction documents the material information was obtained from. For any Tier 2 evaluations, a knowledge factor of 0.75 was applied where the material properties were not specified on the construction documents and a knowledge factor of 0.90 was applied where the material properties were obtained from the construction drawings, specifications, mill certificates and material test results. Material test data from the original construction was not available to justify use of a higher knowledge factor.

1.4 Findings and Recommendations

Findings include structural vulnerabilities and non-structural vulnerabilities. A geo-seismic hazard was previously provided for the site as part of the 2015 TVWD Master Plan Update. A discussion on the impact to the subject facilities is included in Section 2.5.

Structural vulnerabilities identified for the subject facilities and important connected components, the recommended mitigation, and estimated costs are provided in Table 1.6. Additionally, each finding has been assigned a priority of high (H), medium (M), or low (L), which can be used to facilitate integration of mitigation measures into separate projects or in a phased implementation over time. Photographs are provided in Appendix A to assist with the description of the issues that were identified. Findings are also accompanied with figures as required to show the recommended mitigation.

Table 1.6 Summary of Seismic Vulnerabilities

Vulnerability	Location	Description	Reference	Recommendation	Cost$^{(1)(2)(3)}$	Priority$^{(4)}$
S1	Waste Washwater Equalization	The horizontal reinforcing steel in the north and south basin walls at the east corners (#8 @ 12" oc) have a DCR of 1.53 for soil seismic loads. Refer to Figure 1.2.	ACI 350.3-06	Install three (3) concrete braces across the width of the basin with intermediate column support as required to brace the north and south walls. Braces should be located at the mid-height of the wall. Refer to Figure 1.3.	$52,000	L
S2	Waste Washwater Equalization	The out-of-plane wall shear at the north and south walls where the existing concrete beam below the east wall of the building intersects the walls has a DCR of 1.67 for soil seismic loads. Refer to Figure 1.4.	ACI 350.3-06	Install three (3) concrete braces across the width of the basin with intermediate column support as required to brace the north and south walls. Braces should be located at the mid-height of the wall. Refer to Figure 1.2.	$52,000$^{(5)}$	L
S3	High Service Pump Station	The roof joist wall anchorage along the east and west walls of the pump station have a DCR of 1.55. Refer to Figure 1.5.	ASCE 41-13, Tier 1	Add new wall anchorage along the east and west walls mid-way between the existing roof joists. Refer to Figure 1.6.	$72,000$^{(6)}$	H
S4	High Service Pump Station	The roof diaphragm shear capacity is exceeded at approximately 50% of the roof deck area with DCR's that vary from 1.82 to 2.25. Refer to Figure 1.7.	ASCE 41-13, Tier 1	Replace existing deficient deck sections with 16 GA corrugated steel decking.	$85,000	H
S5	High Service Pump Station	The tension capacity of the diaphragm chord at the pump room has a DCR of 1.20 at the connections at the east windows. Refer to Figure 1.8	ASCE 41-13, Tier 1	Strengthen the existing chord connections as required. Refer to Figure 1.9.	$5,000	M
S6	High Service Pump Station	Roof deck shear transfer to the interior wall ledger bolts have DCR's of 3.20 to 3.90. Refer to Figure 1.10.	ASCE 41-13, Tier 1	Add a new top plate over the interior shear walls and install epoxied anchors as required. Refer to Figure 1.11.	$20,000$^{(6)}$	H

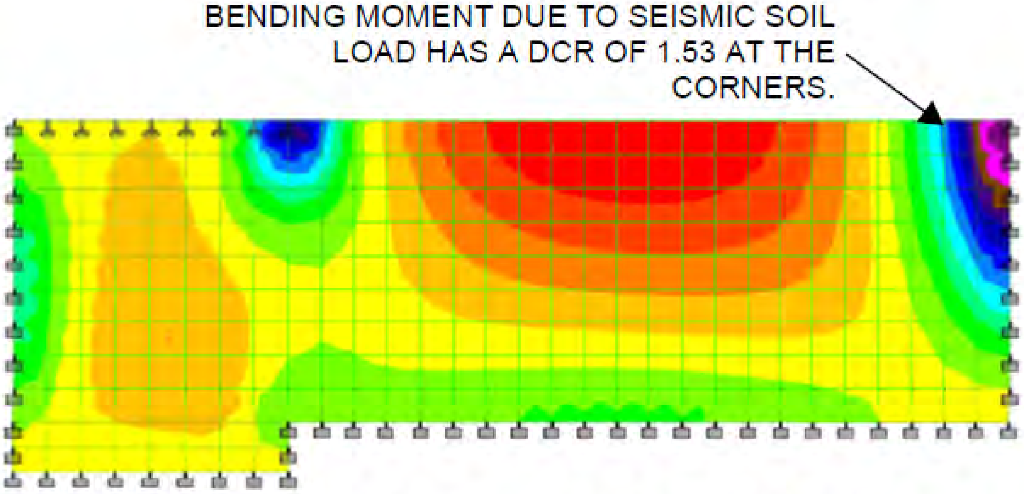
Table 1.6 Summary of Seismic Vulnerabilities (Continued)

Vulnerability	Location	Description	Reference	Recommendation	Cost[(1)(2)(3)]	Priority[(4)]
S7	Solids Dewatering Building	The building has no lateral load resisting system in the transverse direction at the first floor level. The existing concrete joint at the elevated slab to the east and west walls does not have any seismic detailing to establish any concrete moment frame.	ASCE 41-13, Tier 1	Provide steel braced frames at the exterior of the building at the east side that braces the building at the second floor level. This system is anticipated to include three braces, each with their own concrete grade beam. It is assumed that the existing stair will need to be relocated to the west side of the building. Refer to Figure 1.12.	$210,000	H
S8	Solids Dewatering Building	The roof joist wall anchorage along the east and west walls of the building have a DCR of 1.17.	ASCE 41-13, Tier 1	Add new wall anchorage along the east and west walls mid-way between the existing roof joists. Refer to Figure 1.6.	$32,000	M
S9	Solids Dewatering Building	The foundation elements do not have adequate ties across the building, as the floor slab is not connected to the walls or the footing.	ASCE 41-13, Tier 1	Tie the existing floor slab to the walls, which are already doweled to the existing footings. The retrofit is anticipated to include stainless steel angles and epoxy anchors. Refer to Figure 1.13.	$13,000	M
S10	Various (estimated at 8 locations)	The space heaters at all facilities are laterally braced above their center of gravity, which allows the heaters to sway during an earthquake. The space heaters at the Switchgear Room at the High Service Pump Station are not braced at all.	ASCE 41-13, Tier 1	Provide seismic bracing.	$5,000	H
S11	Ozonation	The ozone destruct piping located on the top deck of the Ozonation tank is not seismically braced.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipe down to the concrete deck.	$5,000	M
S12	High Service Pump Station	The cable trays lack longitudinal seismic bracing.	ASCE 41-13, Tier 1	Provide longitudinal seismic bracing of the cable tray.	$5,000	M

Table 1.6 Summary of Seismic Vulnerabilities (Continued)

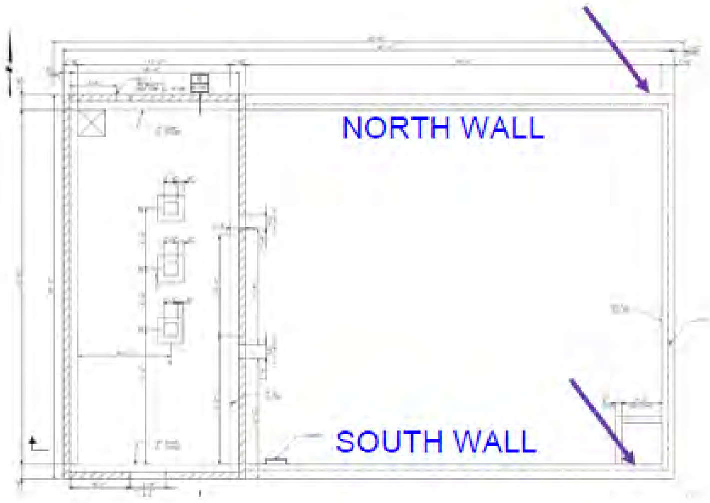
Vulnerability	Location	Description	Reference	Recommendation	Cost(1)(2)(3)	Priority(4)
S13	Chemical Storage / Ozone Generation Room	The chemical pipes that run through the center of the Chemical Storage Room are not seismically braced. The balance of the chemical pipes in the Chemical Storage Room and Ozone Generation Room lack longitudinal seismic bracing.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	$10,000	M
S14	Ozone Generation Room	The ozone and LOX piping is not seismically braced.	ASCE 41-13, Tier 1	Provide seismic bracing of the pipes as required.	$5,000	M

Notes:
1. Cost estimate includes an indirect cost multiplier of 2.0, which is meant to account for contingency, overhead, profit, taxes, etc…
2. The cost threshold is considered to be $2,000. Anything less than this amount will be indicated as such.
3. Soft costs, such as, engineering services, inspection, permitting, etc…, are not included in the cost estimate.
4. H = High, M = Medium, L = Low.
5. The same mitigation recommended for vulnerability S1 will address S2.
6. Assumes that vulnerability S4 is addressed simultaneously, otherwise the cost will need to include removal/replacement of the roofing.



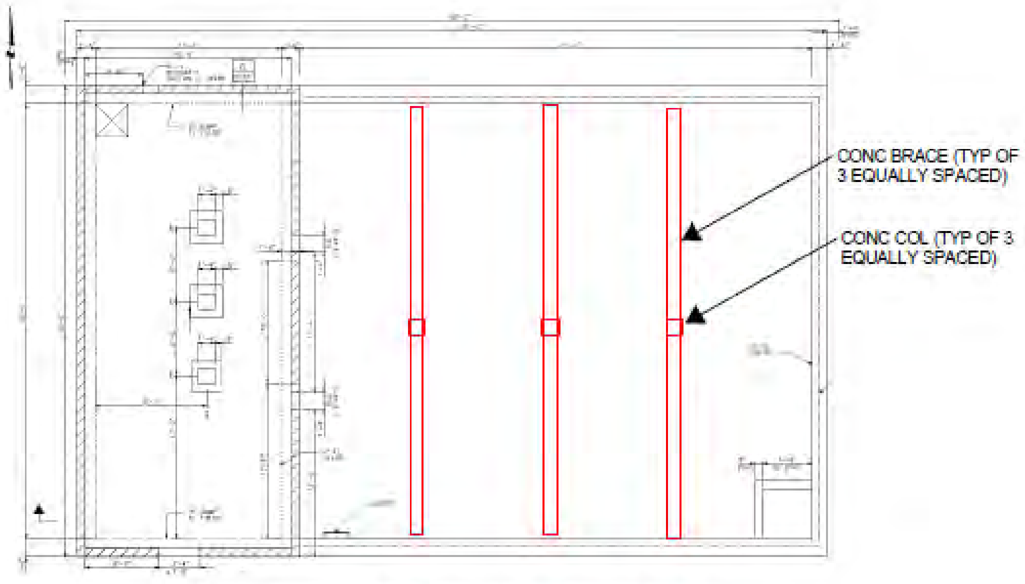
BENDING MOMENT DUE TO SEISMIC SOIL LOAD HAS A DCR OF 1.53 AT THE CORNERS.

ELEVATION OF THE NORTH WALL LOOKING NORTH WITH BENDING CONTOURS.

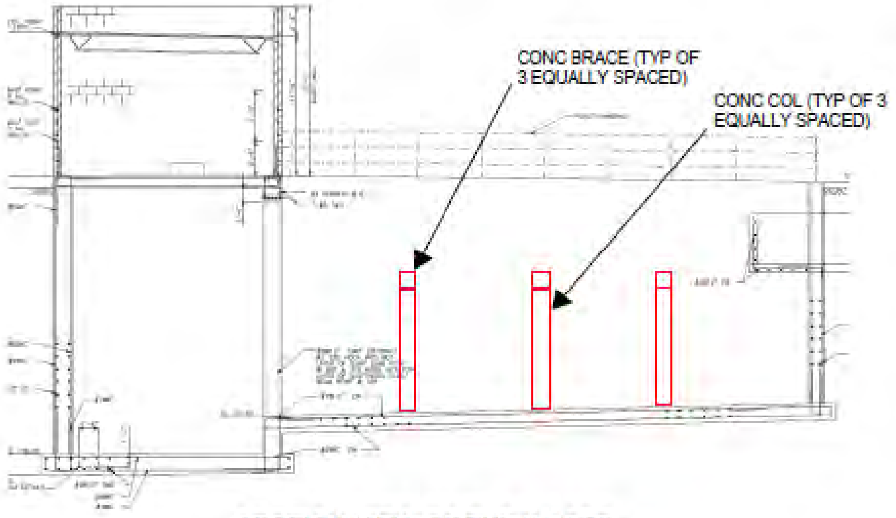


PLAN VIEW OF THE WASTE WASHWATER EQUALIZATION BASIN.

Figure 1.2 Negative Bending Stresses on the Exterior of the North and South Walls at the East Corners Exceed the Reinforcing Steel Capacity

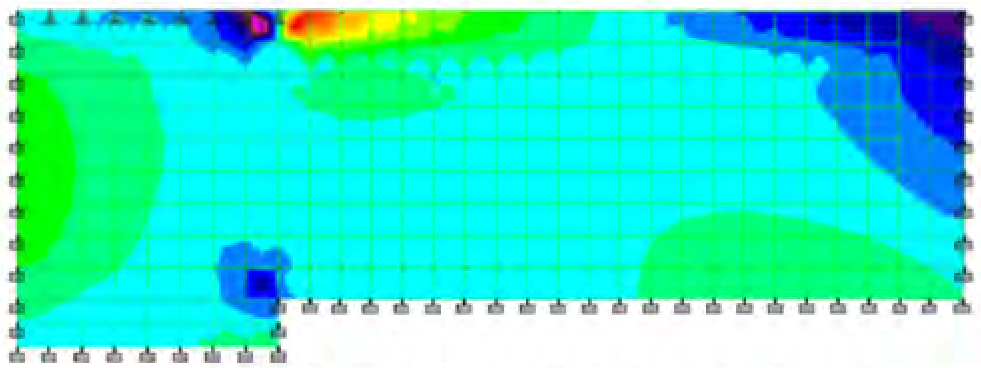


PLAN VIEW OF THE WASTE WASHWATER EQUALIZATION BASIN.



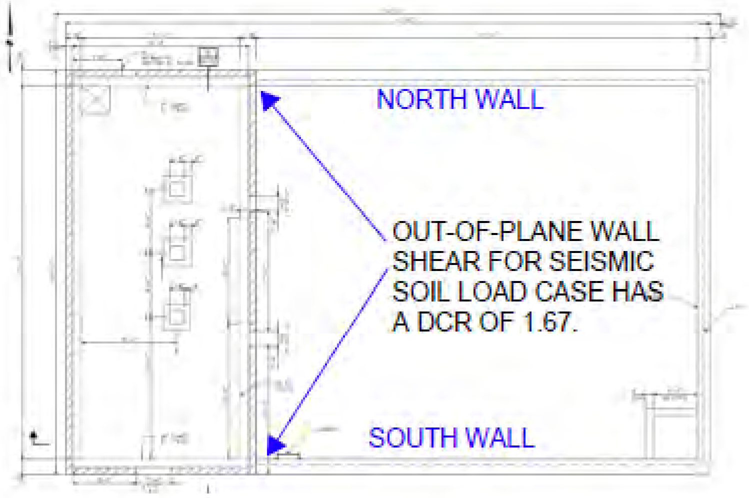
SECTION VIEW OF THE WASTE WASHWATER EQUALIZATION BASIN.

Figure 1.3 Addition of Concrete Braces to Reduce the Bending and Out-of-Plane Shear Forces Applied to the North and South Walls of the Waste Washwater EQ Basin



OUT-OF-PLANE WALL SHEAR FOR SEISMIC SOIL LOAD CASE HAS A DCR OF 1.67 AT CONC BEAM INTERSECTION AT THE NORTH AND SOUTH WALLS.

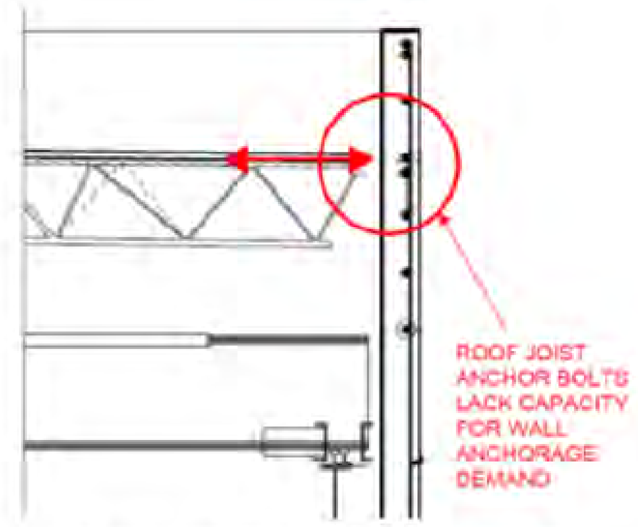
ELEVATION OF THE NORTH WALL LOOKING NORTH WITH SHEAR CONTOURS SHOWN.



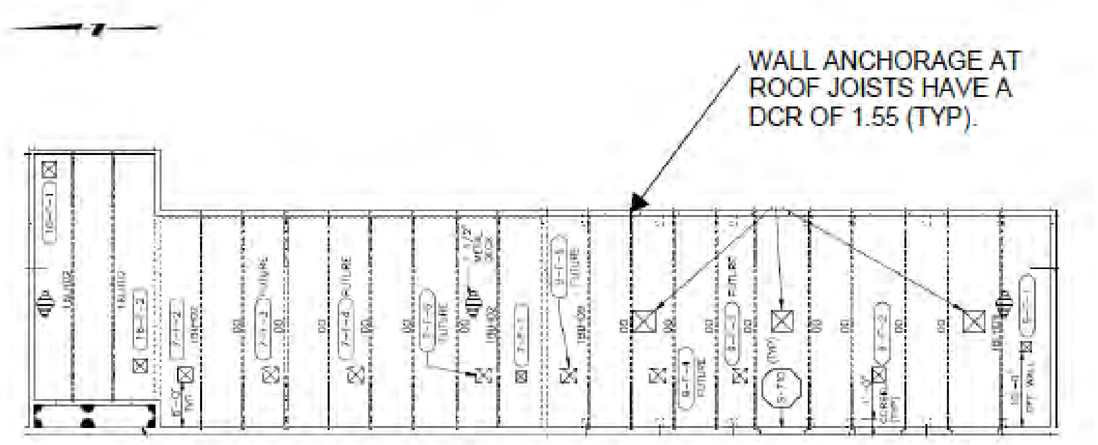
OUT-OF-PLANE WALL SHEAR FOR SEISMIC SOIL LOAD CASE HAS A DCR OF 1.67.

PLAN VIEW OF THE WASTE WASHWATER EQUALIZATION BASIN.

Figure 1.4 Out-of-Plane Shear Force Due to Soil Seismic Loads Exceeds the Wall Shear Capacity at the Intersection of the Concrete Beam with the North and South Walls



PARTIAL SECTION OF THE BUILDING AT THE ROOF LEVEL.



PLAN VIEW OF THE HIGH SERVICE PUMP STATION ROOF.

Figure 1.5 Wall Anchorage Forces at the Roof Joist Connections to the Walls Exceed the Existing Anchorage Capacity

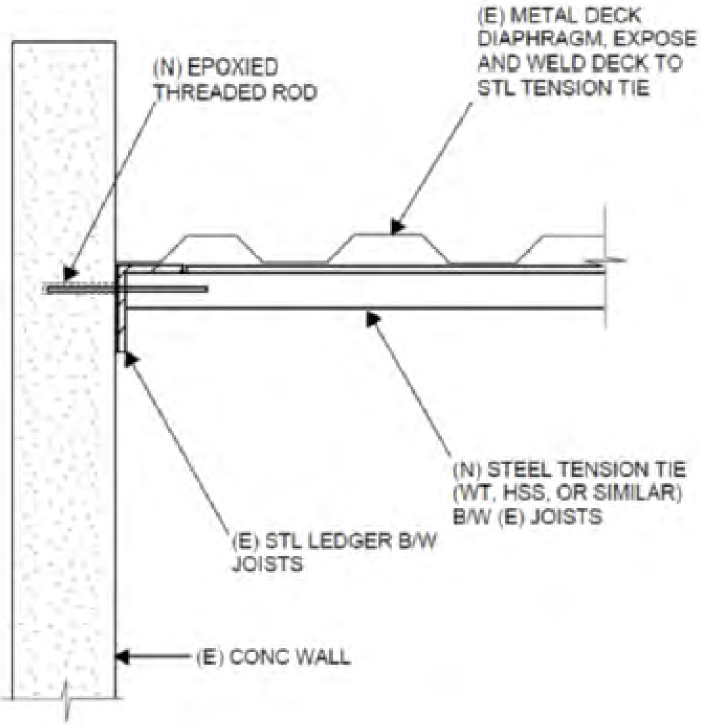


Figure 1.6 Addition of New Wall Anchorage Between Existing Joists to Enhance the Wall Anchorage Capacity

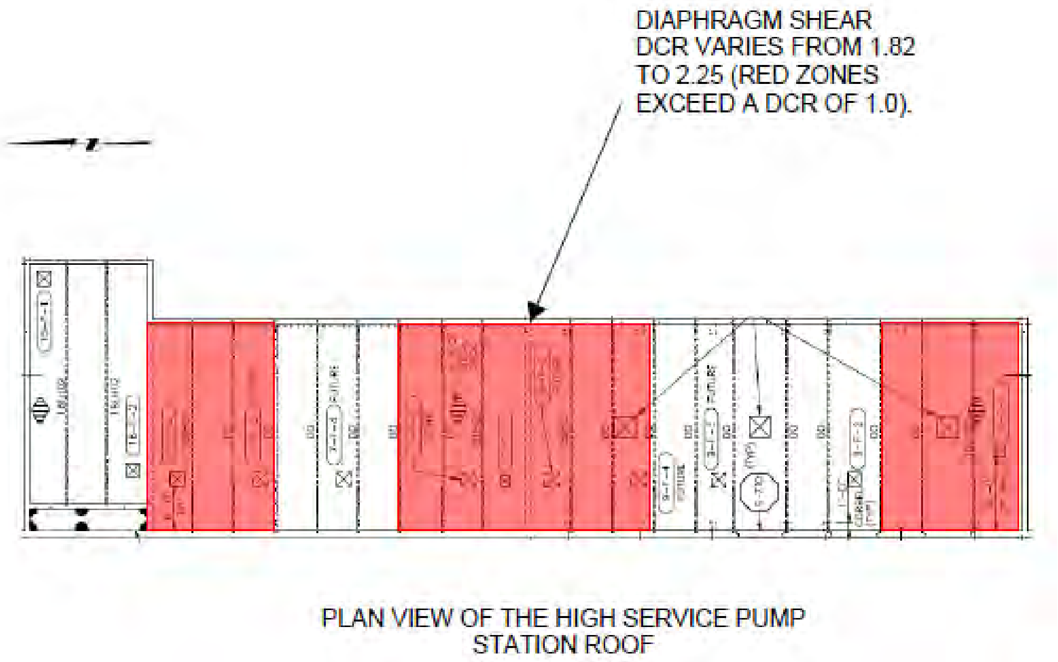


Figure 1.7 Diaphragm Shear Stress at the High Service PS Roof Exceeds the Capacity of the Roof Decking

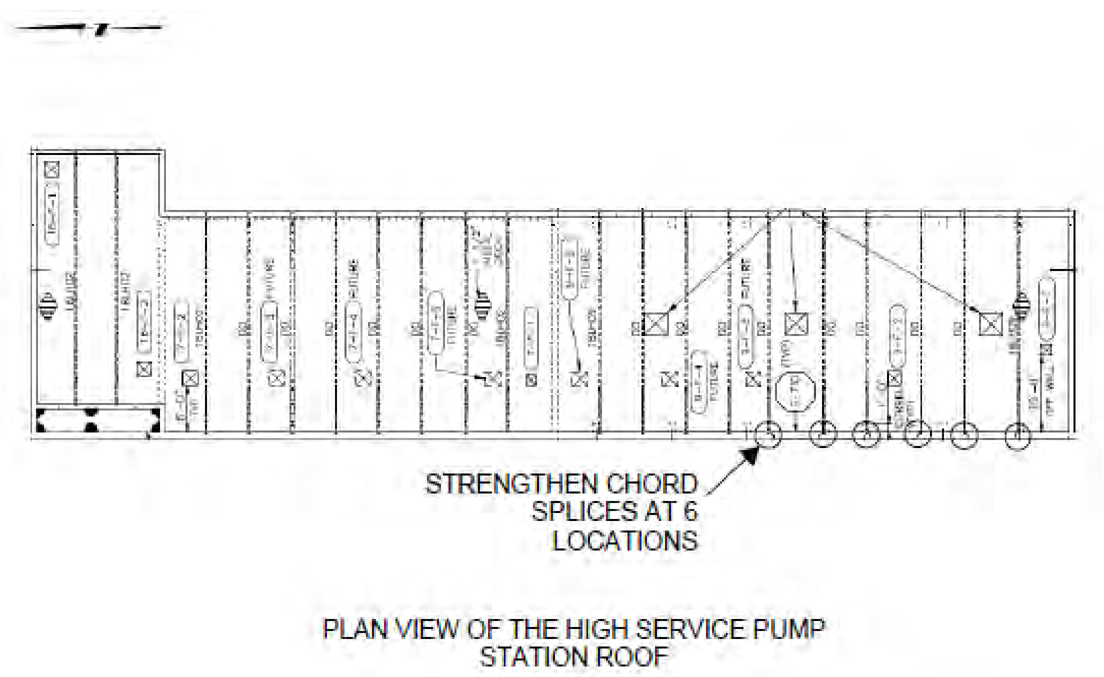


Figure 1.8 Chord Bars are Discontinuous at 3 Large Windows at the West Wall of the High Service PS

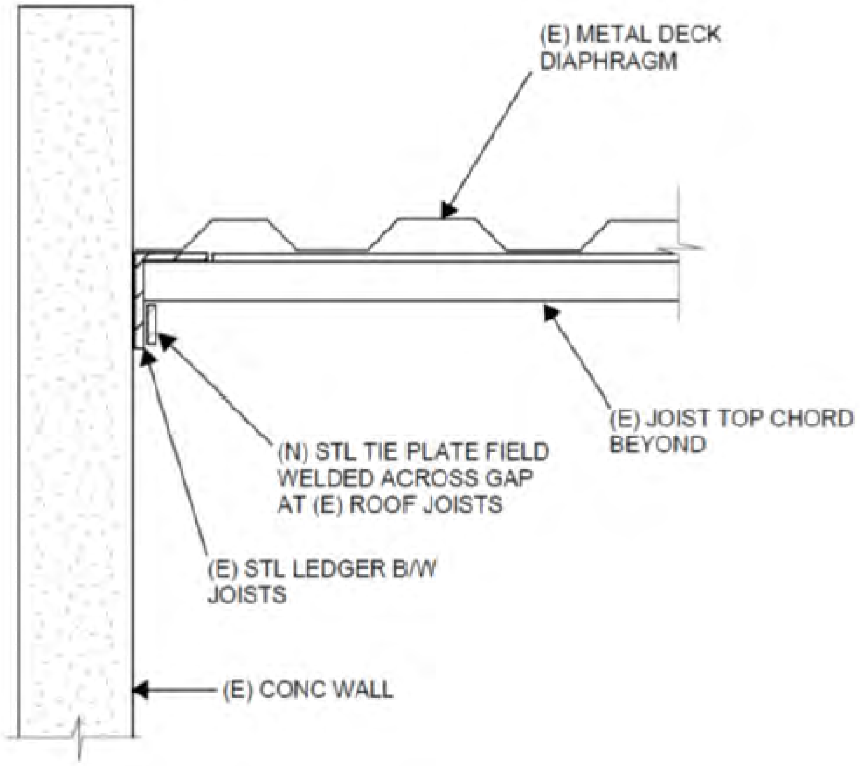


Figure 1.9 Chord Splice as Required at the Ends of the Window to Ensure Chord Continuity is Maintained at the High Service PS

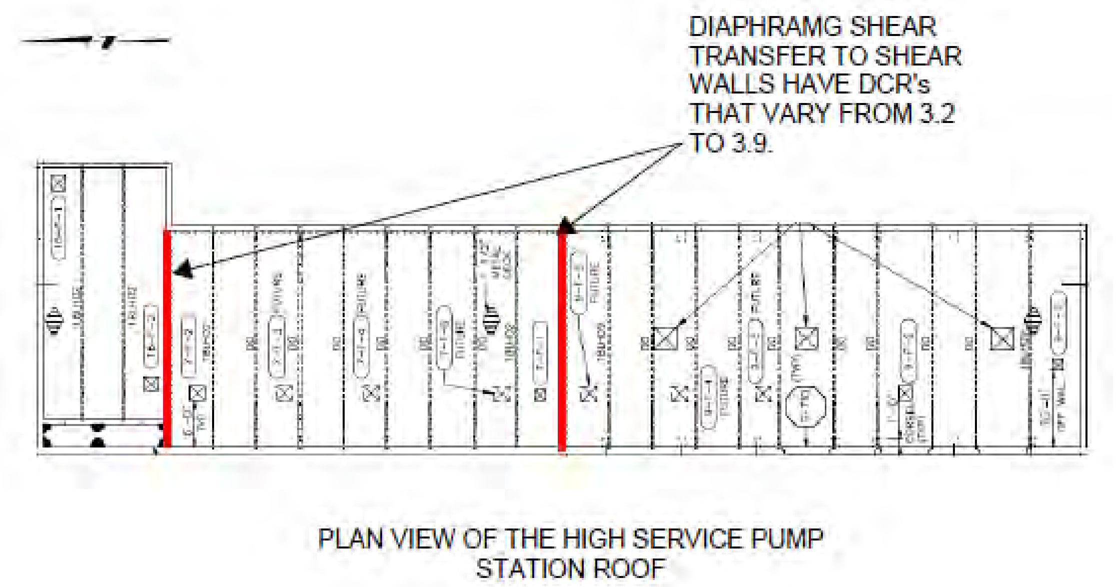


Figure 1.10 Diaphragm Shear Transfer to the Interior Shear Walls of the High Service PS Exceeds the Capacity of the Bolted Connections to the Walls

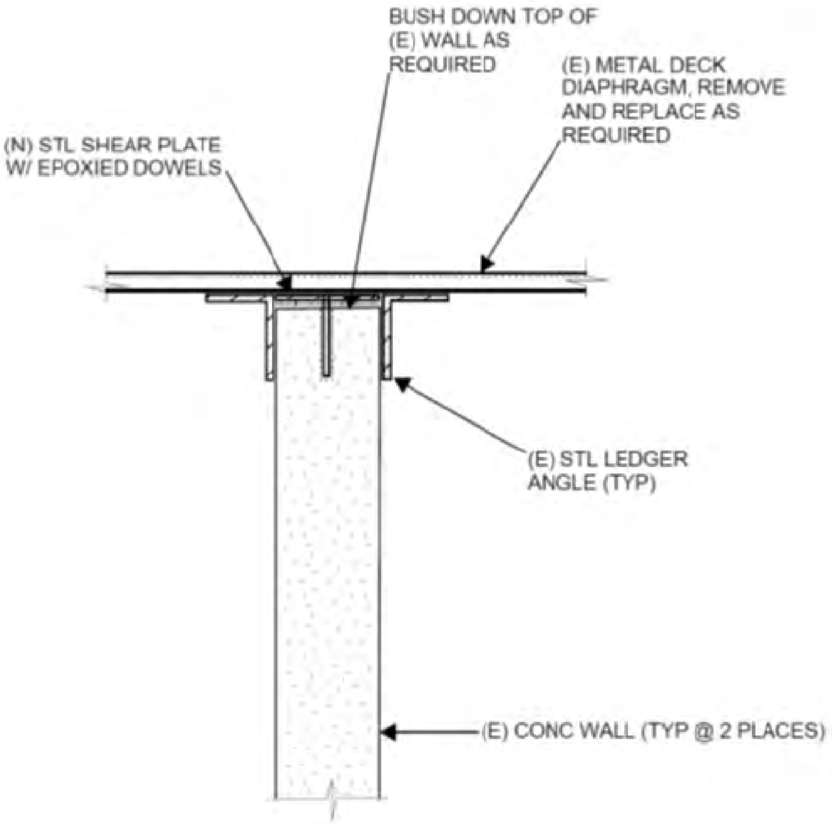
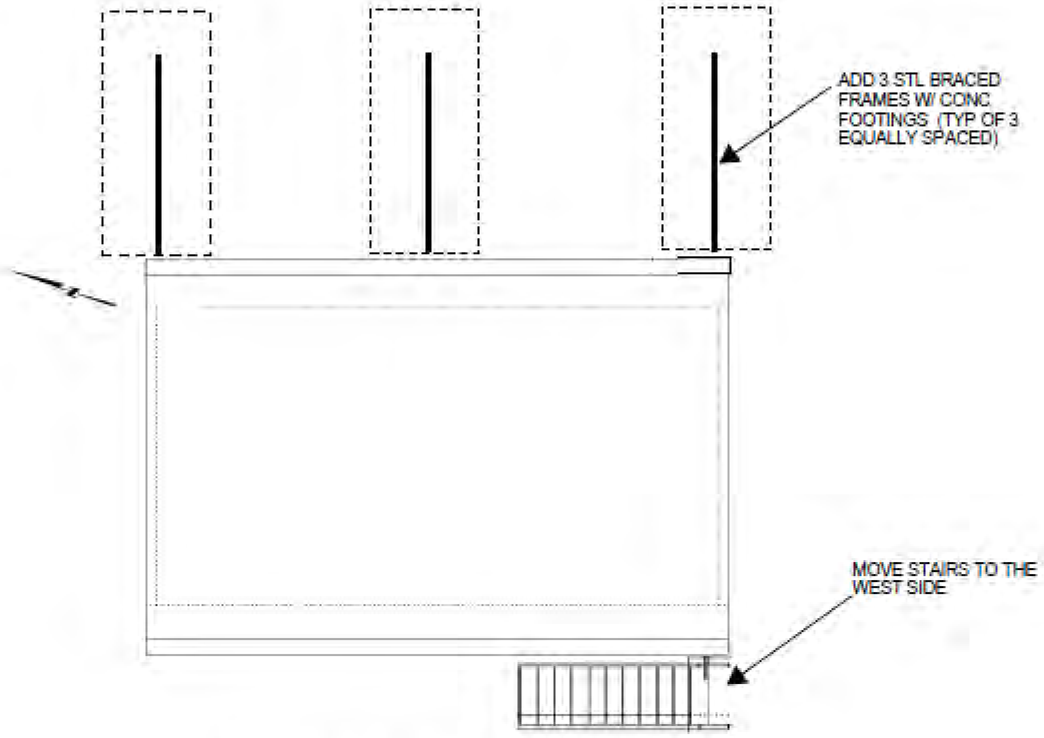
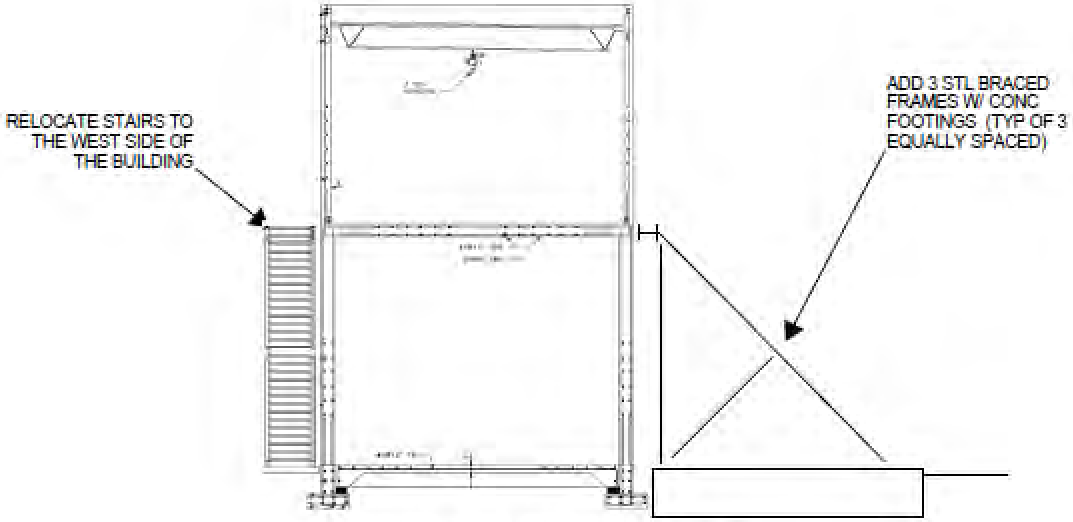


Figure 1.11 Conceptual Retrofit for Increasing the Capacity of the Diaphragm Shear Transfer to the Interior Walls at the High Service PS



FLOOR PLAN VIEW OF THE SOLIDS DEWATERING BUILDING



SECTION VIEW OF THE SOLIDS DEWATERING BUILDING

Figure 1.12 Conceptual Retrofit Scheme to Provide East-West Seismic Bracing for the Solids Dewatering Building

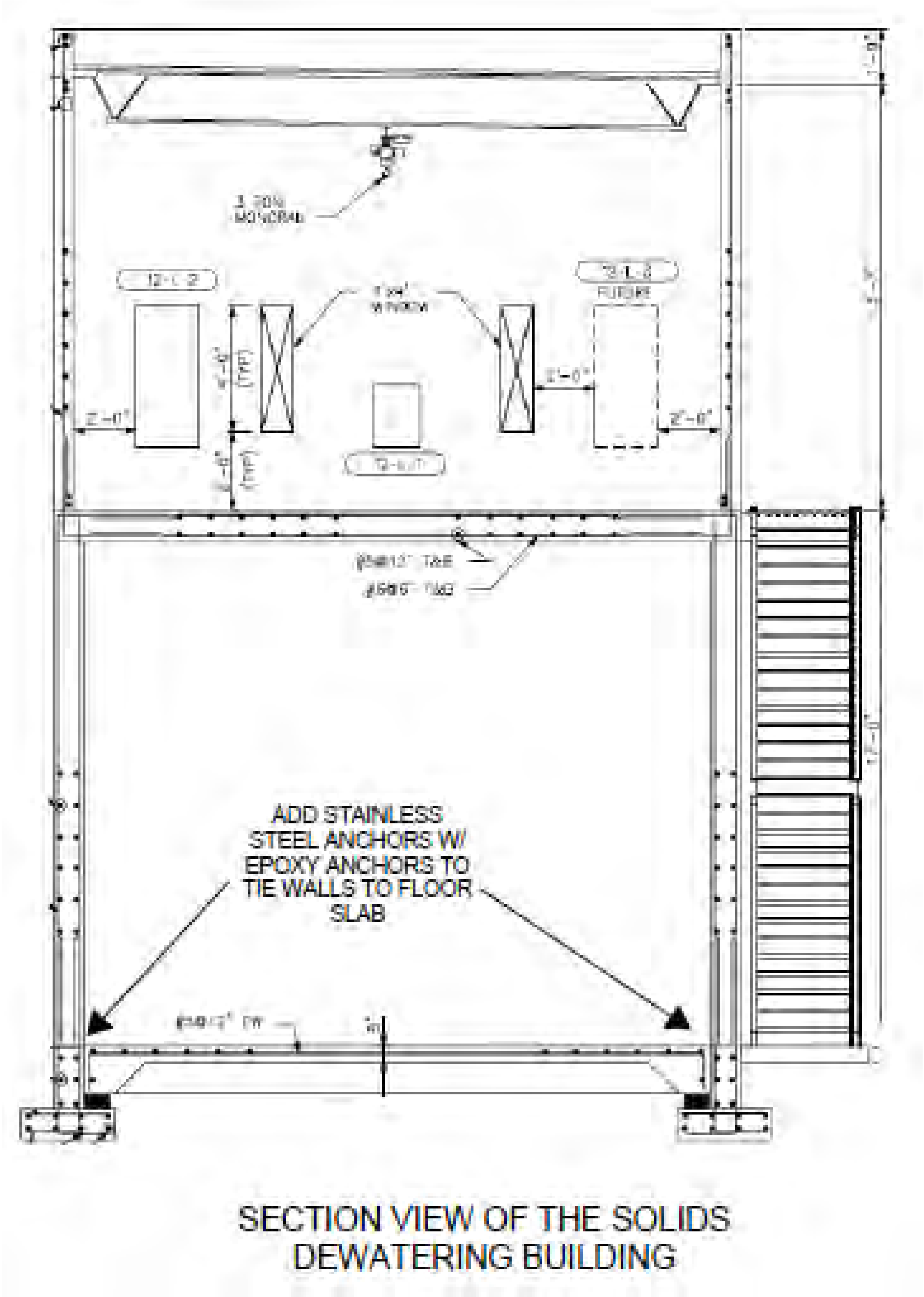


Figure 1.13 Conceptual Retrofit to Tie the Floor Slab Together with the East and West Wall Footings at the Solids Dewatering Building

1.5 Geo-seismic Hazards

Geo-seismic hazards were evaluated by S&W as part of the 2015 TVWD Master Plan Update at the site of the subject facilities and are not further evaluated in this report. It was estimated that the soils below the structures are susceptible to liquefaction and that the soils closer to the Willamette River are additionally susceptible to lateral spread. Lateral spread is a potentially gross instability of the soils and can result in large-scale movement of structures laterally, potentially causing significant structural damage and severance of utility connections that may move differentially.

TVWD is moving forward with mitigation measures to stabilize the soils in the vicinity of the southern section of the plant to help prevent lateral spreading from occurring during an earthquake. Provided that the site soils are stabilized to preclude lateral spreading, the facilities at the site would not be expected to sustain damage to lateral spreading. However, without mitigating liquefaction from occurring, vertical dynamic settlement below the subject facilities at the site can still occur. S&W estimates that the vertical dynamic settlement below the plant, in the vicinity of the subject facilities included in this evaluation, may be on the order of 2.5 to 6.2 inches considering both the 500-year and 2500-year seismic events.

Structures exposed to downward uniform displacements are not generally viewed as creating any gross instability or significant damage to the structure. However, differential settlement can cause tilting, cracking, and other structural damage that can negatively impact the seismic performance of the structure. This is a consideration that is in addition to the findings presented herein for the seismic evaluation of the structures, which is based on exposure to ground-shaking hazards only. Differential settlement is typically estimated to be 1/2 to 2/3 of the total settlement. The level of differential settlement is anticipated to cause some degree of structural damage, but it is not expected to create structural instability or damage that would render the structure unserviceable.

1.6 Summary

The life safety and seismic assessment has revealed some safety issues and seismic vulnerabilities, each of which has been provided with a recommended mitigation along with a cost estimate. The mitigation recommendations have been prioritized as high, medium, or low to help facilitate future planning of projects. Note that seismic vulnerabilities that also pose a potential life safety hazard have also been identified as a life safety issue. Table 1.7 provides a summary of the costs with a corresponding break-down according to the deficiency type and priority.

Table 1.7 Summary of Mitigation Costs

Deficiency Type	Priority(3)	Cost(1)(2)
Life Safety	H	\$350,500
Life Safety	M	\$76,000
Life Safety	L	\$8,000
Life Safety	ALL	\$434,500
Seismic	H	\$392,000
Seismic	M	\$75,000
Seismic	L	\$52,000
Seismic	ALL	\$519,000
Combined	H	\$422,500
Combined	M	\$136,000
Combined	L	\$60,000
Total	ALL	\$618,500

Notes:

1. Cost estimate includes an indirect cost multiplier of 2.0, which is meant to account for contingency, overhead, profit, taxes, etc...
2. Soft costs, such as, engineering services, inspection, permitting, etc..., are not included in the cost estimate.
3. H = High, M = Medium, L = Low.

Attachment A

PHOTOGRAPHS

Photo 1 – LS1 – Access hatch at the Sludge Thickening PS as seen from the underside of the concrete deck

Photo 2 – LS1 – Access hatch at the Sludge Thickening PS as seen from the top side.

Photo 3 – LS2 – Color coded safety warning signs are faded at the south wall of the Ozone Generation Room.

Photo 4 – LS2 – Color coded safety warning signs are faded at the east wall of the Chemical Storage Room.

Photo 5 – LS3 – Guardrail at the north Actiflo™ staircase is less than 42 inches in height.

Photo 6 – LS3 – Guardrail at the north Filter staircase is less than 42 inches in height.

Photo 7 – LS4 – The Actiflo™ gallery has electrical service rated at 1200 amps or higher requiring panic hardware on doors.

Photo 8 – LS4 – The Switchgear Room at the High Service Pump Station has electrical service rated at 1200 amps or higher requiring panic hardware on doors

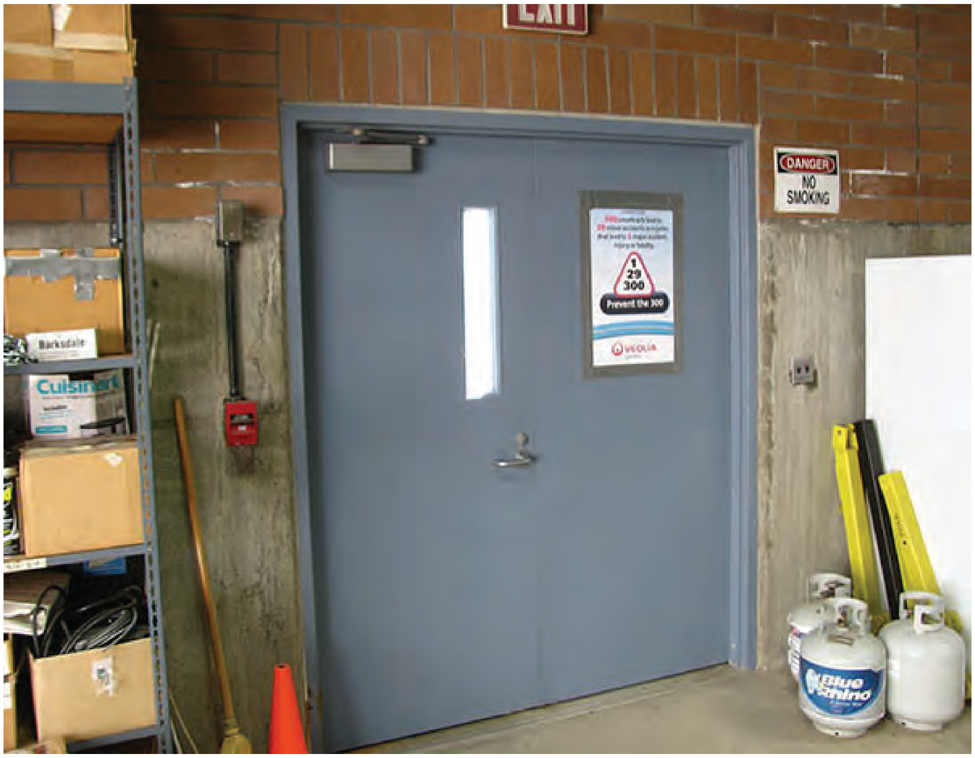


Photo 9 – LS5 – Group occupancy H at the Ozone Generation Room requires panic hardware on the exit doors (one of the south doors shown).

Photo 10 – LS5 – Group occupancy H at the Chemical Storage Room requires panic hardware on the exit doors (the east door shown).

Photo 11 – LS6 – Chemical piping passing directly over the west door at the Ozone Generation Room.

Photo 12 – LS6 – Chemical piping passing directly over the egress route to the east door at the Chemical Storage Room.

Photo 13 – LS7 – Door at the Waste Washwater Pump Station was found propped open.

Photo 14 – LS7 – Door at the Actiflo™ Room was found propped open.

Photo 15 – LS8 – West guardrail on top of the Actiflo™ Basin lacks a kick plate and it is located over a public walkway.

Photo 16 – LS8 – Gate at the Filter ladder pit lacks a kick plate.

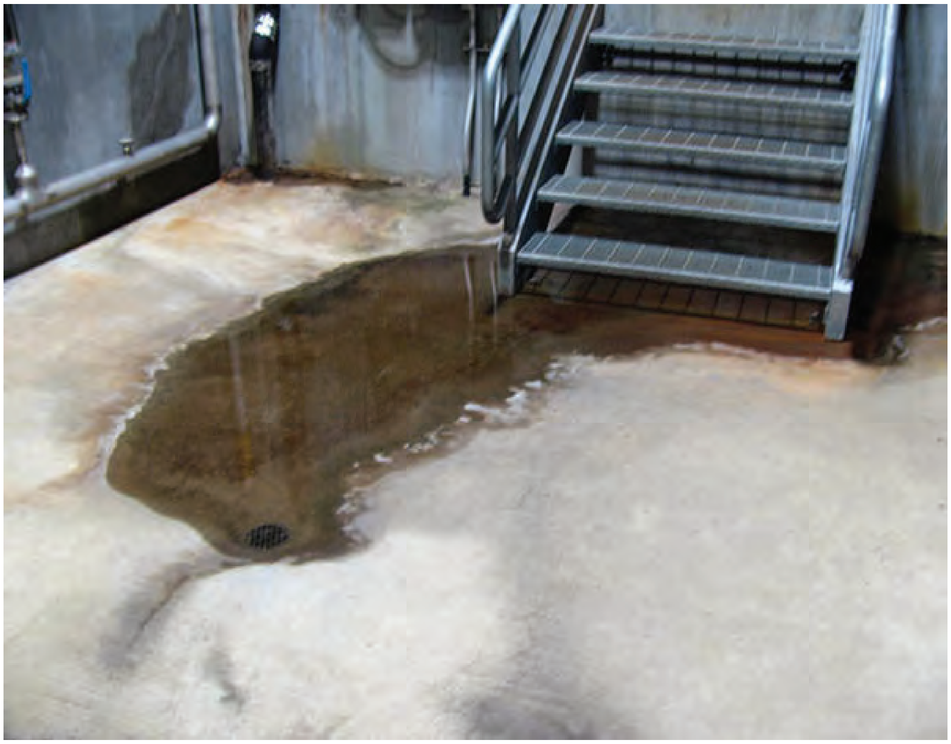


Photo 17 – LS9 – Ponding water on the floor of the Ozone Gallery that is fed by an active leaking expansion joint.

Photo 18 – LS9 – Water on the floor of the south blower room at the Filter Gallery due to active leaks from the water channels above.

Photo 19 – LS10 – Standard electrical receptacle inside the Ozone Gallery.

Photo 20 – LS10 – Standard electrical receptacle inside the Filter Gallery.

Photo 21 – LS11 – The south stairwell at the Ozonation Basin has no dedicated ventilation.

Photo 22 – LS12 – Entrance to the Filter Gallery. The door is located at the top of the stairs.

Photo 23 – LS12 – The east end of the Filter Gallery has a double door that leads out to a ladder pit.

Photo 24 – LS13 – The access ladder to the Waste Washwater EQ Basin does not have any tie-offs for a fall restraint system.

Photo 25 – LS14 – The Solids Dewatering Building does not have any overflow scuppers visible.

Photo 26 – LS14 – The Solids Dewatering Building does not have any overflow scuppers visible.

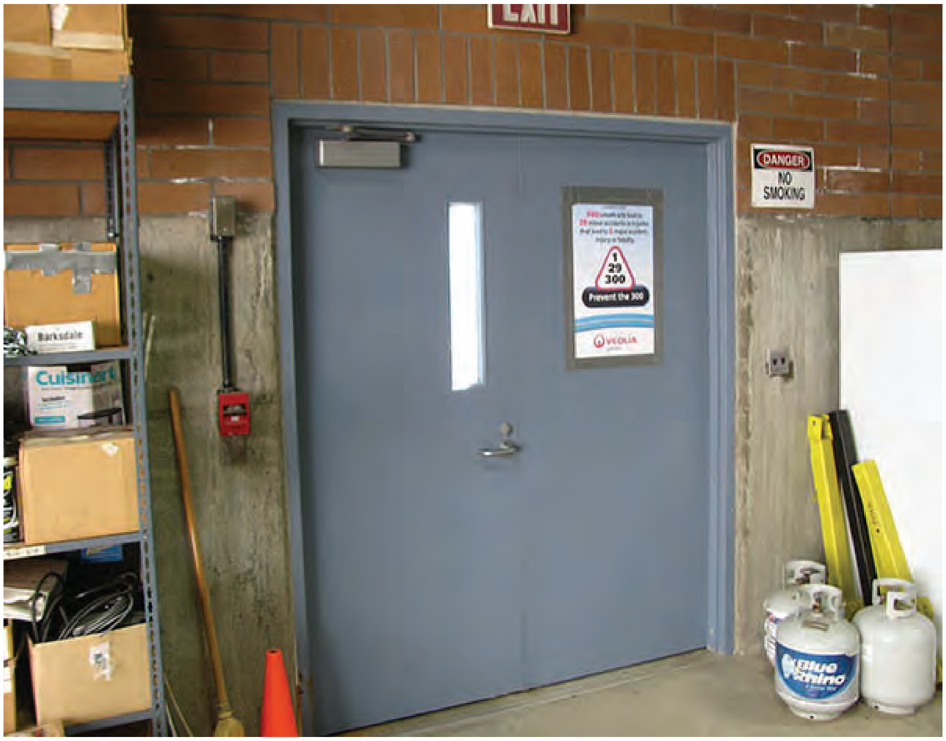


Photo 27 – LS15 – The southeast door that exits from the Ozone Generation Room does not have an emergency shut-off switch for the ozone generation equipment.

Photo 28 – S3 – The roof joist wall anchorage to the walls at the High Service Pump Station lack capacity to meet seismic performance goals.

Photo 29 – S5 – Diaphragm chord splices at the windows along the west wall require strengthening.

Photo 30 – S6 – Interior walls lack diaphragm shear capacity transfer from the roof diaphragm to the shear walls.

Photo 31 – S7 – The Solids Dewatering Building has no lateral load resisting system at the lower level in the east-west direction.

Photo 32 – S8 - The roof joist wall anchorage to the walls at the Solids Dewatering Building lack capacity to meet seismic performance goals.

Photo 33 – S10 – The space heater at the Washwater Pump Station is suspended and unbraced for seismic loads.

Photo 34 – S10 – The space heater at the Switchgear Room at the High Service PS is suspended without any seismic bracing.

Photo 35 – S11 – The ozone destruct piping lacks seismic bracing at the top of the Ozonation Basin.

Photo 36 – S12 – The cable tray within the High Service PS lacks longitudinal seismic bracing.

Photo 37 – S13 – The chemical piping at the Chemical Storage Room lacks transverse seismic bracing.

Photo 38 – S14 – The ozone and LOX piping at the Ozone Generation Room lacks seismic bracing.

Attachment B

TIER 1 CHECKLISTS

APPENDIX C
SUMMARY DATA SHEET

BUILDING DATA

Building Name: ActiFlo
Date: 9 / 5 / 2017
Building Address: 13050 SW Arrowhead Creek Lane, Wilsonville, Oregon 97070
Latitude: North: 45.295
Longitude: West: 122.783
By: Carollo Engineers
Year Built: 2003
Year(s) Remodeled: N/A
Original Design Code: 2000 International Building Code
Area (sf): 361
Length (ft): 19.33
Width (ft): 18.67
No. of Stories: 1
Story Height: 10.0 ft
Total Height: 10.0 ft

USE ☐ Industrial ☐ Office ☐ Warehouse ☐ Hospital ☐ Residential ☐ Educational ☒ Other: Municipal

CONSTRUCTION DATA

Gravity Load Structural System: Metal Deck, Roof Truss Joist, CMU Walls and Concrete Slab
Exterior Transverse Walls: Solid Grouted CMU Walls
Openings? No
Exterior Longitudinal Walls: Solid Grouted CMU Walls
Openings? Man doors
Roof Materials/Framing: Metal deck & Truss Joist
Intermediate Floors/Framing: N/A
Ground Floor: Concrete Slab
Columns: No
Foundation: Concrete Slab
General Condition of Structure:
Levels Below Grade? Yes. Buried concrete structure
Special Features and Comments:

LATERAL-FORCE-RESISTING SYSTEM

	Longitudinal	Transverse
System:	Solid CMU Shear Walls	Solid CMU Shear Walls
Vertical Elements:	Solid CMU Shear Walls	Solid CMU Shear Walls
Diaphragms:	Metal Deck	Metal Deck
Connections:		

EVALUATION DATA

BSE-1N Spectral Response Accelerations: S_{Ds} = 0.611g S_{D1} = 0.656g
Soil Factors: Class = E F_a = 0.992 F_v = 2.40
BSE-1E Spectral Response Accelerations: S_{XS} = 0.611g S_{X1} = 0.372g
Level of Seismicity: High Performance Level: S2 (Damage Control)
Building Period: T = 0.121 sec
Spectral Acceleration: S_a = 0.611g
Modification Factor: $C_mC_1C_2$ = 1.40 Building Weight: W = 39 kips
Pseudo Lateral Force: V= $C_mC_1C_2S_aW$= 33 kips

BUILDING CLASSIFICATION: CMU Shear Wall with Flexible Diaphragm

REQUIRED TIER 1 CHECKLISTS	Yes	No
Basic Configuration Checklist	☒	☐
Building Type RM1 **Structural Checklist**	☒	☐
Nonstructural Component Checklist	☒	☐

FURTHER EVALUATION REQUIREMENT:

Project: Wilamette River WTP

Location: ActiFlo

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.1.2LS LIFE SAFETY BASIC CONFIGURATION CHECKLIST

Low Seismicity

Building System

General

[✓ C] NC N/A U LOAD PATH: The structure shall contain a complete, well defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Commentary: Sec. A.2.1.1. Tier 2: Sec. 5.4.1.1)

C NC [✓ N/A] U ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 4% of the height of the shorter building. This statement shall not apply for the following building types: W1, W1a, and W2. (Commentary: Sec. A.2.1.2. Tier 2: Sec. 5.4.1.2) [No adjacent building]

C NC [✓ N/A] U MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic-force-resisting elements of the main structure. (Commentary: Sec. A.2.1.3. Tier 2: Sec. 5.4.1.3)

Building Configuration

[✓ C] NC N/A U WEAK STORY: The sum of the shear strengths of the seismic-force-resisting system in any story in each direction is not less than 80% of the strength in the adjacent story above. (Commentary: Sec. A2.2.2. Tier 2: Sec. 5.4.2.1)

[✓ C] NC N/A U SOFT STORY: The stiffness of the seismic-force-resisting system in any story is not less than 70% of the seismic-force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic-force-resisting system stiffness of the three stories above. (Commentary: Sec. A.2.2.3. Tier 2: Sec. 5.4.2.2)

[✓ C] NC N/A U VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Commentary: Sec. A.2.2.4. Tier 2: Sec. 5.4.2.3)

[✓ C] NC N/A U GEOMETRY: There are no changes in the net horizontal dimension of the seismic-force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines. (Commentary: Sec. A.2.2.5. Tier 2: Sec. 5.4.2.4)

C NC [✓ N/A] U MASS: There is no change in effective mass more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Commentary: Sec. A.2.2.6. Tier 2: Sec. 5.4.2.5) [Light roof]

[✓ C] NC N/A U TORSION: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Commentary: Sec. A.2.2.7. Tier 2: Sec. 5.4.2.6)

Moderate Seismicity: Complete the Following Items in Addition to the Items for Low Seismicity.

Geologic Site Hazards

C [✓ NC] N/A U LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 ft under the building. (Commentary: Sec. A.6.1.1. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SLOPE FAILURE: The building site is sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or is capable of accommodating any predicted movements without failure. (Commentary: Sec. A.6.1.2. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. (Commentary: Sec. A.6.1.3. Tier 2: 5.4.3.1)[Based on USGS earthquake map]

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Foundation Configuration

[✓ C] NC N/A U OVERTURNING: The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than $0.6S_a$. (Commentary: Sec. A.6.2.1. Tier 2: Sec. 5.4.3.3)

C NC [✓ N/A] U TIES BETWEEN FOUNDATION ELEMENTS: The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Commentary: Sec. A.6.2.2. Tier 2: Sec. 5.4.3.4) [CMU building on top of buried concrete structure]

Project: Wilamette River WTP

Location: ActiFlo

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.15LS LIFE SAFETY STRUCTURAL CHECKLIST FOR BUILDING TYPES RM1: REINFORCED MASONRY BEARING WALLS WITH FLEXIBLE DIAPHRAGMS AND RM2: REINFORCED MASONRY BEARING WALLS WITH STIFF DIAPHRAGMS

Low and Moderate Seismicity

Seismic-Force-Resisting System

[✓ C] NC N/A U REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1)

[✓ C] NC N/A U SHEAR STRESS CHECK: The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 4.5.3.3, is less than 70 lb/in.^{2}. (Commentary: Sec. A.3.2.4.1. Tier 2: Sec. 5.5.3.1.1)

[✓ C] NC N/A U REINFORCING STEEL: The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls is greater than 0.002 of the wall with the minimum of 0.0007 in either of the two directions; the spacing of reinforcing steel is less than 48 in., and all vertical bars extend to the top of the walls. (Commentary: Sec. A.3.2.4.2. Tier 2: Sec. 5.5.3.1.3)

Stiff Diaphragms

C NC [✓ N/A] U TOPPING SLAB: Precast concrete diaphragm elements are interconnected by a continuous reinforced concrete topping slab. (Commentary: Sec. A.4.5.1. Tier 2: Sec. 5.6.4)

Connections

[✓ C] NC N/A U WALL ANCHORAGE: Exterior concrete or masonry walls that are dependent on the diaphragm for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections shall have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 4.5.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1)

C NC [✓ N/A] U WOOD LEDGERS: The connection between the wall panels and the diaphragm does not induce cross-grain bending or tension in the wood ledgers. (Commentary: Sec. A.5.1.2. Tier 2: Sec. 5.7.1.3)

[✓ C] NC N/A U TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of seismic forces to the shear walls. (Commentary: Sec. A.5.2.1. Tier 2: Sec. 5.7.2)

C NC [✓ N/A] U TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements are doweled for transfer of forces into the shear wall or frame elements. (Commentary: Sec. A.5.2.3. Tier 2: Sec. 5.7.2) [The roof is flexible diaphragm with metal deck]

[✓ C] NC N/A U FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4) [Foundation dowels matching to wall vertical reinforcing bars]

C NC [✓ N/A] U GIRDER–COLUMN CONNECTION: There is a positive connection using plates, connection hardware, or straps between the girder and the column support. (Commentary: Sec. A.5.4.1. Tier 2: Sec. 5.7.4.1)

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Stiff Diaphragms

C NC [✓ N/A] U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

C NC [✓ N/A] U OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls are not greater than 8 ft long. (Commentary: Sec. A.4.1.6. Tier 2: Sec. 5.6.1.3)

Flexible Diaphragms

[✓ C] NC N/A U CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2)

[✓ C] NC N/A U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

[✓ C] NC N/A U OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls are not greater than 8 ft long. (Commentary: Sec. A.4.1.6. Tier 2: Sec. 5.6.1.3)

C NC [✓ N/A] U STRAIGHT SHEATHING: All straight sheathed diaphragms have aspect ratios less than 2-to-1 in the direction being considered. (Commentary: Sec. A.4.2.1. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U SPANS: All wood diaphragms with spans greater than 24 ft consist of wood structural panels or diagonal sheathing. (Commentary: Sec. A.4.2.2. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft and aspect ratios less than or equal to 4-to-1. (Commentary: Sec. A.4.2.3. Tier 2: Sec. 5.6.2)

[✓ C] NC N/A U OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than wood, metal deck, concrete, or horizontal bracing. (Commentary: Sec. A.4.7.1. Tier 2: Sec. 5.6.5)

Connections

C NC [✓ N/A] U STIFFNESS OF WALL ANCHORS: Anchors of concrete or masonry walls to wood structural elements are installed taut and are stiff enough to limit the relative movement between the wall and the diaphragm to no greater than 1/8 in. before engagement of the anchors. (Commentary: Sec. A.5.1.4. Tier 2: Sec. 5.7.1.2)

APPENDIX C
SUMMARY DATA SHEET

BUILDING DATA

Building Name: Washwater Basin Pump Station Date: 9 / 5 / 2017
Building Address: 13050 SW Arrowhead Creek Lane, Wilsonville, Oregon 97070
Latitude: North: 45.295 Longitude: West: 122.783 By: Carollo Engineers
Year Built: 2003 Year(s) Remodeled: N/A Original Design Code: 2000 International Building Code
Area (sf): 611 Length (ft): 36.67 Width (ft): 16.67
No. of Stories: 1 Story Height: 11.33-ft Total Height: 11.33-ft

USE ☐ Industrial ☐ Office ☐ Warehouse ☐ Hospital ☐ Residential ☐ Educational ☒ Other: Municipal

CONSTRUCTION DATA

Gravity Load Structural System: Metal Deck, Roof Truss Joist, CMU Walls and Concrete Slab
Exterior Transverse Walls: Solid Grouted CMU Walls Openings? Man door & Louver
Exterior Longitudinal Walls: Solid Grouted CMU Walls Openings? Windows
Roof Materials/Framing: Metal deck & Truss Joist
Intermediate Floors/Framing: N/A
Ground Floor: Concrete Slab
Columns: No Foundation: Concrete Slab
General Condition of Structure:
Levels Below Grade? Yes. Buried concrete structure
Special Features and Comments:

LATERAL-FORCE-RESISTING SYSTEM

	Longitudinal	Transverse
System:	Solid CMU Shear Walls	Solid CMU Shear Walls
Vertical Elements:	Solid CMU Shear Walls	Solid CMU Shear Walls
Diaphragms:	Metal Deck	Metal Deck
Connections:		

EVALUATION DATA

BSE-1N Spectral Response Accelerations: S_{Ds} = 0.611g S_{D1} = 0.656g
Soil Factors: Class = E F_a = 0.992 F_v = 2.40
BSE-1E Spectral Response Accelerations: S_{XS} = 0.611g S_{X1} = 0.372g
Level of Seismicity: High Performance Level: S2 (Damage Control)
Building Period: T = 0.124 Sec
Spectral Acceleration: S_a = 0.611g
Modification Factor: $C_mC_1C_2$ = 1.40 Building Weight: W = 83 kips
Pseudo Lateral Force: V= $C_mC_1C_2S_aW$= 71 kips

BUILDING CLASSIFICATION: CMU Shear Wall with Flexible Diaphragm

REQUIRED TIER 1 CHECKLISTS	**Yes**	**No**
Basic Configuration Checklist	☒	☐
Building Type RM1 **Structural Checklist**	☒	☐
Nonstructural Component Checklist	☒	☐

FURTHER EVALUATION REQUIREMENT:

Project: Wilamette River WTP

Location: Washwater Basin Pump Station

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.1.2LS LIFE SAFETY BASIC CONFIGURATION CHECKLIST

Low Seismicity

Building System

General

[✓ C] NC N/A U LOAD PATH: The structure shall contain a complete, well defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Commentary: Sec. A.2.1.1. Tier 2: Sec. 5.4.1.1)

C NC [✓ N/A] U ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 4% of the height of the shorter building. This statement shall not apply for the following building types: W1, W1a, and W2. (Commentary: Sec. A.2.1.2. Tier 2: Sec. 5.4.1.2) [No adjacent building]

C NC [✓ N/A] U MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic-force-resisting elements of the main structure. (Commentary: Sec. A.2.1.3. Tier 2: Sec. 5.4.1.3)

Building Configuration

[✓ C] NC N/A U WEAK STORY: The sum of the shear strengths of the seismic-force-resisting system in any story in each direction is not less than 80% of the strength in the adjacent story above. (Commentary: Sec. A2.2.2. Tier 2: Sec. 5.4.2.1)

[✓ C] NC N/A U SOFT STORY: The stiffness of the seismic-force-resisting system in any story is not less than 70% of the seismic-force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic-force-resisting system stiffness of the three stories above. (Commentary: Sec. A.2.2.3. Tier 2: Sec. 5.4.2.2)

[✓ C] NC N/A U VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Commentary: Sec. A.2.2.4. Tier 2: Sec. 5.4.2.3)

[✓ C] NC N/A U GEOMETRY: There are no changes in the net horizontal dimension of the seismic-force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines. (Commentary: Sec. A.2.2.5. Tier 2: Sec. 5.4.2.4)

C NC [✓ N/A] U MASS: There is no change in effective mass more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Commentary: Sec. A.2.2.6. Tier 2: Sec. 5.4.2.5) [Light roof]

[✓ C] NC N/A U TORSION: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Commentary: Sec. A.2.2.7. Tier 2: Sec. 5.4.2.6)

Moderate Seismicity: Complete the Following Items in Addition to the Items for Low Seismicity.

Geologic Site Hazards

C [✓ NC] N/A U LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 ft under the building. (Commentary: Sec. A.6.1.1. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SLOPE FAILURE: The building site is sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or is capable of accommodating any predicted movements without failure. (Commentary: Sec. A.6.1.2. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. (Commentary: Sec. A.6.1.3. Tier 2: 5.4.3.1) [Based on USGS earthquake map]

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Foundation Configuration

[✓ C] NC N/A U OVERTURNING: The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than $0.6S_a$. (Commentary: Sec. A.6.2.1. Tier 2: Sec. 5.4.3.3)

C NC [✓ N/A] U TIES BETWEEN FOUNDATION ELEMENTS: The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Commentary: Sec. A.6.2.2. Tier 2: Sec. 5.4.3.4) [CMU building on top of buried concrete structure]

Project: Wilamette River WTP
Location: Washwater Basin Pump Station

Completed by: Carollo Engineers (Caleb Che)
Date: 9 / 5 / 2017

16.15LS LIFE SAFETY STRUCTURAL CHECKLIST FOR BUILDING TYPES RM1: REINFORCED MASONRY BEARING WALLS WITH FLEXIBLE DIAPHRAGMS AND RM2: REINFORCED MASONRY BEARING WALLS WITH STIFF DIAPHRAGMS

Low and Moderate Seismicity

Seismic-Force-Resisting System

[✓ C] NC N/A U REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1)

[✓ C] NC N/A U SHEAR STRESS CHECK: The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 4.5.3.3, is less than 70 lb/in.^{2}. (Commentary: Sec. A.3.2.4.1. Tier 2: Sec. 5.5.3.1.1)

[✓ C] NC N/A U REINFORCING STEEL: The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls is greater than 0.002 of the wall with the minimum of 0.0007 in either of the two directions; the spacing of reinforcing steel is less than 48 in., and all vertical bars extend to the top of the walls. (Commentary: Sec. A.3.2.4.2. Tier 2: Sec. 5.5.3.1.3)

Stiff Diaphragms

C NC [✓ N/A] U TOPPING SLAB: Precast concrete diaphragm elements are interconnected by a continuous reinforced concrete topping slab. (Commentary: Sec. A.4.5.1. Tier 2: Sec. 5.6.4)

Connections

[✓ C] NC N/A U WALL ANCHORAGE: Exterior concrete or masonry walls that are dependent on the diaphragm for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections shall have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 4.5.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1) [East & West Walls: Wall anchorage at truss joist support adequate for wall out-of-plane]
[North & South Walls: Anchor bolts, ledger angle & steel deck adequate for wall out-of-plane]

C NC [✓ N/A] U WOOD LEDGERS: The connection between the wall panels and the diaphragm does not induce cross-grain bending or tension in the wood ledgers. (Commentary: Sec. A.5.1.2. Tier 2: Sec. 5.7.1.3)

[✓ C] NC N/A U TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of seismic forces to the shear walls. (Commentary: Sec. A.5.2.1. Tier 2: Sec. 5.7.2)

C NC [✓ N/A] U TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements are doweled for transfer of forces into the shear wall or frame elements. (Commentary: Sec. A.5.2.3. Tier 2: Sec. 5.7.2) [The roof is flexible diaphragm with metal deck]

[✓ C] NC N/A U FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4) [Foundation dowels matching to wall vertical reinforcing bars]

C NC [✓ N/A] U GIRDER–COLUMN CONNECTION: There is a positive connection using plates, connection hardware, or straps between the girder and the column support. (Commentary: Sec. A.5.4.1. Tier 2: Sec. 5.7.4.1)

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Stiff Diaphragms

C NC [✓ N/A] U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

C NC [✓ N/A] U OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls are not greater than 8 ft long. (Commentary: Sec. A.4.1.6. Tier 2: Sec. 5.6.1.3)

Flexible Diaphragms

[✓ C] NC N/A U CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2)

[✓ C] NC N/A U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

[✓ C] NC N/A U OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls are not greater than 8 ft long. (Commentary: Sec. A.4.1.6. Tier 2: Sec. 5.6.1.3)

C NC [✓ N/A] U STRAIGHT SHEATHING: All straight sheathed diaphragms have aspect ratios less than 2-to-1 in the direction being considered. (Commentary: Sec. A.4.2.1. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U SPANS: All wood diaphragms with spans greater than 24 ft consist of wood structural panels or diagonal sheathing. (Commentary: Sec. A.4.2.2. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft and aspect ratios less than or equal to 4-to-1. (Commentary: Sec. A.4.2.3. Tier 2: Sec. 5.6.2)

[✓ C] NC N/A U OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than wood, metal deck, concrete, or horizontal bracing. (Commentary: Sec. A.4.7.1. Tier 2: Sec. 5.6.5)

Connections

C NC [✓ N/A] U STIFFNESS OF WALL ANCHORS: Anchors of concrete or masonry walls to wood structural elements are installed taut and are stiff enough to limit the relative movement between the wall and the diaphragm to no greater than 1/8 in. before engagement of the anchors. (Commentary: Sec. A.5.1.4. Tier 2: Sec. 5.7.1.2)

APPENDIX C
SUMMARY DATA SHEET

BUILDING DATA

Building Name: High Service Pump Station Date: 5 / 18 / 2015

Building Address: 13050 SW Arrowhead Creek Lane, Wilsonville, Oregon 97070

Latitude: North: 45.295 Longitude: West: 122.783 By: Carollo Engineers

Year Built: 2003 Year(s) Remodeled: N/A Original Design Code: 2000 International Building Code

Area (sf): 4180 Length (ft): 138.33 Width (ft): 29.17

No. of Stories: 1 Story Height: 22.33 ft Total Height: 22.33 ft

USE ☐ Industrial ☐ Office ☐ Warehouse ☐ Hospital ☐ Residential ☐ Educational ☒ Other: Municipal

CONSTRUCTION DATA

Gravity Load Structural System: Metal Deck, Steel Truss Joist, Concrete Walls and Concrete Slab

Exterior Transverse Walls: Cast-in-Place Reinforced Concrete Walls Openings? Windows and doors

Exterior Longitudinal Walls: Cast-in-Place Reinforced Concrete Walls Openings? Windows and doors

Roof Materials/Framing: Metal deck supported on steel truss joist

Intermediate Floors/Framing: N/A

Ground Floor: Concrete Slab

Columns: No columns Foundation: Concrete Slab

General Condition of Structure:

Levels Below Grade? Buried concrete structure

Special Features and Comments:

LATERAL-FORCE-RESISTING SYSTEM

	Longitudinal	Transverse
System:	Concrete Shear Walls	Concrete Shear Walls
Vertical Elements:	Concrete Shear Walls	Concrete Shear Walls
Diaphragms:	Metal Deck	Metal Deck
Connections:		

EVALUATION DATA

BSE-1N Spectral Response Accelerations: S_{Ds} = 0.611g S_{D1} = 0.656g

Soil Factors: Class = E F_a = 0.992 F_v = 2.40

BSE-1E Spectral Response Accelerations: S_{XS} = 0.611g S_{X1} = 0.372g

Level of Seismicity: High Performance Level: S1 (Immediate Occupancy)

Building Period: T = 0.205 sec

Spectral Acceleration: S_a = 0.611g

Modification Factor: $C_mC_1C_2$ = 1.40 Building Weight: W = 691 kips

Pseudo Lateral Force: $V = C_mC_1C_2S_aW$ = 591 kips

BUILDING CLASSIFICATION: Concrete Shear Wall with Flexible Diaphragm

REQUIRED TIER 1 CHECKLISTS	**Yes**	**No**
Basic Configuration Checklist	☒	☐
Building Type C2a **Structural Checklist**	☒	☐
Nonstructural Component Checklist	☒	☐

FURTHER EVALUATION REQUIREMENT:

Project: Wilamette River WTP

Location: High Service Pump Station

Completed by: Carollo Engineers (James Doering)

Date: 5 / 18 / 2015

16.1.2IO IMMEDIATE OCCUPANCY BASIC CONFIGURATION CHECKLIST

Very Low Seismicity

Building System

General

[✓ C] NC N/A U LOAD PATH: The structure shall contain a complete, well-defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Commentary: Sec. A.2.1.1. Tier 2: Sec. 5.4.1.1)

[✓ C] NC N/A U ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 4% of the height of the shorter building. This statement need not apply for the following building types: W1, W1a, and W2. (Commentary: Sec. A.2.1.2. Tier 2: Sec. 5.4.1.2)

[✓ C] NC N/A U MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic-force-resisting elements of the main structure. (Commentary: Sec. A.2.1.3. Tier 2: Sec. 5.4.1.3)

Building Configuration

[✓ C] NC N/A U WEAK STORY: The sum of the shear strengths of the seismic-force-resisting system in any story in each direction shall not be less than 80% of the strength in the adjacent story above. (Commentary: Sec. A.2.2.2. Tier 2: Sec. 5.4.2.1)

[✓ C] NC N/A U SOFT STORY: The stiffness of the seismic-force-resisting system in any story shall not be less than 70% of the seismic-force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic-force-resisting system stiffnessof the three stories above. (Commentary: Sec. A.2.2.3. Tier 2: Sec. 5.4.2.2)

C [✓ NC] N/A U VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Commentary: Sec. A.2.2.4. Tier 2: Sec. 5.4.2.3)

[✓ C] NC N/A U GEOMETRY: There are no changes in the net horizontal dimension of the seismic-force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines. (Commentary: Sec. A.2.2.5. Tier 2: Sec. 5.4.2.4)

[✓ C] NC N/A U MASS: There is no change in effective mass more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Commentary: Sec. A.2.2.6. Tier 2: Sec. 5.4.2.5)

[✓ C] NC N/A U TORSION: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Commentary: Sec. A.2.2.7. Tier 2: Sec. 5.4.2.6)

Low Seismicity: Complete the Following Items in Additionto the Items for Very Low Seismicity.

Geologic Site Hazards

C [✓ NC] N/A U LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 ft under the building. (Commentary: Sec. A.6.1.1. Tier 2: 5.4.3.1)

C [✓ NC] N/A U SLOPE FAILURE: The building site is sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or is capable of accommodating any predicted movements without failure. (Commentary: Sec. A.6.1.2. Tier 2: 5.4.3.1)

C NC [✓ N/A] U SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. (Commentary: Sec. A.6.1.3. Tier 2: 5.4.3.1)

Moderate and High Seismicity: Complete the Following Items in Addition to the Items for Low Seismicity.

Foundation Configuration

[✓ C] NC N/A U OVERTURNING: The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than $0.6S_a$. (Commentary: Sec. A.6.2.1. Tier 2: Sec. 5.4.3.3)

[✓ C] NC N/A U TIES BETWEEN FOUNDATION ELEMENTS: The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Commentary: Sec. A.6.2.2. Tier 2: Sec. 5.4.3.4)

Project: Wilamette River WTP

Location: High Service Pump Station

Completed by: Carollo Engineers (James Doering)

Date: 5 / 18 / 2015

16.10IO IMMEDIATE OCCUPANCY STRUCTURAL CHECKLIST FOR BUILDING TYPES C2: CONCRETE SHEAR WALLS WITH STIFF DIAPHRAGMS AND C2A: CONCRETE SHEAR WALLS WITH FLEXIBLE DIAPHRAGMS

Very Low Seismicity

Seismic-Force-Resisting System

C NC [✓ N/A] U COMPLETE FRAMES: Steel or concrete frames classified as secondary components form a complete vertical-load-carrying system. (Commentary: Sec. A.3.1.6.1. Tier 2: Sec. 5.5.2.5.1)

[✓ C] NC N/A U REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1)

[✓ C] NC N/A U SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 4.5.3.3, is less than the greater of 100 lb/in.^{2} or $2\sqrt{f'_c}$. (Commentary: Sec. A.3.2.2.1. Tier 2: Sec. 5.5.3.1.1)

[✓ C] NC N/A U REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area is not less than 0.0012 in the vertical direction and 0.0020 in the horizontal direction. The spacing of reinforcing steel is equal to or less than 18 in. (Commentary: Sec. A.3.2.2.2. Tier 2: Sec. 5.5.3.1.3)

Connections

C [✓ NC] N/A U WALL ANCHORAGE AT FLEXIBLE DIAPHRAGMS: Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 4.5.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1)

[✓ C] NC N/A U TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of loads to the shear walls, and the connections are able to develop the lesser of the shear strength of the walls or diaphragms. (Commentary: Sec. A.5.2.1. Tier 2: Sec. 5.7.2)

[✓ C] NC N/A U FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation, and the dowels are able to develop the lesser of the strength of the walls or the uplift capacity of the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4)

Foundation System

C NC [✓ N/A] U DEEP FOUNDATIONS: Piles and piers are capable of transferring the lateral forces between the structure and the soil. (Commentary: Sec. A.6.2.3)

C NC [✓ N/A] U SLOPING SITES: The difference in foundation embedment depth from one side of the building to another shall not exceed one story high. (Commentary: Sec. A.6.2.4)

Low, Moderate, and High Seismicity: Complete the Following Items in Addition to the Items for Very Low Seismicity.

Seismic-Force-Resisting System

C NC [✓ N/A] U DEFLECTION COMPATIBILITY: Secondary components have the shear capacity to develop the flexural strength of the components and are compliant with the following items: COLUMN-BAR SPLICES, BEAM-BAR SPLICES, COLUMN-TIE SPACING, STIRRUP SPACING, and STIRRUP AND TIE HOOK in the Immediate Occupancy Structural Checklist for Building Type C1. (Commentary: Sec. A.3.1.6.2. Tier 2: Sec. 5.5.2.5.2)

C NC [✓ N/A] U FLAT SLABS: Flat slabs or plates not part of seismic-force-resisting system have continuous bottom steel through the column joints. (Commentary: Sec. A.3.1.6.3. Tier 2: Sec. 5.5.2.5.3)

C NC [✓ N/A] U COUPLING BEAMS: The stirrups in coupling beams over means of egress are spaced at or less than *d*/2 and are anchored into the confined core of the beam with hooks of 135 degrees or more. The ends of both walls to which the coupling beam is attached are supported at each end to resist vertical loads caused by overturning. Coupling beams have the capacity in shear to develop the uplift capacity of the adjacent wall. (Commentary: Sec.A.3.2.2.3. Tier 2: Sec. 5.5.3.2.1)

[✓ C] NC N/A U OVERTURNING: All shear walls have aspect ratios less than 4-to-1. Wall piers need not be considered. (Commentary: Sec. A.3.2.2.4. Tier 2: Sec. 5.5.3.1.4)

[✓ C] NC N/A U CONFINEMENT REINFORCING: For shear walls with aspect ratios greater than 2-to-1, the boundary elements are confined with spirals or ties with spacing less than $8d_b$. (Commentary: Sec. A.3.2.2.5. Tier 2: Sec. 5.5.3.2.2)

[✓ C] NC N/A U WALL REINFORCING AT OPENINGS: There is added trim reinforcement around all wall openings with a dimension greater than three times the thickness of the wall. (Commentary: Sec. A.3.2.2.6. Tier 2: Sec. 5.5.3.1.5)

C [✓ NC] N/A U WALL THICKNESS: Thicknesses of bearing walls are not less than 1/25 the unsupported height or length, whichever is shorter, nor less than 4 in. (Commentary: Sec. A.3.2.2.7. Tier 2: Sec. 5.5.3.1.2)

Connections

C NC [✓ N/A] U UPLIFT AT PILE CAPS: Pile caps shall have top reinforcement, and piles are anchored to the pile caps; the pile cap reinforcement and pile anchorage are able to develop the tensile capacity of the piles. (Commentary: Sec. A.5.3.8.Tier 2: Sec. 5.7.3.5)

Diaphragms (Flexible or Stiff)

[✓ C] NC N/A U DIAPHRAGM CONTINUITY: The diaphragms are not composed of split-level floors and do not have expansion joints. (Commentary: Sec. A.4.1.1. Tier 2: Sec. 5.6.1.1)

[✓ C] NC N/A U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 15% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

[✓ C] NC N/A U PLAN IRREGULARITIES: There is tensile capacity to develop the strength of the diaphragm at reentrant corners or other locations of plan irregularities. (Commentary: Sec. A.4.1.7. Tier 2: Sec. 5.6.1.4)

C NC [✓ N/A] U DIAPHRAGM REINFORCEMENT AT OPENINGS: There is reinforcing around all diaphragm openings larger than 50% of the building width in either major plan dimension. (Commentary: Sec. A.4.1.8. Tier 2: Sec. 5.6.1.5)

Flexible Diaphragms

[✓ C] NC N/A U CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2)

C NC [✓ N/A] U STRAIGHT SHEATHING: All straight sheathed diaphragms have aspect ratios less than 1-to-1 in the direction being considered. (Commentary: Sec.A.4.2.1. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U SPANS: All wood diaphragms with spans greater than 12 ft consist of wood structural panels or diagonal sheathing. (Commentary: Sec. A.4.2.2. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 30 ft and aspect ratios less than or equal to 3-to-1. (Commentary: Sec. A.4.2.3. Tier 2: Sec. 5.6.2)

C [✓ NC] N/A U NONCONCRETE FILLED DIAPHRAGMS: Untopped metal deck diaphragms or metal deck diaphragms with fill other than concrete consist of horizontal spans of less than 40 ft and have aspect ratios less than 4-to-1. (Commentary: Sec. A.4.3.1. Tier 2: Sec. 5.6.3)

C NC [✓ N/A] U OTHER DIAPHRAGMS: The diaphragm does not consist of a system other than wood, metal deck, concrete, or horizontal bracing. (Commentary: Sec. A.4.7.1. Tier 2: Sec. 5.6.5)

APPENDIX C
SUMMARY DATA SHEET

BUILDING DATA

Building Name: Sludge Thickener (Stair Housing) Date: 9 / 5 / 2017

Building Address: 13050 SW Arrowhead Creek Lane, Wilsonville, Oregon 97070

Latitude: North: 45.295 Longitude: West: 122.783 By: Carollo Engineers

Year Built: 2003 Year(s) Remodeled: N/A Original Design Code: 2000 International Building Code

Area (sf): 97 Length (ft): 15.0 Width (ft): 12.0

No. of Stories: 1 Story Height: 10.5-ft Total Height: 10.5 ft

USE ☐ Industrial ☐ Office ☐ Warehouse ☐ Hospital ☐ Residential ☐ Educational ☒ Other: Municipal

CONSTRUCTION DATA

Gravity Load Structural System: Metal Deck, Concrete Walls and Foundation Slab

Exterior Transverse Walls: Cast-in-Place Reinforced Concrete Walls Openings? No

Exterior Longitudinal Walls: Cast-in-Place Reinforced Concrete Walls Openings? Man access door

Roof Materials/Framing: Metal deck supported on concrete walls

Intermediate Floors/Framing: N/A

Ground Floor: Concrete Slab

Columns: No Foundation: Concrete Slab

General Condition of Structure:

Levels Below Grade? Yes. Buried concrete structure

Special Features and Comments:

LATERAL-FORCE-RESISTING SYSTEM

	Longitudinal	Transverse
System:	Concrete Shear Walls	Concrete Shear Walls
Vertical Elements:	Concrete Shear Walls	Concrete Shear Walls
Diaphragms:	Metal Deck	Metal Deck
Connections:		

EVALUATION DATA

BSE-1N Spectral Response Accelerations: S_{Ds} = 0.611g S_{D1} = 0.656g

Soil Factors: Class = E F_a = 0.992 F_v = 2.40

BSE-1E Spectral Response Accelerations: S_{XS} = 0.611g S_{X1} = 0.372g

Level of Seismicity: High Performance Level: S2 (Damage Control)

Building Period: T = 0.117 sec

Spectral Acceleration: S_a = 0.611g

Modification Factor: $C_mC_1C_2$ = 1.40 Building Weight: W = 54 kips

Pseudo Lateral Force: V= $C_mC_1C_2S_aW$= 46 kips

BUILDING CLASSIFICATION: Concrete Shear Wall with Flexible Diaphragm

REQUIRED TIER 1 CHECKLISTS	Yes	No
Basic Configuration Checklist	☒	☐
Building Type C2a **Structural Checklist**	☒	☐
Nonstructural Component Checklist	☒	☐

FURTHER EVALUATION REQUIREMENT:

Project: Wilamette River WTP

Location: Sludge Thickener (Stair Housing)

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.1.2LS LIFE SAFETY BASIC CONFIGURATION CHECKLIST

Low Seismicity

Building System

General

[✓ C] NC N/A U LOAD PATH: The structure shall contain a complete, well defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Commentary: Sec. A.2.1.1. Tier 2: Sec. 5.4.1.1)

C NC [✓ N/A] U ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 4% of the height of the shorter building. This statement shall not apply for the following building types: W1, W1a, and W2. (Commentary: Sec. A.2.1.2. Tier 2: Sec. 5.4.1.2) [No adjacent building]

C NC [✓ N/A] U MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic-force-resisting elements of the main structure. (Commentary: Sec. A.2.1.3. Tier 2: Sec. 5.4.1.3)

Building Configuration

[✓ C] NC N/A U WEAK STORY: The sum of the shear strengths of the seismic-force-resisting system in any story in each direction is not less than 80% of the strength in the adjacent story above. (Commentary: Sec. A2.2.2. Tier 2: Sec. 5.4.2.1)

[✓ C] NC N/A U SOFT STORY: The stiffness of the seismic-force-resisting system in any story is not less than 70% of the seismic-force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic-force-resisting system stiffness of the three stories above. (Commentary: Sec. A.2.2.3. Tier 2: Sec. 5.4.2.2)

[✓ C] NC N/A U VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Commentary: Sec. A.2.2.4. Tier 2: Sec. 5.4.2.3)

[✓ C] NC N/A U GEOMETRY: There are no changes in the net horizontal dimension of the seismic-force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines. (Commentary: Sec. A.2.2.5. Tier 2: Sec. 5.4.2.4)

C NC [✓ N/A] U MASS: There is no change in effective mass more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Commentary: Sec. A.2.2.6. Tier 2: Sec. 5.4.2.5) [Light roof]

[✓ C] NC N/A U TORSION: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Commentary: Sec. A.2.2.7. Tier 2: Sec. 5.4.2.6)

Moderate Seismicity: Complete the Following Items in Addition to the Items for Low Seismicity.

Geologic Site Hazards

C [✓ NC] N/A U LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 ft under the building. (Commentary: Sec. A.6.1.1. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SLOPE FAILURE: The building site is sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or is capable of accommodating any predicted movements without failure. (Commentary: Sec. A.6.1.2. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. (Commentary: Sec. A.6.1.3. Tier 2: 5.4.3.1)[Based on USGS earthquake map]

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Foundation Configuration

[✓ C] NC N/A U OVERTURNING: The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than 0.6S_a. (Commentary: Sec. A.6.2.1. Tier 2: Sec. 5.4.3.3)

C NC [✓ N/A] U TIES BETWEEN FOUNDATION ELEMENTS: The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Commentary: Sec. A.6.2.2. Tier 2: Sec. 5.4.3.4) [Stair housing resting on 12-in thick slab]

Project: Wilamette River WTP

Location: Sludge Thickener (Stair Housing)

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.10LS LIFE SAFETY STRUCTURAL CHECKLIST FOR BUILDING TYPES C2: CONCRETE SHEAR WALLS WITH STIFF DIAPHRAGMS AND C2A: CONCRETE SHEAR WALLS WITH FLEXIBLE DIAPHRAGMS

Low and Moderate Seismicity

Seismic-Force-Resisting System

C NC [✓ N/A] U COMPLETE FRAMES: Steel or concrete frames classified as secondary components form a complete vertical-load-carrying system. (Commentary: Sec. A.3.1.6.1. Tier 2: Sec. 5.5.2.5.1)

[✓ C] NC N/A U REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1)

[✓ C] NC N/A U SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 4.5.3.3, is less than the greater of 100 lb/in.^{2} or $2\sqrt{f'_c}$. (Commentary: Sec. A.3.2.2.1. Tier 2: Sec. 5.5.3.1.1)

[✓ C] NC N/A U REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area is not less than 0.0012 in the vertical direction and 0.0020 in the horizontal direction. (Commentary: Sec. A.3.2.2.2. Tier 2: Sec. 5.5.3.1.3)

Connections

[✓ C] NC N/A U WALL ANCHORAGE AT FLEXIBLE DIAPHRAGMS: Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 4.5.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1) [Anchor bolts, ledger and roof deck adequate for wall out-of-plane] [Walls can also span between the side walls]

[✓ C] NC N/A U TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of seismic forces to the shear walls. (Commentary: Sec. A.5.2.1. Tier 2: Sec. 5.7.2)

[✓ C] NC N/A U FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation with vertical bars equal in size and spacing to the vertical wall reinforcing immediately above the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4) [Foundation dowels are same as wall vertical reinforcing bars]

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Seismic-Force-Resisting System

C NC [✓ N/A] U DEFLECTION COMPATIBILITY: Secondary components have the shear capacity to develop the flexural strength of the components. (Commentary: Sec. A.3.1.6.2. Tier 2: Sec. 5.5.2.5.2) [No secondary components]

C NC [✓ N/A] U FLAT SLABS: Flat slabs or plates not part of the seismic-force-resisting system have continuous bottom steel through the column joints. (Commentary: Sec. A.3.1.6.3. Tier 2: Sec. 5.5.2.5.3)

C NC [✓ N/A] U COUPLING BEAMS: The stirrups in coupling beams over means of egress are spaced at or less than *d*/2 and are anchored into the confined core of the beam with hooks of 135 degrees or more. The ends of both walls to which the coupling beam is attached are supported at each end to resist vertical loads caused by overturning. (Commentary: Sec. A.3.2.2.3. Tier 2: Sec. 5.5.3.2.1)

Connections

C NC [✓ N/A] U UPLIFT AT PILE CAPS: Pile caps have top reinforcement, and piles are anchored to the pile caps. (Commentary: Sec. A.5.3.8. Tier 2: Sec. 5.7.3.5)

Diaphragms (Flexible or Stiff)

[✓ C] NC N/A U DIAPHRAGM CONTINUITY: The diaphragms are not composed of split-level floors and do not have expansion joints. (Commentary: Sec. A.4.1.1. Tier 2: Sec. 5.6.1.1)

C NC [✓ N/A] U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3) [No openings]

Flexible Diaphragms

C NC [✓ N/A] U CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2) [Rood deck spans between walls]

C NC [✓ N/A] U STRAIGHT SHEATHING: All straight sheathed diaphragms have aspect ratios less than 2-to-1 in the direction being considered. (Commentary: Sec. A.4.2.1. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U SPANS: All wood diaphragms with spans greater than 24 ft consist of wood structural panels or diagonal sheathing. (Commentary: Sec. A.4.2.2. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft and aspect ratios less than or equal to 4-to-1. (Commentary: Sec. A.4.2.3. Tier 2: Sec. 5.6.2)

[✓ C] NC N/A U OTHER DIAPHRAGMS: The diaphragm does not consist of a system other than wood, metal deck, concrete, or horizontal bracing. (Commentary: Sec. A.4.7.1. Tier 2: Sec. 5.6.5)

APPENDIX C
SUMMARY DATA SHEET

BUILDING DATA

Building Name: Sludge Dewatering Building   Date: 9 / 5 / 2017
Building Address: 13050 SW Arrowhead Creek Lane, Wilsonville, Oregon 97070
Latitude: North: 45.295   Longitude: West: 122.783   By: Carollo Engineers
Year Built: 2003   Year(s) Remodeled: N/A   Original Design Code: 2000 International Building Code
Area (sf): 680   Length (ft): 35.0   Width (ft): 22.0
No. of Stories: 2   Story Height: 1st: 16ft; 2nd: 13.83ft   Total Height: 30.83 ft

USE ☐ Industrial ☐ Office ☐ Warehouse ☐ Hospital ☐ Residential ☐ Educational ☒ Other: Municipal

CONSTRUCTION DATA

Gravity Load Structural System: Metal Deck, Steel Truss Joist, Concrete Slab, Concrete Walls and Wall Footing
Exterior Transverse Walls: Cast-in-Place Reinforced Concrete Walls   Openings? Windows and Truck Access
Exterior Longitudinal Walls: Cast-in-Place Reinforced Concrete Walls   Openings? Man access doors
Roof Materials/Framing: Metal deck supported on steel truss joist
Intermediate Floors/Framing: Concrete slab supported on concrete walls
Ground Floor: Slab-on-grade
Columns: No columns   Foundation: Continuous wall footing
General Condition of Structure:
Levels Below Grade? No
Special Features and Comments:

LATERAL-FORCE-RESISTING SYSTEM

	Longitudinal	Transverse
System:	Concrete Shear Walls	Concrete Shear Walls
Vertical Elements:	Concrete Shear Walls	Concrete Shear Walls
Diaphragms:	Metal Deck & Concrete Slab	Metal Deck & Concrete Slab
Connections:		

EVALUATION DATA

BSE-1N Spectral Response Accelerations: $S_{DS} =$ 0.611g $S_{D1} =$ 0.656g
Soil Factors: Class = E $F_a =$ 0.992 $F_v =$ 2.40
BSE-1E Spectral Response Accelerations: $S_{XS} =$ 0.611g $S_{X1} =$ 0.372g
Level of Seismicity: High   Performance Level: S2 (Damage Control)
Building Period: $T =$ 0.263 sec
Spectral Acceleration: $S_a =$ 0.611g
Modification Factor: $C_mC_1C_2 =$ 1.40   Building Weight: $W =$ 506 kips
Pseudo Lateral Force: $V = C_mC_1C_2S_aW =$ 433 kips

BUILDING CLASSIFICATION: Concrete Shear Wall

REQUIRED TIER 1 CHECKLISTS	Yes	No
Basic Configuration Checklist	☒	☐
Building Type C2 Structural Checklist	☒	☐
Nonstructural Component Checklist	☒	☐

FURTHER EVALUATION REQUIREMENT:

Project: Wilamette River WTP

Location: Sludge Dewatering Building

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.1.2LS LIFE SAFETY BASIC CONFIGURATION CHECKLIST

Low Seismicity

Building System

General

C [✓ NC] N/A U LOAD PATH: The structure shall contain a complete, well defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Commentary: Sec. A.2.1.1. Tier 2: Sec. 5.4.1.1) [Shear wall discontinuous in transverse direction]

C NC [✓ N/A] U ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 4% of the height of the shorter building. This statement shall not apply for the following building types: W1, W1a, and W2. (Commentary: Sec. A.2.1.2. Tier 2: Sec. 5.4.1.2) [No adjacent building]

C NC [✓ N/A] U MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic-force-resisting elements of the main structure. (Commentary: Sec. A.2.1.3. Tier 2: Sec. 5.4.1.3)

Building Configuration

C [✓ NC] N/A U WEAK STORY: The sum of the shear strengths of the seismic-force-resisting system in any story in each direction is not less than 80% of the strength in the adjacent story above. (Commentary: Sec. A2.2.2. Tier 2: Sec. 5.4.2.1) [Shear wall discontinuous in transverse direction]

C [✓ NC] N/A U SOFT STORY: The stiffness of the seismic-force-resisting system in any story is not less than 70% of the seismic-force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic-force-resisting system stiffness of the three stories above. (Commentary: Sec. A.2.2.3. Tier 2: Sec. 5.4.2.2) [Shear wall discontinuous in transverse direction]

C [✓ NC] N/A U VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Commentary: Sec. A.2.2.4. Tier 2: Sec. 5.4.2.3) [Shear wall discontinuous in transverse direction]

C [✓ NC] N/A U GEOMETRY: There are no changes in the net horizontal dimension of the seismic-force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines. (Commentary: Sec. A.2.2.5. Tier 2: Sec. 5.4.2.4) [Shear wall discontinuous in transverse direction]

C NC [✓ N/A] U MASS: There is no change in effective mass more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Commentary: Sec. A.2.2.6. Tier 2: Sec. 5.4.2.5) [Light roof]

[✓ C] NC N/A U TORSION: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Commentary: Sec. A.2.2.7. Tier 2: Sec. 5.4.2.6)

Moderate Seismicity: Complete the Following Items in Addition to the Items for Low Seismicity.

Geologic Site Hazards

C [✓ NC] N/A U LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 ft under the building. (Commentary: Sec. A.6.1.1. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SLOPE FAILURE: The building site is sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or is capable of accommodating any predicted movements without failure. (Commentary: Sec. A.6.1.2. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. (Commentary: Sec. A.6.1.3. Tier 2: 5.4.3.1) [Based on USGS earthquake map]

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Foundation Configuration

C [✓ NC] N/A U OVERTURNING: The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than $0.6S_a$. (Commentary: Sec. A.6.2.1. Tier 2: Sec. 5.4.3.3) [Shear wall discontinuous in transverse direction]

C [✓ NC] N/A U TIES BETWEEN FOUNDATION ELEMENTS: The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Commentary: Sec. A.6.2.2. Tier 2: Sec. 5.4.3.4)

Project: Wilamette River WTP

Location: Sludge Dewatering Building

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.10LS LIFE SAFETY STRUCTURAL CHECKLIST FOR BUILDING TYPES C2: CONCRETE SHEAR WALLS WITH STIFF DIAPHRAGMS AND C2A: CONCRETE SHEAR WALLS WITH FLEXIBLE DIAPHRAGMS

Low and Moderate Seismicity

Seismic-Force-Resisting System

C NC [✓ N/A] U COMPLETE FRAMES: Steel or concrete frames classified as secondary components form a complete vertical-load-carrying system. (Commentary: Sec. A.3.1.6.1. Tier 2: Sec. 5.5.2.5.1)

C [✓ NC] N/A U REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1) [Shear wall discontinuous in transverse direction]

C [✓ NC] N/A U SHEAR STRESS CHECK: The shear stress in the concrete shear walls, calculated using the Quick Check procedure of Section 4.5.3.3, is less than the greater of 100 lb/in.^{2} or $2\sqrt{f'_c}$. (Commentary: Sec. A.3.2.2.1. Tier 2: Sec. 5.5.3.1.1) [Shear wall discontinuous in transverse direction]

[✓ C] NC N/A U REINFORCING STEEL: The ratio of reinforcing steel area to gross concrete area is not less than 0.0012 in the vertical direction and 0.0020 in the horizontal direction. (Commentary: Sec. A.3.2.2.2. Tier 2: Sec. 5.5.3.1.3)

Connections

C [✓ NC] N/A U WALL ANCHORAGE AT FLEXIBLE DIAPHRAGMS: Exterior concrete or masonry walls that are dependent on flexible diaphragms for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 4.5.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1) [Wall anchorage at truss joist support is not adequate; DCR = 1.60]

C [✓ NC] N/A U TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of seismic forces to the shear walls. (Commentary: Sec. A.5.2.1. Tier 2: Sec. 5.7.2) [Shear wall discontinuous in transverse direction]

[✓ C] NC N/A U FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation with vertical bars equal in size and spacing to the vertical wall reinforcing immediately above the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4)

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Seismic-Force-Resisting System

C NC [✓ N/A] U DEFLECTION COMPATIBILITY: Secondary components have the shear capacity to develop the flexural strength of the components. (Commentary: Sec. A.3.1.6.2. Tier 2: Sec. 5.5.2.5.2)

C NC [✓ N/A] U FLAT SLABS: Flat slabs or plates not part of the seismic-force-resisting system have continuous bottom steel through the column joints. (Commentary: Sec. A.3.1.6.3. Tier 2: Sec. 5.5.2.5.3)

C NC [✓ N/A] U COUPLING BEAMS: The stirrups in coupling beams over means of egress are spaced at or less than $d/2$ and are anchored into the confined core of the beam with hooks of 135 degrees or more. The ends of both walls to which the coupling beam is attached are supported at each end to resist vertical loads caused by overturning. (Commentary: Sec. A.3.2.2.3. Tier 2: Sec. 5.5.3.2.1)

Connections

C NC [✓ N/A] U UPLIFT AT PILE CAPS: Pile caps have top reinforcement, and piles are anchored to the pile caps. (Commentary: Sec. A.5.3.8. Tier 2: Sec. 5.7.3.5)

Diaphragms (Flexible or Stiff)

[✓ C] NC N/A U DIAPHRAGM CONTINUITY: The diaphragms are not composed of split-level floors and do not have expansion joints. (Commentary: Sec. A.4.1.1. Tier 2: Sec. 5.6.1.1)

[✓ C] NC N/A U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

Flexible Diaphragms

[✓ C] NC N/A U CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2)

C NC [✓ N/A] U STRAIGHT SHEATHING: All straight sheathed diaphragms have aspect ratios less than 2-to-1 in the direction being considered. (Commentary: Sec. A.4.2.1. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U SPANS: All wood diaphragms with spans greater than 24 ft consist of wood structural panels or diagonal sheathing. (Commentary: Sec. A.4.2.2. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft and aspect ratios less than or equal to 4-to-1. (Commentary: Sec. A.4.2.3. Tier 2: Sec. 5.6.2)

[✓ C] NC N/A U OTHER DIAPHRAGMS: The diaphragm does not consist of a system other than wood, metal deck, concrete, or horizontal bracing. (Commentary: Sec. A.4.7.1. Tier 2: Sec. 5.6.5)

APPENDIX C
SUMMARY DATA SHEET

BUILDING DATA

Building Name: Chemical / Admin / Ozone Generation Building Date: 9 / 5 / 2017

Building Address: 13050 SW Arrowhead Creek Lane, Wilsonville, Oregon 97070

Latitude: North: 45.295 Longitude: West: 122.783 By: Carollo Engineers

Year Built: 2003 Year(s) Remodeled: N/A Original Design Code: 2000 International Building Code

Area (sf): 13,255 Length (ft): 124.67 Width (ft): 116.33

No. of Stories: 1 Story Height: 16.0 ft Total Height: 16.0 ft

USE ☐ Industrial ☐ Office ☐ Warehouse ☐ Hospital ☐ Residential ☐ Educational ☒ Other: Municipal

CONSTRUCTION DATA

Gravity Load Structural System: Metal Deck, Roof Truss Joist or Steel Beams, Steel Columns, Brick Masonry Walls and Concrete Wall Footing

Exterior Transverse Walls: Solid Grouted Brick Masonry Walls Openings? Access Doors

Exterior Longitudinal Walls: Solid Grouted Brick Masonry Walls Openings? Access Doors

Roof Materials/Framing: Metal deck, Truss Joist & Steel Beams

Intermediate Floors/Framing: N/A

Ground Floor: Concrete Slab

Columns: Steel Tube Columns Foundation: Concrete Wall Footing

General Condition of Structure:

Levels Below Grade? No.

Special Features and Comments:

LATERAL-FORCE-RESISTING SYSTEM

	Longitudinal	Transverse
System:	Solid Grouted Brick Masonry Walls	Solid Grouted Brick Masonry Walls
Vertical Elements:	Solid Grouted Brick Masonry Walls	Solid Grouted Brick Masonry Walls
Diaphragms:	Metal Deck	Metal Deck
Connections:		

EVALUATION DATA

BSE-1N Spectral Response Accelerations: S_{Ds} = 0.611g S_{D1} = 0.656g

Soil Factors: Class = E F_a = 0.992 F_v = 2.40

BSE-1E Spectral Response Accelerations: S_{XS} = 0.611g S_{X1} = 0.372g

Level of Seismicity: High Performance Level: S2 (Damage Control)

Building Period: T = 0.121 sec

Spectral Acceleration: S_a = 0.611g

Modification Factor: $C_mC_1C_2$ = 1.40 Building Weight: W = 659 kips

Pseudo Lateral Force: V=

$C_mC_1C_2S_aW$= 564 kips

BUILDING CLASSIFICATION: Brick Masonry Wall with Flexible Diaphragm

REQUIRED TIER 1 CHECKLISTS	**Yes**	**No**
Basic Configuration Checklist	☒	☐
Building Type RM1 **Structural Checklist**	☒	☐
Nonstructural Component Checklist	☒	☐

FURTHER EVALUATION REQUIREMENT:

Project: Wilamette River WTP

Location: Chemical / Admin / Ozone Generation Building

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.1.2LS LIFE SAFETY BASIC CONFIGURATION CHECKLIST

Low Seismicity

Building System

General

[✓ C] NC N/A U LOAD PATH: The structure shall contain a complete, well defined load path, including structural elements and connections, that serves to transfer the inertial forces associated with the mass of all elements of the building to the foundation. (Commentary: Sec. A.2.1.1. Tier 2: Sec. 5.4.1.1)

C NC [✓ N/A] U ADJACENT BUILDINGS: The clear distance between the building being evaluated and any adjacent building is greater than 4% of the height of the shorter building. This statement shall not apply for the following building types: W1, W1a, and W2. (Commentary: Sec. A.2.1.2. Tier 2: Sec. 5.4.1.2) [No adjacent building]

C NC [✓ N/A] U MEZZANINES: Interior mezzanine levels are braced independently from the main structure or are anchored to the seismic-force-resisting elements of the main structure. (Commentary: Sec. A.2.1.3. Tier 2: Sec. 5.4.1.3)

Building Configuration

C NC [✓ N/A] U WEAK STORY: The sum of the shear strengths of the seismic-force-resisting system in any story in each direction is not less than 80% of the strength in the adjacent story above. (Commentary: Sec. A2.2.2. Tier 2: Sec. 5.4.2.1)

C NC [✓ N/A] U SOFT STORY: The stiffness of the seismic-force-resisting system in any story is not less than 70% of the seismic-force-resisting system stiffness in an adjacent story above or less than 80% of the average seismic-force-resisting system stiffness of the three stories above. (Commentary: Sec. A.2.2.3. Tier 2: Sec. 5.4.2.2)

C NC [✓ N/A] U VERTICAL IRREGULARITIES: All vertical elements in the seismic-force-resisting system are continuous to the foundation. (Commentary: Sec. A.2.2.4. Tier 2: Sec. 5.4.2.3)

C NC [✓ N/A] U GEOMETRY: There are no changes in the net horizontal dimension of the seismic-force-resisting system of more than 30% in a story relative to adjacent stories, excluding one-story penthouses and mezzanines. (Commentary: Sec. A.2.2.5. Tier 2: Sec. 5.4.2.4)

C NC [✓ N/A] U MASS: There is no change in effective mass more than 50% from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Commentary: Sec. A.2.2.6. Tier 2: Sec. 5.4.2.5) [Light roof]

[✓ C] NC N/A U TORSION: The estimated distance between the story center of mass and the story center of rigidity is less than 20% of the building width in either plan dimension. (Commentary: Sec. A.2.2.7. Tier 2: Sec. 5.4.2.6)

Moderate Seismicity: Complete the Following Items in Addition to the Items for Low Seismicity.

Geologic Site Hazards

C [✓ NC] N/A U LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 ft under the building. (Commentary: Sec. A.6.1.1. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SLOPE FAILURE: The building site is sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or is capable of accommodating any predicted movements without failure. (Commentary: Sec. A.6.1.2. Tier 2: 5.4.3.1) [Based on available soil report]

[✓ C] NC N/A U SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site are not anticipated. (Commentary: Sec. A.6.1.3. Tier 2: 5.4.3.1)[Based on USGS earthquake map]

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Foundation Configuration

[✓ C] NC N/A U OVERTURNING: The ratio of the least horizontal dimension of the seismic-force-resisting system at the foundation level to the building height (base/height) is greater than $0.6S_a$. (Commentary: Sec. A.6.2.1. Tier 2: Sec. 5.4.3.3)

C NC [✓ N/A] U TIES BETWEEN FOUNDATION ELEMENTS: The foundation has ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Site Class A, B, or C. (Commentary: Sec. A.6.2.2. Tier 2: Sec. 5.4.3.4) [Wall footings restrained by slab]

Project: Wilamette River WTP

Location: Chemical / Admin / Ozone Generation Building

Completed by: Carollo Engineers (Caleb Che)

Date: 9 / 5 / 2017

16.15LS LIFE SAFETY STRUCTURAL CHECKLIST FOR BUILDING TYPES RM1: REINFORCED MASONRY BEARING WALLS WITH FLEXIBLE DIAPHRAGMS AND RM2: REINFORCED MASONRY BEARING WALLS WITH STIFF DIAPHRAGMS

Low and Moderate Seismicity

Seismic-Force-Resisting System

[✓ C] NC N/A U REDUNDANCY: The number of lines of shear walls in each principal direction is greater than or equal to 2. (Commentary: Sec. A.3.2.1.1. Tier 2: Sec. 5.5.1.1)

[✓ C] NC N/A U SHEAR STRESS CHECK: The shear stress in the reinforced masonry shear walls, calculated using the Quick Check procedure of Section 4.5.3.3, is less than 70 lb/in.^{2}. (Commentary: Sec. A.3.2.4.1. Tier 2: Sec. 5.5.3.1.1)

[✓ C] NC N/A U REINFORCING STEEL: The total vertical and horizontal reinforcing steel ratio in reinforced masonry walls is greater than 0.002 of the wall with the minimum of 0.0007 in either of the two directions; the spacing of reinforcing steel is less than 48 in., and all vertical bars extend to the top of the walls. (Commentary: Sec. A.3.2.4.2. Tier 2: Sec. 5.5.3.1.3)

Stiff Diaphragms

C NC [✓ N/A] U TOPPING SLAB: Precast concrete diaphragm elements are interconnected by a continuous reinforced concrete topping slab. (Commentary: Sec. A.4.5.1. Tier 2: Sec. 5.6.4)

Connections

[✓ C] NC N/A U WALL ANCHORAGE: Exterior concrete or masonry walls that are dependent on the diaphragm for lateral support are anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections shall have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 4.5.3.7. (Commentary: Sec. A.5.1.1. Tier 2: Sec. 5.7.1.1) [Perpendicular to Steel Deck: Wall anchorage at truss joist support adequate for wall out-of-plane]
[Parallel to Steel Deck: Anchor bolts, ledger angle & steel deck adequate for wall out-of-plane]

C NC [✓ N/A] U WOOD LEDGERS: The connection between the wall panels and the diaphragm does not induce cross-grain bending or tension in the wood ledgers. (Commentary: Sec. A.5.1.2. Tier 2: Sec. 5.7.1.3)

[✓ C] NC N/A U TRANSFER TO SHEAR WALLS: Diaphragms are connected for transfer of seismic forces to the shear walls. (Commentary: Sec. A.5.2.1. Tier 2: Sec. 5.7.2)

C NC [✓ N/A] U TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements are doweled for transfer of forces into the shear wall or frame elements. (Commentary: Sec. A.5.2.3. Tier 2: Sec. 5.7.2) [The roof is flexible diaphragm with metal deck]

[✓ C] NC N/A U FOUNDATION DOWELS: Wall reinforcement is doweled into the foundation. (Commentary: Sec. A.5.3.5. Tier 2: Sec. 5.7.3.4) [Foundation dowels matching to wall vertical reinforcing bars]

C NC [✓ N/A] U GIRDER–COLUMN CONNECTION: There is a positive connection using plates, connection hardware, or straps between the girder and the column support. (Commentary: Sec. A.5.4.1. Tier 2: Sec. 5.7.4.1)

High Seismicity: Complete the Following Items in Addition to the Items for Low and Moderate Seismicity.

Stiff Diaphragms

C NC [✓ N/A] U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

C NC [✓ N/A] U OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls are not greater than 8 ft long. (Commentary: Sec. A.4.1.6. Tier 2: Sec. 5.6.1.3)

Flexible Diaphragms

[✓ C] NC N/A U CROSS TIES: There are continuous cross ties between diaphragm chords. (Commentary: Sec. A.4.1.2. Tier 2: Sec. 5.6.1.2)

[✓ C] NC N/A U OPENINGS AT SHEAR WALLS: Diaphragm openings immediately adjacent to the shear walls are less than 25% of the wall length. (Commentary: Sec. A.4.1.4. Tier 2: Sec. 5.6.1.3)

[✓ C] NC N/A U OPENINGS AT EXTERIOR MASONRY SHEAR WALLS: Diaphragm openings immediately adjacent to exterior masonry shear walls are not greater than 8 ft long. (Commentary: Sec. A.4.1.6. Tier 2: Sec. 5.6.1.3)

C NC [✓ N/A] U STRAIGHT SHEATHING: All straight sheathed diaphragms have aspect ratios less than 2-to-1 in the direction being considered. (Commentary: Sec. A.4.2.1. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U SPANS: All wood diaphragms with spans greater than 24 ft consist of wood structural panels or diagonal sheathing. (Commentary: Sec. A.4.2.2. Tier 2: Sec. 5.6.2)

C NC [✓ N/A] U DIAGONALLY SHEATHED AND UNBLOCKED DIAPHRAGMS: All diagonally sheathed or unblocked wood structural panel diaphragms have horizontal spans less than 40 ft and aspect ratios less than or equal to 4-to-1. (Commentary: Sec. A.4.2.3. Tier 2: Sec. 5.6.2)

[✓ C] NC N/A U OTHER DIAPHRAGMS: The diaphragm shall not consist of a system other than wood, metal deck, concrete, or horizontal bracing. (Commentary: Sec. A.4.7.1. Tier 2: Sec. 5.6.5)

Connections

C NC [✓ N/A] U STIFFNESS OF WALL ANCHORS: Anchors of concrete or masonry walls to wood structural elements are installed taut and are stiff enough to limit the relative movement between the wall and the diaphragm to no greater than 1/8 in. before engagement of the anchors. (Commentary: Sec. A.5.1.4. Tier 2: Sec. 5.7.1.2)

Attachment C

CALCULATIONS

WILLAMETTE RIVER WATER TREATMENT PLANT
SEISMIC EVALUATION
STRUCTURAL CALCULATIONS

PREPARED BY
CAROLLO ENGINEERS

DATE: AUGUST 14, 2017
JOB #: 10721A.10

WILLAMETTE RIVER WATER TREATMENT PLANT
SEISMIC EVALUATION
STRUCTURAL CALCULATIONS

TABLE OF CONTENTS

ASCE 41 - EXISTING BUILDINGS
EVALUATION CRITERIA & PARAMETERS

Table C2-1. Probabililty of Exceedance and Mean Return Period

Probability of Exceedance	Mean Return Period (years)
50%/30 years	43
50%/50 years	72
20%/50 years	225
10%/50 years	475
5%/50 years	975
2%/50 years	2,475

Table C2-2. Performance Objectives

	Target Building Performance Levels			
Seismic Hazard Level	Operational Performance Level (1-A)	Immediate Occupancy Performance Level (1-B)	Life Safety Performance Level (3-C)	Collapse Prevention Performance Level (5-D)
50%/50 years	a	b	c	d
BSE-1E (20%/50 years)	e	f	g	h
BSE-2E (5%/50 years)	i	j	k	l
BSE-2N (ASCE 7 MCE_R)	m	n	o	p

NOTES: Each cell in the above matrix represents a discrete Performance Objective.
The Performance Objectives in the matrix above can be used to represent the three specific Performance Objectives for a standard building that would be considered Risk Category I & II defined in Sections 2.2.1, 2.2.2, and 2.2.3, as follows:

Basic Performance Objective for Existing Buildings (BPOE)	g and l
Enhanced Objectives	g and i, j, m, n, o, or p l and e or f g and l and a, or b k, m, n, or o alone
Limited Objectives	g alone l alone c, d, e, or f

The BPOE varies by Risk Category. This standard does not specify how to assign a building to a Risk Category. Risk Categories are used here to facilitate the coordination with regulations, building codes, and policies, such as the *International Building Code* and the *International Existing Building Code*, which do use them. The intention is that regulations, building codes, and policies need to cover all Risk Categories but might prefer to cite this standard in a simple way. Defining the BPOE as in Table 2-1 allows a regulation, building code, or policy to simply cite the BPOE without creating its own table to spell out the Seismic Hazard Level and Performance Levels for each Risk Category.

The BPOE, or objectives close to it, has been used for characterizing seismic performance in other standards and regulations and has been implemented in many individual projects and mitigation programs. The BPOE also approximates the regulatory policy traditionally applied to existing buildings in many seismically active areas of the United States. The BPOE accepts a lower level of safety and a higher risk of collapse than would that provided by similar standards for new buildings. Buildings meeting the BPOE are expected to experience little damage from relatively frequent, moderate earthquakes but significantly more damage and potential economic loss from the most severe and infrequent earthquakes that could affect them. The level of damage and potential economic loss experienced by buildings rehabilitated to the BPOE likely will be greater than that expected in similar, properly designed and constructed new buildings or existing buildings evaluated and retrofit to the Basic Performance Objective Equivalent to New Building Standards (BPON) in Section 2.2.4.

There are three overarching historical reasons for accepting a somewhat greater risk in existing buildings:

- Accepting performance less than “full code” ensures that recent buildings are not immediately rendered deficient whenever the code changes in such a manner as to become more conservative.
- The increase in risk is tempered by the recognition that an existing building often has a shorter remaining life than a new building. That is, if the traditional code-based demand

Table 2-1. Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1[a]	Tier 2[a]	Tier 3	
Risk Category	BSE-1E	BSE-1E	BSE-1E	BSE-2E
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III All Structures Except Noted Below	See footnote *b* for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV High Service Pump Station	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

[a] For Tier 1 and 2 assessments, seismic performance for the BSE-2E is not explicitly evaluated.
[b] For Risk Category III, the Tier 1 screening checklists shall be based on the Life Safety Performance Level (S-3), except that checklist statements using the Quick Check procedures of Section 4.5.3 shall be based on MS-factors and other limits that are an average of the values for Life Safety and Immediate Occupancy.

Table 4-7. Checklists Required for a Tier 1 Screening

Level of Seismicity[b]	Level of Building Performance[c]	Required Checklists[a] Very Low Seismicity Checklist (Sec 16.1.1)	Basic Configuration Checklist (Sec. 16.1.2)	Life Safety Checklist (Sec. 16.2LS through 16.15LS)	Immediate Occupancy Checklist (Sec. 16.2IO through 16.15IO)	Life Safety Nonstructural Checklist (Sec. 16.17)	Position Retention Nonstructural Checklist (Sec. 16.17)
Very low	LS	X					
Very low	IO		X		X		X
Low	LS		X	X		X	
Low	IO		X		X		X
Moderate	LS		X	X		X	
Moderate	IO		X		X		X
High	LS		X	X		X	
High	IO		X		X		X

[a] An X designates the checklist that must be completed for a Tier 1 screening as a function of the level of seismicity and level of performance.
[b] Defined in Section 2.5.
[c] LS = Life Safety Performance Level, and IO = Immediate Occupancy Performance Level (defined in Section 2.3.3).

marked “Compliant” (C), “Noncompliant” (NC), “Unknown” (U), or “Not Applicable” (N/A). Compliant statements identify issues that are acceptable according to the criteria of this standard, whereas noncompliant or unknown statements identify issues that require further investigation to demonstrate compliance with the applicable Performance Objective. Certain evaluation statements may not apply to the specific building being evaluated.

Quick Checks for Tier 1 shall be performed in accordance with Section 4.5 where necessary to complete an evaluation statement.

The checklist for Very Low Seismicity, located in Section 16.1.1, shall be completed for buildings in Very Low Seismicity being evaluated to the Life Safety Performance Level. For buildings in Very Low Seismicity being evaluated to the Immediate Occupancy Performance Level and buildings in levels of Low, Moderate, or High Seismicity, the appropriate structural and nonstructural checklists shall be completed in accordance with Table 4-7.

The appropriate structural checklists shall be selected based on the common building types defined in Table 3-1. Buildings being evaluated to the Life Safety Performance Level shall use the applicable checklists in Chapter 16 denoted “LS” after the section number. Buildings being evaluated to the Immediate Occupancy Performance Level shall use the applicable checklists in Chapter 16 denoted “IO” after the section number.

A building with a different lateral-force-resisting system in each principal direction shall use two sets of structural checklists, one for each direction. A building with more than one type of lateral-force-resisting system along a single axis of the building being evaluated to the Life Safety Performance Level, including changes in seismic-force-resisting system over the height, may be evaluated using the applicable checklist(s) in Chapter 16 subject to the requirements in Section 3.3.1.2.2.

Two nonstructural checklists also are provided in Chapter 16: Life Safety and Position Retention. Refer to Table 4-7 for the applicability of the nonstructural checklists.

C4.4 SELECTION AND USE OF CHECKLISTS

The evaluation statements provided in the checklists form the core of the Tier 1 screening methodology. These evaluation statements are based on observed earthquake structural damage during actual earthquakes. The checklists do not necessarily identify the response of the structure to ground motion; rather, the design professional obtains a general sense of the structure’s deficiencies and potential behavior during an earthquake.

Although the section numbers in parentheses after each evaluation statement correspond to Tier 2 evaluation procedures, they also correspond to commentary in Appendix A regarding the statement’s purpose. If additional information on the evaluation statement is required, please refer to the commentary in the Tier 2 procedure and Appendix A for that evaluation statement.

4.5 TIER 1 ANALYSIS

4.5.1 Overview Analyses performed as part of the Tier 1 screening process are limited to Quick Checks. Quick Checks shall be used to calculate the stiffness and strength of certain building components to determine whether the building complies with certain evaluation criteria. Quick Checks shall be performed in accordance with Section 4.5.3 where they are triggered by evaluation statements from the checklists of Chapter 16. Seismic forces for use in the Quick Checks shall be computed in accordance with Section 4.5.2.

4.5.2 Seismic Forces

4.5.2.1 Pseudo Seismic Force The pseudo seismic force, in a given horizontal direction of a building, shall be calculated in accordance with Eqs. (4-1) or (4-2), if applicable.

$$V = CS_aW \tag{4-1}$$

where V = Pseudo seismic force.
C = Modification factor to relate expected maximum inelastic displacements to displacements calculated for linear elastic response; C shall be taken from Table 4-8.
S_a = Response spectral acceleration at the fundamental period of the building in the direction under consideration. The value of S_a shall be calculated in accordance with the procedures in Section 4.5.2.3.
W = Effective seismic weight of the building, including the total dead load and applicable portions of other gravity loads listed below:

1. In areas used for storage, a minimum of 25% of the floor live load shall be applicable. The live load shall be permitted to be reduced for tributary area as approved by the code official. Floor live load in public garages and open parking structures need not be considered.

Table 4-8. Modification Factor, C

	Number of Stories			
Building Type[a]	1	2	3	≥4
Wood (W1, W1a, W2) Moment frame (S1, S3, C1, PC2a)	1.3	1.1	1.0	1.0
Shear wall (S4, S5, C2, C3, PC1a, PC2, RM2, URMa) Braced frame (S2)	1.4	1.2	1.1	1.0
Unreinforced masonry (URM) Flexible diaphragms (S1a, S2a, S5a, C2a, C3a, PC1, RM1)	1.0	1.0	1.0	1.0

[a] Defined in Table 3-1.

2. Where an allowance for partition load is included in the floor load design, the actual partition weight or a minimum weight of 10 lb/ft^2 of floor area, whichever is greater, shall be applied.
3. Total operating weight of permanent equipment.
4. Where the design flat roof snow load calculated in accordance with ASCE 7 exceeds 30 lb/ft^2, the effective snow load shall be taken as 20% of the design snow load. Where the design flat roof snow load is 30 lb/ft^2 or less, the effective snow load shall be permitted to be zero.

Alternatively, for buildings in which the bottom of the foundation is less than 3 ft below exterior grade with a slab or tie beams to connect interior footings and being evaluated for the Life Safety Performance Level, Eq. (4-2) shall be permitted to be used to compute the pseudo seismic force:

$$V = 0.75W \tag{4-2}$$

If Eq. (4-2) is used, an M_s-factor of 1.0 shall be used to compute the component forces and stresses for the Quick Checks of Section 4.5.3.

C4.5.2.1 Pseudo Seismic Force The seismic evaluation procedure of this standard, as well as those in FEMA P-750 (2009c), (BSSC 2009), and ASCE 7 (2010), is based on a widely accepted philosophy that permits nonlinear response of a building where subjected to a ground motion that is representative of the design earthquake. FEMA P-750 (2009c) and ASCE 7 (2010) account for nonlinear seismic response in a linear static analysis procedure by including a response modification factor, R, in calculating a reduced equivalent base shear to produce a rough approximation of the internal forces during a design earthquake. In other words, the base shear is representative of the force that the building is expected to resist, but the building displacements are significantly less than the actual displacements of the building during a design earthquake. Thus, in this R-factor approach, displacements calculated from the reduced base shear need to be increased by another factor (C_d or R) where checking drift or ductility requirements. In summary, this procedure is based on equivalent seismic forces and pseudo displacements.

The linear static analysis procedure in this standard takes a different approach to account for the nonlinear seismic response. Pseudo static seismic forces are applied to the structure to obtain actual displacements during a design earthquake. The pseudo seismic force of Eq. (4-1) represents the force required, in a linear static analysis, to impose the expected deformation of the structure in its yielded state where subjected to the design earthquake motions. The modification factor C in Eq. (4-1) is intended to replace the product of modification factors C_1, C_2, and C_m in Chapter 7. The factor C increases the pseudo seismic force where the period of the structure is low. The effect of the period of the structure is replaced by the number of stories in Table 4-8. Furthermore, the factor C is larger where a higher level of ductility in the building is relied upon. Thus, unreinforced masonry buildings have a lower factor as compared with concrete shear wall or moment-frame structures. In assigning values for coefficient C, representative average values (instead of using most conservative values) for coefficients C_1, C_2, and C_m were considered.

The pseudo seismic force does not represent an actual seismic force that the building must resist in traditional design codes. In summary, this procedure is based on equivalent displacements and pseudo seismic forces. For additional commentary regarding this linear static analysis approach, please refer to the Commentary in Chapter 7.

For short and stiff buildings with low ductility located in levels of High Seismicity, the required building strength in accordance with Eq. (4-1) may exceed the force required to cause sliding at the foundation level. The strength of the structure, however, does not need to exceed the sliding resistance at the foundation–soil interface. It is assumed that this sliding resistance is equal to 0.75W. Thus, where Eq. (4-2) is applied to these buildings, the required strength of structural components need not exceed 0.75W.

4.5.2.2 Story Shear Forces The pseudo seismic force calculated in accordance with Section 4.5.2.1 shall be distributed vertically in accordance with Eqs. (4-3a and 4-3b). For buildings six stories or fewer high, the value of k shall be permitted to be taken as 1.0.

$$F_x = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k} V \tag{4-3a}$$

$$V_j = \sum_{x=j}^{n} F_x \tag{4-3b}$$

where V_j = Story shear at story level j;
n = Total number of stories above ground level;
j = Number of story levels under consideration;
W = Total seismic weight, per Section 4.5.2.1;
V = Pseudo seismic force from Eq. (4-1) or (4-2);
w_i = Portion of total building weight W located on or assigned to floor level i;
w_x = Portion of total building weight W located on or assigned to floor level x;
h_i = Height (ft) from the base to floor level i;
h_x = Height (ft) from the base to floor level x; and
k = 1.0 for $T \le 0.5$ s and 2.0 for $T > 2.5$ s; linear interpolation shall be used for intermediate values of k.

For buildings with stiff or rigid diaphragms, the story shear forces shall be distributed to the lateral-force-resisting elements based on their relative rigidities. For buildings with flexible diaphragms (Types S1a, S2a, S5a, C2a, C3a, PC1, RM1, and URM), story shear shall be calculated separately for each line of lateral resistance.

4.5.2.3 Spectral Acceleration Spectral acceleration, S_a, for use in computing the pseudo seismic force shall be computed in accordance with Eq. (4-4).

$$S_a = \frac{S_{X1}}{T} \tag{4-4}$$

but S_a shall not exceed S_{XS}.

where T is the fundamental period of vibration of the building, calculated in accordance with Section 4.5.2.4, and

S_{X1} and S_{XS} are as defined in Section 2.4 for the Seismic Hazard Level specified in Section 4.1.2. Alternatively, a site-specific response spectrum shall be permitted to be developed according to Section 2.4.2 for the Seismic Hazard Level specified in Section 4.1.2.

4.5.2.4 Period The fundamental period of a building, in the direction under consideration, shall be calculated in accordance with Eq. (4-5).

$$T = C_t h_n^{\beta} \tag{4-5}$$

where T = Fundamental period (seconds) in the direction under consideration;
C_t = 0.035 for moment-resisting frame systems of steel (Building Types S1 and S1a);
= 0.018 for moment-resisting frames of reinforced concrete (Building Type C1);
= 0.030 for eccentrically braced steel frames (Building Types S2 and S2a);
= 0.020 for all other framing systems;
h_n = height (ft) above the base to the roof level;
β = 0.80 for moment-resisting frame systems of steel (Building Types S1 and S1a);
= 0.90 for moment-resisting frame systems of reinforced concrete (Building Type C1); and
= 0.75 for all other framing systems.

Alternatively, for steel or reinforced-concrete moment frames of 12 stories or fewer, the fundamental period of the building may be calculated as follows:

$$T = 0.10n \tag{4-6}$$

where n = number of stories above the base.

C4.5.2.4 Period The values of C_t given in this standard are intended to be reasonable lower bound (not mean) values for structures, including the contribution of nonstructural elements. The value of T used in the evaluation should be as close as possible to, but less than, the true period of the structure.

4.5.3 Quick Checks for Strength and Stiffness Quick Checks shall be used to compute the stiffness and strength of building components. Quick Checks are triggered by evaluation statements in the checklists of Chapter 16 and are required to determine the compliance of certain building components. The seismic forces used in the Quick Checks shall be calculated in accordance with Section 4.5.2.

~~**4.5.3.1 Story Drift for Moment Frames** Eq. (4-7) shall be used to calculate the drift ratios of regular, multi-story, multi-bay moment frames with columns continuous above and below the story under consideration. The drift ratio is based on the deflection caused by flexural displacement of a representative column, including the effect of end rotation caused by bending of the representative beam.~~

$$D_r = \left(\frac{k_b + k_c}{k_b k_c}\right)\left(\frac{h}{12E}\right)V_c \tag{4-7}$$

~~where D_r = Drift ratio: Interstory displacement divided by story height;~~
~~k_b = I/L for the representative beam;~~
~~k_c = I/h for the representative column;~~
~~h = Story height (in.);~~
~~I = Moment of inertia (in.^{4});~~
~~L = Beam length from center-to-center of adjacent columns (in.);~~
~~E = Modulus of elasticity (kip/in.^{2}); and~~
~~V_c = Shear in the column (kip).~~

~~The column shear forces are calculated using the story shear forces in accordance with Section 4.5.2.2. For reinforced concrete frames, an effective cracked section moment of inertia equal to one-half of gross value shall be used.~~

~~Eq. (4-7) also may be used for the first floor of the frame if columns are fixed against rotation at the bottom. However, if columns are pinned at the bottom, the drift ratio shall be multiplied by 2.~~

~~For other configurations of frames, the Quick Check need not be performed; however, a Tier 2 evaluation, including calculation of the drift ratio, shall be completed based on principles of structural mechanics.~~

~~**C4.5.3.1 Story Drift for Moment Frames** Eq. (4-7) assumes that all of the columns in the frame have similar stiffness.~~

~~**4.5.3.2 Shear Stress in Concrete Frame Columns** The average shear stress, v_j^{avg}, in the columns of concrete frames shall be computed in accordance with Eq. (4-8).~~

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{n_c}{n_c - n_f}\right)\left(\frac{V_j}{A_c}\right) \tag{4-8}$$

~~where n_c = Total number of columns;~~
~~n_f = Total number of frames in the direction of loading;~~
~~A_c = Summation of the cross-sectional area of all columns in the story under consideration;~~
~~V_j = Story shear computed in accordance with Section 4.5.2.2; and~~
~~M_s = System modification factor; M_s shall be taken as equal to 2.0 for buildings being evaluated to the Life Safety Performance Level and equal to 1.3 for buildings being evaluated to the Immediate Occupancy Performance Level.~~

~~**C4.5.3.2 Shear Stress in Concrete Frame Columns** Eq. (4-8) assumes that all of the columns in the frame have similar stiffness.~~

~~The inclusion of the term $[n_c/(n_c - n_f)]$ in Eq. (4-8) is based on the assumption that the end column carries half the load of a typical interior column. This equation is not theoretically correct for a one-bay frame and yields shear forces that are twice the correct force; however, because of the lack of redundancy in one-bay frames, this level of conservatism is considered appropriate.~~

4.5.3.3 Shear Stress in Shear Walls The average shear stress in shear walls, v_j^{avg}, shall be calculated in accordance with Eq. (4-9).

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{A_w}\right) \tag{4-9}$$

where V_j = Story shear at level j computed in accordance with Section 4.5.2.2.
A_w = Summation of the horizontal cross-sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration where computing A_w. For masonry walls, the net area shall be used. For wood-framed walls, the length shall be used rather than the area.
M_s = System modification factor; M_s shall be taken from Table 4-9.

Table 4-9. M_s Factors for Shear Walls

Wall Type	Level of Performance LS	Level of Performance IO
Reinforced concrete, precast concrete, wood, and reinforced masonry	4.0	2.0
Unreinforced masonry	1.5	1.0

Table 4-10. M_s Factors for Diagonal Braces

Brace Type	d/t[a]	Level of Performance LS	Level of Performance IO
Tube[b]	$<90/(F_{ye})^{1/2}$	6.0	2.5
	$>190/(F_{ye})^{1/2}$	3.0	1.5
Pipe[b]	$<1500/F_{ye}$	6.0	2.5
	$>6000/F_{ye}$	3.0	1.5
Tension-only		3.0	1.5
All others		6.0	2.5

[a] Depth-to-thickness ratio.

[b] Interpolation to be used for tubes and pipes.

$F_{ye} = 1.25F_y$; expected yield stress.

4.5.3.4 Diagonal Bracing The average axial stress in diagonal bracing elements, f_j^{avg}, shall be calculated in accordance with Eq. (4-10).

$$f_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{sN_{br}}\right)\left(\frac{L_{br}}{A_{br}}\right) \qquad (4\text{-}10)$$

where L_{br} = Average length of the braces (ft);

N_{br} = Number of braces in tension and compression if the braces are designed for compression; number of diagonal braces in tension if the braces are designed for tension only;

s = Average span length of braced spans (ft);

A_{br} = Average area of a diagonal brace (in.^{2});

V_j = Maximum story shear at each level (kip); and

M_s = System modification factor; M_s shall be taken from Table 4-10.

4.5.3.5 Precast Connections The strength of the connection in precast concrete moment frames shall be greater than the moment in the girder, M_{gj}, calculated in accordance with Eq. (4-11).

$$M_{gj} = \frac{V_j}{M_s}\left(\frac{1}{n_c - n_f}\right)\left(\frac{h}{2}\right) \qquad (4\text{-}11)$$

Where n_c = Total number of columns;

n_f = Total number of frames in the direction of loading;

V_j = Story shear at the level directly below the connection under consideration;

h = Typical column story height; and

M_s = System modification factor taken as equal to 2.0 for buildings being evaluated to the Life Safety Performance Level and equal to 1.3 for buildings being evaluated to the Immediate Occupancy Performance Level.

C4.5.3.5 Precast Connections The term $[1/(n_c - n_f)]$ in Eq. (4-11) is based on the assumption that the end column carries half the load of a typical interior column.

4.5.3.6 Column Axial Stress Caused by Overturning The axial stress of columns in moment frames at the base subjected to overturning forces, p_{ot}, shall be calculated in accordance with Eq. (4-12).

$$p_{ot} = \frac{1}{M_s}\left(\frac{2}{3}\right)\left(\frac{Vh_n}{Ln_f}\right)\left(\frac{1}{A_{col}}\right) \qquad (4\text{-}12)$$

where n_f = Total number of frames in the direction of loading;

V = Pseudo seismic force;

h_n = Height (ft) above the base to the roof level;

L = Total length of the frame (ft);

M_s = System modification factor taken as equal to 2.0 for buildings being evaluated to the Life Safety Performance Level and equal to 1.3 for buildings being evaluated to the Immediate Occupancy Performance Level; and

A_{col} = Area of the end column of the frame.

C4.5.3.6 Column Axial Stress Caused by Overturning The 2/3 factor in Eq. (4-12) assumes a triangular force distribution with the resultant applied at 2/3 the height of the building.

4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \qquad (4\text{-}13)$$

Where w_p = unit weight of the wall;

A_p = area of wall tributary to the connection;

ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and

S_{XS} = value specified in Section 4.5.2.3.

4.5.3.8 Prestressed Elements The average prestress in prestressed or post-tensioned elements, f_p, shall be calculated in accordance with Eq. (4-14).

$$f_p = \frac{f_{pe} n_p}{A_p} \qquad (4\text{-}14)$$

where f_{pe} = Effective force of a prestressed strand;

n_p = Number of prestressed strands; and

A_p = Gross area of prestressed concrete elements.

C4.5.3.8 Prestressed Elements The average prestress is simply calculated as the effective force of a prestressed strand times the number of strands divided by the gross concrete area. In many cases, half-inch strands are used, which correspond to an effective force of 25 kip per strand.

4.5.3.9 Flexural Stress in Columns and Beams of Steel Moment Frames The average flexural stress in the columns and beams of steel frames at each level shall be computed in accordance with Eq. (4-15).

$$f_j^{avg} = V_j \frac{1}{M_s}\left(\frac{n_c}{n_c - n_f}\right)\left(\frac{h}{2}\right)\frac{1}{Z} \qquad (4\text{-}15)$$

where n_c = Total number of frame columns at the level, j, under consideration.

n_f = Total number of frames in the direction of loading at the level, j, under consideration.

V_j = Story shear computed in accordance with Section 4.5.2.2.

h = Story height (in.).

Z = For columns, the sum of the plastic section moduli of all the frame columns at the level under consideration. For beams, it is the sum of the plastic section moduli of all the frame beams with moment-resisting connections. If a beam has moment-resisting connections at both ends, then the contribution of that beam to the sum is twice the plastic section modulus of that beam (in^3).

M_s = System modification factor; M_s shall be taken as equal to 8.0 for buildings being evaluated to the Life Safety Performance Level and equal to 3.0 for buildings being evaluated to the Immediate Occupancy Performance Level for columns and beams satisfying the checklist items for compactness and column axial stress. If the columns or beams do not satisfy the checklist statements for compactness and column axial stress for the Immediate Occupancy Performance Level, then this item must be marked noncompliant.

C4.5.3.9 Flexural Stress in Columns and Beams of Steel Moment Frames Eq. (4-15) assumes that all of the columns in the frame have similar stiffness.

The inclusion of the term $[n_c/(n_c - n_f)]$ in Eq. (4-15) is based on the assumption that the end column carries half the load of a typical interior column. This equation is not theoretically correct for a one-bay frame and yields forces that are twice the correct force. However, because of the lack of redundancy in the one-bay frame, this level of conservatism is considered appropriate. The equation may also be conservative when checking the top level of a frame.

7.4.1.3 Determination of Forces and Deformations for LSP Forces and deformations in elements and components shall be calculated for the pseudo seismic force of Section 7.4.1.3.1, using component stiffnesses calculated in accordance with Chapters 8 through 12. Pseudo seismic forces shall be distributed throughout the building in accordance with Sections 7.4.1.3.2 through 7.4.1.3.4. Alternatively, for unreinforced masonry buildings in which the fundamental period is calculated using Eq. (7-20), pseudo seismic forces shall be permitted to be distributed in accordance with Section 7.4.1.3.5. Actions and deformations shall be modified to consider the effects of torsion in accordance with Section 7.2.3.2.

7.4.1.3.1 Pseudo Seismic Force for LSP The pseudo lateral force in a given horizontal direction of a building shall be determined using Eq. (7-21). This force shall be used to evaluate or retrofit the vertical elements of the seismic-force-resisting system.

$$V = C_1 C_2 C_m S_a W \qquad (7\text{-}21)$$

where V = Pseudo lateral force; and

C_1 = Modification factor to relate expected maximum inelastic displacements to displacements calculated for linear elastic response. For fundamental periods less than 0.2 s, C_1 need not be taken as greater than the value at $T = 0.2$ s. For fundamental periods greater than 1.0 s, $C_1 = 1.0$.

$$C_1 = 1 + \frac{\mu_{\text{strength}} - 1}{aT^2} \qquad (7\text{-}22)$$

where a = Site class factor;

= 130 site Class A or B;

= 90 site Class C;

= 60 site Class D, E, or F;

μ_{strength} = Ratio of elastic strength demand to yield strength coefficient calculated in accordance with Eq. (7-31) with the elastic base shear capacity substituted for shear yield strength, V_y;

T = Fundamental period of the building in the direction under consideration, calculated in accordance with Section 7.4.1.2, including modification for SSI effects of Section 7.2.7, if applicable;

C_2 = Modification factor to represent the effect of pinched hysteresis shape, cyclic stiffness degradation, and strength deterioration on maximum displacement response. For fundamental periods greater than 0.7 s, $C_2 = 1.0$.

$$C_2 = 1 + \frac{1}{800}\left(\frac{\mu_{\text{strength}} - 1}{T}\right)^2 \qquad (7\text{-}23)$$

Alternately, it shall be permitted to use C_1C_2 per Table 7-3, where $m_{\max}$ is the largest m-factor for all primary elements of the building in the direction under consideration.

C_m = Effective mass factor to account for higher modal mass participation effects obtained from Table 7-4.

C_m shall be taken as 1.0 if the fundamental period, T, is greater than 1.0 s;

S_a = response spectrum acceleration, at the fundamental period and damping ratio of the building in the direction under consideration. The value of S_a shall be obtained from the procedure specified in Section 2.4; and

W = effective seismic weight of the building, including the total dead load and applicable portions of other gravity loads listed below:

1. In areas used for storage, a minimum 25% of the floor live load shall be applicable. The live load shall be permitted to be reduced for tributary area as approved by the authority having jurisdiction. Floor live load in public garages and open parking structures is not applicable.
2. Where an allowance for partition load is included in the floor load design, the actual partition weight or a minimum weight of 10 lb/in.^{2} of floor area, whichever is greater, shall be applicable.
3. Total operating weight of permanent equipment.
4. Where the flat roof snow load calculated in accordance with ASCE 7 exceeds 30 lb/ft^2, the effective snow load shall be taken as 20% of the snow load. Where the flat roof snow load is less than 30 lb/ft^2, the effective snow load shall be permitted to be zero.

C7.4.1.3.1 Pseudo Lateral Force for LSP **Coefficient C_1.** This modification factor is used to account for the difference in maximum elastic and inelastic displacement amplitudes in structures with relatively stable and full hysteretic loops. The values of the coefficient are based on analytical and experimental investigations of the earthquake response of yielding structures. The quantity μ_{strength} is the ratio of the required elastic strength to the yield strength of the structure. Alternatively, μ_{strength} may be considered using:

$$\mu_{\text{strength}} = \frac{\text{DCR}_{\max}}{1.5} C_m \geq 1.0 \qquad (\text{C7-3})$$

where DCR$_{\max}$ is the largest DCR computed for any primary component of a building in the direction of response under consideration, taking $C_1 = C_2 = C_m = 1.0$.

The expression above is obtained by substituting Eq. (7-17) into Eq. (7-31) and assuming that the elastic base shear capacity (fully yielded strength, V_y) is mobilized at a shear that is 1.5 times the shear at first yield (as indicated by the largest primary component DCR). The latter assumption is based on representative values for system overstrength. As is indicated in Fig. C12.1-1 of FEMA P-750 (2009c), the factor relating force level to fully

Table 7-3. Alternate Values for Modification Factors C_1C_2

Fundamental Period	$m_{\max} < 2$	$2 \leq m_{\max} < 6$	$m_{\max} \geq 6$
$T \leq 0.3$	1.1	1.4	1.8
$0.3 < T \leq 1.0$	1.0	1.1	1.2
$T > 1.0$	1.0	1.0	1.1

$C_1C_2C_m$ = 1.4 -> For Concrete & Masonry Shear Walls

Table 7-4. Values for Effective Mass Factor C_m

No. of Stories	Concrete Moment Frame	Concrete Shear Wall	Concrete Pier-Spandrel	Steel Moment Frame	Steel Concentrically Braced Frame	Steel Eccentrically Braced Frame	Other
1–2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3 or more	0.9	0.8	0.8	0.9	0.9	0.9	1.0

NOTE: C_m shall be taken as 1.0 if the fundamental period, T, in the direction of response under consideration is greater than 1.0 s.

The Type 2 curve depicted in Fig. 7-4 is representative of ductile behavior where there is an elastic range (points 0 to 1 on the curve) and a plastic range (points 1 to 3). The plastic range can have either a positive or negative post-elastic slope (points 1 to 3) followed by substantial loss of seismic-force-resisting capacity at point 3. Loss of gravity-load-resisting capacity takes place at the deformation associated with point 4. Primary component actions exhibiting this behavior shall be classified as deformation-controlled if the plastic range is such that $e \geq 2g$; otherwise, they shall be classified as force controlled. Secondary component actions exhibiting this behavior shall be classified as deformation controlled if $f \geq 2g$; otherwise, they shall be classified as force controlled.

The Type 3 curve depicted in Fig. 7-4 is representative of a brittle or nonductile behavior where there is an elastic range (points 0 to 1 on the curve) followed by loss of seismic-force-resisting capacity at point 3 and loss of gravity-load-resisting capacity at the deformation associated with point 4. Primary component actions exhibiting this behavior shall be classified as force controlled. Secondary component actions exhibiting this behavior shall be classified as deformation controlled if $f \geq 2g$; otherwise, they shall be classified as force controlled.

For nonlinear procedures, force-controlled components defined in Chapters 8 through 12 may be reclassified as Type 3 deformation-controlled components, provided the following criteria are met:

1. The component action being reclassified exhibits the Type 3 deformation-controlled performance defined in this section;
2. The gravity-load-resisting load path is not altered, or if it is altered, an alternate load path is provided to ensure local stability is maintained in accordance with the load combinations of Section 7.2.2 at the anticipated maximum displacements predicted by the analysis;
3. The total gravity load supported by all components that are reclassified from force controlled to deformation controlled does not exceed 5% of the total gravity load being supported at that story; and
4. All remaining deformation-controlled components meet the acceptance criteria to achieve the target performance level and all remaining force-controlled components are not overstressed.

Where overstrength of Type 3 components alters the expected mechanism in the building, the analysis shall be repeated with the affected Type 3 component strengths increased by the ratio Q_{CE}/Q_y, and all components shall be rechecked.

C7.5.1.2 Deformation-Controlled and Force-Controlled Actions

Acceptance criteria for primary components that exhibit Type 1 behavior typically are within the elastic or plastic ranges between points 0 and 2, depending on the performance level. Acceptance criteria for secondary components that exhibit Type 1 behavior can be within any of the performance ranges.

Acceptance criteria for primary and secondary components exhibiting Type 2 behavior are within the elastic or plastic ranges, depending on the performance level.

Acceptance criteria for primary and secondary components exhibiting Type 3 behavior are always within the elastic range.

Table C7-1 provides some examples of possible deformation- and force-controlled actions in common framing systems. Classification of deformation- or force-controlled actions are specified for foundation and framing components in Chapters 8 through 12.

Table C7-1. Examples of Possible Deformation-Controlled and Force-Controlled Actions

Component	Deformation-Controlled Action	Force-Controlled Action
Moment frames		
• Beams	Moment (*M*)	Shear (*V*)
• Columns	—	Axial load (*P*), *V*
• Joints	—	V^a
Shear walls	*M*, *V*	*P*
Braced frames		
• Braces	*P*	—
• Beams	—	*P*
• Columns	—	*P*
• Shear link	*V*	*P*, *M*
Connections	*P*, *V*, M^b	*P*, *V*, *M*
Diaphragms	*M*, V^c	*P*, *V*, *M*

[a] Shear may be a deformation-controlled action in steel moment frame construction.

[b] Axial, shear, and moment may be deformation-controlled actions for certain steel and wood connections.

[c] If the diaphragm carries lateral loads from vertical-force-resisting elements above the diaphragm level, then *M* and *V* shall be considered force-controlled actions.

A given component may have a combination of both deformation- and force-controlled actions.

Classification as a deformation-controlled action is not up to the discretion of the user. Deformation-controlled actions have been defined in this standard by the designation of *m*-factors or nonlinear deformation capacities in Chapters 8 through 12. Additionally, there are specific provisions for nonlinear analyses when certain force-controlled actions may be reclassified as deformation controlled. Where such values are not designated and component testing justifying Type 1 or Type 2 behavior is absent, actions are to be taken as force controlled.

Figure C7-3 shows the generalized force versus deformation curves used throughout this standard to specify element modeling and acceptance criteria for deformation-controlled actions in any of the four basic material types. Linear response is depicted between point A (unloaded element) and an effective yield point B. The slope from point B to point C is typically a small percentage (0% to 10%) of the elastic slope and is included to represent phenomena such as strain hardening. Point C has an ordinate that represents the strength of the element and an abscissa value equal to the deformation at which significant strength degradation begins (line CD). Beyond point D, the element responds with substantially reduced strength to point E. At deformations greater than point E, the element seismic strength is essentially zero.

The sharp transition as shown on idealized curves in Fig. C7-3 between points C and D can result in computational difficulty and an inability to converge where it is used as modeling input in nonlinear computerized analysis software. For some types of suddenly degrading components (e.g., pre-Northridge connection fracture), this is reflective of the observed component behavior. However, to avoid this computational instability, a small slope (e.g., 10 vertical to 1 horizontal) may be provided to the segment of these curves between points C and D. Alternatively, the slope may be based on data from testing of comparable specimens. (e.g., for reinforced concrete components, it may be acceptable to connect points 2 and 3 for Type 1 components). See PEER/ATC 72-1 (2010) for additional guidance.

For some components, it is convenient to prescribe acceptance criteria in terms of deformation (such as θ or Δ), whereas for

C7.5.1.4 Material Properties Where calculations are used to determine expected or lower-bound strengths of components, expected or lower-bound material properties, respectively, shall be used.

7.5.1.5 Component Capacities

7.5.1.5.1 General Detailed criteria for calculation of individual component force and deformation capacities shall comply with the requirements in individual materials chapters as follows:

1. Foundations: Chapter 8;
2. Components composed of steel or cast iron: Chapter 9;
3. Components composed of reinforced concrete: Chapter 10;
4. Components composed of reinforced or unreinforced masonry: Chapter 11;
5. Components composed of timber, cold-formed steel light frame, gypsum, or plaster products: Chapter 12;
6. Nonstructural (architectural, mechanical, and electrical) components: Chapter 13; and
7. Seismic isolation systems and energy dissipation systems: Chapter 14.

Elements and components composed of combinations of materials are covered in the chapters associated with each material.

7.5.1.5.2 Linear Procedures If linear procedures are used, capacities for deformation-controlled actions shall be defined as the product of m-factors, κ-factors, and expected strengths, Q_{CE}. Capacities for force-controlled actions shall be defined as lower-bound strengths, Q_{CL}, as summarized in Table 7-6.

7.5.1.5.3 Nonlinear Procedures If nonlinear procedures are used, component capacities for deformation-controlled actions shall be taken as permissible inelastic deformation limits. Component capacities for force-controlled actions shall be taken as lower-bound strengths, Q_{CL}, as summarized in Table 7-7.

Table 7-6. Calculation of Component Action Capacity: Linear Procedures

Parameter	Deformation Controlled	Force Controlled
Existing material strength	Expected mean value with allowance for strain-hardening	Lower-bound value (approximately mean value 1σ level)
Existing action capacity	κQ_{CE}	κQ_{CL}
New material strength	Expected material strength	Specified material strength
New action capacity	Q_{CE}	Q_{CL}

Table 7-7. Calculation of Component Action Capacity: Nonlinear Procedures

Parameter	Deformation Controlled	Force Controlled
Deformation capacity (existing component)	$\kappa \times$ Deformation limit	N/A
Deformation capacity (new component)	Deformation limit	N/A
Strength capacity (existing component)	N/A	$\kappa \times Q_{CL}$
Strength capacity (new component)	N/A	Q_{CL}

7.5.2 Linear Procedures

7.5.2.1 Forces and Deformations Component forces and deformations shall be calculated in accordance with linear analysis procedures of Sections 7.4.1 or 7.4.2.

7.5.2.1.1 Deformation-Controlled Actions for LSP or LDP Deformation-controlled actions, Q_{UD}, shall be calculated in accordance with Eq. (7-34):

$$Q_{UD} = Q_G + Q_E \tag{7-34}$$

where Q_E = Action caused by the response to the selected Seismic Hazard Level calculated using either Section 7.4.1 or Section 7.4.2;

Q_G = Action caused by gravity loads as defined in Section 7.2.2; and

Q_{UD} = Deformation-controlled action caused by gravity loads and earthquake forces.

C7.5.2.1.1 Deformation-Controlled Actions for LSP or LDP Because of possible anticipated nonlinear response of the structure, the actions as represented by Eq. (7-34) may exceed the actual strength of the component to resist these actions. The acceptance criteria of Section 7.5.2.2.1 take this overload into account through use of a factor, m, that is an indirect measure of the nonlinear deformation capacity of the component.

7.5.2.1.2 Force-Controlled Actions for LSP or LDP Force-controlled actions, Q_{UF}, shall be calculated using one of the following methods:

1. Q_{UF} shall be taken as the maximum action that can be developed in a component based on a limit-state analysis considering the expected strength of the components delivering force to the component under consideration, or the maximum action developed in the component as limited by the nonlinear response of the building.
2. Alternatively, Q_{UF} shall be calculated in accordance with Eq. (7-35).

$$Q_{UF} = Q_G \pm \frac{Q_E}{C_1 C_2 J} \tag{7-35}$$

where Q_{UF} = Force-controlled action caused by gravity loads in combination with earthquake forces; and

J = Force-delivery reduction factor, greater than or equal to 1.0, taken as the smallest demand capacity ratio (DCR) of the components in the load path delivering force to the component in question, calculated in accordance with Eq. (7-16).

Alternatively, values of J equal to 2.0 for a high level of seismicity, 1.5 for a moderate level of seismicity, and 1.0 for a low level of seismicity shall be permitted where not based on calculated DCRs. J shall be taken as 1.0 for the Immediate Occupancy Structural Performance Level.

In any case where the forces contributing to Q_{UF} are delivered by components of the seismic-force-resisting system that remain elastic, J shall be taken as 1.0.

C7.5.2.1.2 Force-Controlled Actions for LSP or LDP The basic approach for calculating force-controlled actions for evaluation or retrofit differs from that used for deformation-controlled actions because nonlinear deformations associated with force-controlled actions are not permitted. Therefore, force demands for force-controlled actions should not exceed the force capacity (strength).

Ideally, an inelastic mechanism for the structure is identified, and the force-controlled actions, Q_{UF}, for evaluation or retrofit are determined by limit analysis using that mechanism. This approach always produces a conservative estimate of the actions, even if an incorrect mechanism is selected. Where it is not possible to use limit (or plastic) analysis, or in cases where forces do not produce significant nonlinear response in the building, it is acceptable to determine the force-controlled actions for evaluation or retrofit using Eq. (7-35).

Coefficients C_1 and C_2 were introduced in Eq. (7-21) to amplify the base shear to achieve a better estimate of the maximum displacements expected for buildings responding in the inelastic range. Displacement amplifiers, C_1 and C_2, are divided out of Eq. (7-35) when seeking an estimate of the force level present in a component where the building is responding inelastically.

Because J is included for force-controlled actions, it may appear to be more advantageous to treat an action as force controlled where m-factors are less than J. However, proper application of force-controlled criteria requires a limit state analysis of demand and lower-bound calculation of capacity that yields a reliable result whether an action is treated as force or deformation controlled.

7.5.2.2 Acceptance Criteria for Linear Procedures

7.5.2.2.1 Acceptance Criteria for Deformation-Controlled Actions for LSP or LDP Deformation-controlled actions in primary and secondary components shall satisfy Eq. (7-36).

$$m\kappa Q_{CE} > Q_{UD} \tag{7-36}$$

where m = Component capacity modification factor to account for expected ductility associated with this action at the selected Structural Performance Level. m-factors are specified in Chapters 8 through 12 and 14;

Q_{CE} = Expected strength of component deformation-controlled action of an element at the deformation level under consideration. Q_{CE}, the expected strength, shall be determined considering all coexisting actions on the component under the loading condition by procedures specified in Chapters 8 through 14; and

κ = Knowledge factor defined in Section 6.2.4.

7.5.2.2.2 Acceptance Criteria for Force-Controlled Actions for LSP or LDP Force-controlled actions in primary and secondary components shall satisfy Eq. (7-37):

$$\kappa Q_{CL} > Q_{UF} \tag{7-37}$$

where Q_{CL} = Lower-bound strength of a force-controlled action of an element at the deformation level under consideration. Q_{CL}, the lower-bound strength, shall be determined considering all coexisting actions on the component under the loading condition by procedures specified in Chapters 8 through 12 and 14.

7.5.2.2.3 Verification of Analysis Assumptions for LSP or LDP In addition to the requirements in Section 7.2.14, the following verification of analysis assumptions shall be made.

Where moments caused by gravity loads in horizontally spanning primary components exceed 75% of the expected moment strength at any location, the possibility for inelastic flexural action at locations other than member ends shall be specifically investigated by comparing flexural actions with expected member strengths. Where linear procedures are used, formation of flexural plastic hinges away from member ends shall not be permitted.

7.5.3 Nonlinear Procedures

7.5.3.1 Forces and Deformations Component forces and deformations shall be calculated in accordance with nonlinear analysis procedures of Sections 7.4.3 or 7.4.4.

7.5.3.2 Acceptance Criteria for Nonlinear Procedures

7.5.3.2.1 Acceptance Criteria for Deformation-Controlled Actions for NSP or NDP Primary and secondary components shall have expected deformation capacities not less than maximum deformation demands calculated at target displacements. Primary and secondary component demands shall be within the acceptance criteria for nonlinear components at the selected Structural Performance Level. Expected deformation capacities shall be determined considering all coexisting forces and deformations in accordance with Chapters 8 through 14.

C7.5.3.2.1 Acceptance Criteria for Deformation-Controlled Actions for NSP or NDP Where all components are explicitly modeled with full backbone curves, the NSP or NDP can be used to evaluate the full contribution of all components to the seismic force resistance of the structure as they degrade to residual strength values. Where degradation is explicitly evaluated in the analysis, components can be relied upon for lateral-force resistance out to the secondary component limits of response.

Studies on the effects of different types of strength degradation are presented in FEMA 440 (2005). As components degrade, the post-yield slope of the force–displacement curve becomes negative. The strength ratio, μ_{max}, limits the extent of degradation based on the degree of negative post-yield slope.

7.5.3.2.2 Acceptance Criteria for Force-Controlled Actions for NSP or NDP Primary and secondary components shall have lower-bound strengths not less than the maximum analysis forces. Lower-bound strengths shall be determined considering all coexisting forces and deformations by procedures specified in Chapters 8 through 12 and 14.

7.5.3.2.3 Verification of Analysis Assumptions for NSP or NDP In addition to the requirements in Section 7.2.14, the following verification of analysis assumptions shall be made:

Flexural plastic hinges shall not form away from component ends unless they are explicitly accounted for in modeling and analysis.

7.6 ALTERNATIVE MODELING PARAMETERS AND ACCEPTANCE CRITERIA

It shall be permitted to derive required parameters and acceptance criteria using the experimentally obtained cyclic response characteristics of a subassembly, determined in accordance with this section. Where relevant data on the inelastic force–deformation behavior for a structural subassembly are not available, such data shall be obtained from experiments consisting of physical tests of representative subassemblies as specified in this section. Approved independent review of this process shall be conducted.

C7.6 ALTERNATIVE MODELING PARAMETERS AND ACCEPTANCE CRITERIA

This section provides guidance for developing appropriate data to evaluate construction materials and detailing systems not specifically addressed by this standard. This standard specifies stiffnesses, m-factors, strengths, and deformation capacities for a wide range of components. To the extent practical, this standard unless a larger or smaller number of deformation cycles is determined considering earthquake duration and dynamic properties of the structure.

C10.3.2.1 General In this standard, actions are classified as either deformation controlled or force controlled. Actions are considered to be deformation controlled where the component behavior is well documented by test results. Where linear or nonlinear acceptance criteria are tabulated in this chapter, the committee has judged the action to be deformation controlled and expected material properties should be used. Where such acceptance criteria are not specified, the action should be assumed force controlled, thereby requiring the use of lower-bound material properties, or the design professional may opt to perform testing to validate the classification of deformation controlled. Section 7.6 provides guidance on procedures to be followed during testing, and Section 7.5.1.2 provides a methodology based on the test data to distinguish force-controlled from deformation-controlled actions. Further guidance on the testing of moment-frame components can be found in ACI 374.1.

In some cases, including short-period buildings and those subjected to a long-duration design earthquake, a building may be expected to be subjected to additional cycles to the design deformation levels beyond the three cycles recommended in Section 10.3.2.1. The increased number of cycles may lead to reductions in resistance and deformation capacity. The effects on strength and deformation capacity of additional deformation cycles should be considered in design.

10.3.2.2 Deformation-Controlled Actions Strengths used for deformation-controlled actions shall be taken as equal to expected strengths Q_{CE} obtained experimentally or calculated using accepted principles of mechanics. Expected strength is defined as the mean maximum resistance expected over the range of deformations to which a concrete component is likely to be subjected. Where calculations are used to define expected strength, expected material properties shall be used. Unless specified in this standard, other procedures specified in ACI 318 to calculate design strengths shall be permitted, except that the strength reduction factor ϕ shall be taken equal to unity. Deformation capacities for acceptance of deformation-controlled actions calculated by nonlinear procedures shall be as specified in Sections 10.4 through 10.12. For components constructed of lightweight concrete, Q_{CE} shall be modified in accordance with ACI 318 procedures for lightweight concrete.

C10.3.2.2 Deformation-Controlled Actions Expected yield strength of reinforcing steel, as specified in Section 10.2.2.1.2, includes material overstrength considerations.

10.3.2.3 Force-Controlled Actions Strengths used for force-controlled actions shall be taken as lower-bound strengths Q_{CL}, obtained experimentally or calculated using established principles of mechanics. Lower-bound strength is defined as the mean less one standard deviation of resistance expected over the range of deformations and loading cycles to which the concrete component is likely to be subjected. Where calculations are used to define lower-bound strengths, lower-bound estimates of material properties shall be used. Unless other procedures are specified in this standard, procedures specified in ACI 318 to calculate design strengths shall be permitted, except that the strength reduction factor ϕ shall be taken equal to unity. For components constructed of lightweight concrete, Q_{CL} shall be modified in accordance with ACI 318 procedures for lightweight concrete.

10.3.2.4 Component Ductility Demand Classification Table 10-6 provides classification of component ductility demands as low, moderate, or high based on the maximum value of the demand–capacity ratio (DCR) defined in Section 7.3.1.1 for linear procedures or the calculated displacement ductility for nonlinear procedures.

Table 10-6. Component Ductility Demand Classification

Maximum Value of DCR or Displacement Ductility	Descriptor
<2	Low ductility demand
2 to 4	Moderate ductility demand
>4	High ductility demand

10.3.3 Flexure and Axial Loads Flexural strength of members with and without axial loads shall be calculated according to ACI 318 or by other demonstrated rational methods, such as sectional analysis using appropriate concrete and steel constitutive models. Deformation capacity of members with and without axial loads shall be calculated considering shear, flexure, and reinforcement slip deformations, or based on acceptance criteria given in this standard. Strengths and deformation capacities of components with monolithic flanges shall be calculated considering concrete and developed longitudinal reinforcement within the effective flange width, as defined in Section 10.3.1.3.

Strength and deformation capacities shall be determined based on the available development of longitudinal reinforcement. Where longitudinal reinforcement has embedment or development length that is insufficient for reinforcement strength development, flexural strength shall be calculated based on limiting stress capacity of the embedded bar as defined in Section 10.3.5.

Where flexural deformation capacities are calculated from basic principles of mechanics, reductions in deformation capacity caused by applied shear shall be considered. Where using analytical models for flexural deformability that do not directly consider effect of shear and design shear equals or exceeds $6\sqrt{f'_c}A_w$, lb/in.^{2} ($0.5\sqrt{f'_c}A_w$, MPa), the design value shall not exceed 80% of the value calculated using the analytical model.

For concrete columns under combined axial load and biaxial bending, the combined strength shall be evaluated considering biaxial bending. When using linear procedures, the design axial load P_{UF} shall be calculated as a force controlled action per Section 7.5.2. The design moments M_{UD} should be calculated about each of two orthogonal axes. Combined strength shall be based on principles of mechanics with applied bending moments calculated as $M_{UDx}/(m_x\kappa)$ and $M_{UDy}/(m_y\kappa)$ about the x- and y-axes, respectively. Acceptance shall be based on the applied bending moments lying within the expected strength envelope calculated at an axial load level of P_{UF}.

C10.3.3 Flexure and Axial Loads Laboratory tests indicate that flexural deformability may be reduced as coexisting shear forces increase. As flexural ductility demands increase, shear capacity decreases, which may result in a shear failure before theoretical flexural deformation capacities are reached. Use caution where flexural deformation capacities are determined by calculation. FEMA 306 (1998b) (Section 5.2) is a resource for guidance on the interaction between shear and flexure.

The combined strength under uniaxial or biaxial bending with axial load is difficult to generalize in a closed-form solution, given the range of column section geometries encountered. For a particular class of rectangular column sections, closed-form solutions based on section capacities about the principal axes have been developed that provide excellent agreement when compared with a more generalized analysis (Hsu 1988, Furlong

Table 9-4. *(Continued)*

Component/Action	*m*-Factors for Linear Procedures[a]				
		Primary		Secondary	
	IO	LS	CP	LS	CP
Composite Top and Clip Angle Bottom[j]					
a. Failure of deck reinforcement	1.25	2	3	4	6
b. Local flange yielding and web crippling of column	1.5	4	6	5	7
c. Yield of bottom flange angle	1.5	4	6	6	7
d. Tensile yield of rivets or bolts at column flange	1.25	1.5	2.5	2.5	3.5
e. Shear yield of beam flange connections	1.25	2.5	3.5	3.5	4.5
Shear connection with slab[h]	$2.4–0.011d_{bg}$	—	—	$13.0–0.290d_{bg}$	$17.0–0.387d_{bg}$
Shear connection without slab[i]	$8.9–0.193d_{bg}$	—	—	$13.0–0.290d_{bg}$	$17.0–0.387d_{bg}$
Eccentrically Braced Frame (EBF) Link Beam[k,l]					
a. $e \le \frac{1.6\, M_{CE}}{V_{CE}}$	1.5	9	13	13	15
b. $e \ge \frac{2.6\, M_{CE}}{V_{CE}}$	Same as for beams				
c. $\frac{1.6\, M_{CE}}{V_{CE}} < e < \frac{2.6\, M_{CE}}{V_{CE}}$	Linear interpolation shall be used				
Braces in Compression (except EBF braces)					
a. Slender[m] $\frac{Kl}{r} \ge 4.2\sqrt{E/F_y}$					
1. *W*, *I*, 2*L* in-plane[n], 2*C* in-plane[n]	1.25	6	8	7	9
2. 2*L* out-of-plane[n], 2*C* out-of-plane[n]	1.25	5	7	6	8
3. HSS, pipes, tubes, *L*	1.25	5	7	6	8
b. Stocky[m,o] $\frac{Kl}{r} \le 2.1\sqrt{E/F_y}$					
1. *W*, *I*, 2*L* in-plane[n], 2*C* in-plane[n]	1.25	5	7	6	8
2. 2*L* out-of-plane[n], 2*C* out-of-plane[n]	1.25	4	6	5	7
3. HSS, pipes, tubes	1.25	4	6	5	7
c. Intermediate	Linear interpolation between the values for slender and stocky braces (after application of all applicable modifiers) shall be used.				
Braces in Tension (except EBF braces)[p,w]	1.25	5[q,r]	7[q,r]	8[r,s]	10[r,s]
Buckling-Restrained Braces[t,u]	2.3	5.6	7.5	7.5	10
Beams, Columns in Tension (except EBF Beams, Columns)	1.25	3	5	6	7
Steel Plate Shear Walls[v]	1.5	8	12	12	14
Diaphragm Components					
Diaphragm shear yielding or panel or plate buckling	1.25	2	3	2	3
Diaphragm chords and collectors—Full lateral support	1.25	6	8	6	8
Diaphragm chords and collectors—Limited lateral support	1.25	2	3	2	3

m-factors for flexible steel deck diaphragm shear

[a] Columns in moment or braced frames shall be permitted to be designed for the maximum force delivered by connecting members. For rectangular or square columns, replace $b_f/2t_f$ with b/t, replace 52 with 110, and replace 65 with 190.

[b] Columns with $P/P_{CL} > 0.5$ shall be considered force controlled.

[c] $m = 9(1 – 5/3\ P/P_{CL})$ in the plane of bending.

[d] $m = 12(1 – 5/3\ P/P_{CL})$ in the plane of bending.

[e] $m = 15(1 – 5/3\ P/P_{CL})$ in the plane of bending.

[f] $m = 18(1 – 5/3\ P/P_{CL})$ in the plane of bending.

[g] Tabulated values shall be modified as indicated in Section 9.4.2.4.2, Item 4.

[h] d is the beam depth; d_{bg} is the depth of the bolt group.

[i] Web plate or stiffened seat shall be considered to carry shear. Without shear connection, action shall not be classified as secondary. If $d_b > 18$ in., multiply *m*-factors by $18/d_b$, but values need not be less than 1.0.

[j] For high-strength bolts, divide values by 2.0, but values need not be less than 1.25.

[k] Values are for link beams with three or more web stiffeners. If no stiffeners, divide values by 2.0, but values need not be less than 1.25. Linear interpolation shall be used for one or two stiffeners.

[l] Assumes ductile detailing for flexural link, in accordance with AISC *341*.

[m] In addition to consideration of connection capacity in accordance with Section 9.5.2.4.1, values for braces shall be modified for connection robustness as follows: Where brace connections do not satisfy the requirements of AISC 341, F2.6, the acceptance criteria shall be multiplied by 0.8.

[n] Stitches for built-up members: Where the stitches for built-up braces do not satisfy the requirements of AISC 341, F2.5b, the acceptance criteria shall be multiplied by 0.5.

[o] Section compactness: Acceptance criteria applies to brace sections that are concrete-filled or seismically compact according to Table D1.1 of AISC 341 for highly ductile members. Where the brace section is noncompact according to Table B4.1 of AISC 360, the acceptance criteria shall be multiplied by 0.5. For intermediate compactness conditions, the acceptance criteria shall be multiplied by a value determined by linear interpolation between the seismically compact and the noncompact cases.

[p] For tension-only bracing, *m*-factors shall be divided by 2.0, but need not be less than 1.25.

[q] For 2*L*, HSS, pipe, and single angle, *m*-factors shall be multiplied by 0.8.

[r] In addition to consideration of connection capacity in accordance with Section 9.5.2.4.1, values for braces shall be modified for connection robustness as follows: Where brace connections do not satisfy the requirements of AISC 341, Section F2.6, the acceptance criteria shall be multiplied by 0.8.

[s] For 2*L*, HSS, pipe, and single angle, *m*-factors shall be multiplied by 0.7.

[t] Maximum strain of the buckling-restrained brace (BRB) core shall not exceed 2.5%.

[u] If testing to demonstrate compliance with Section 9.5.4.4.2 is not available, the acceptance criteria shall be multiplied by 0.7.

[v] Applicable if stiffeners, or concrete backing, is provided to prevent buckling.

[w] Regardless of the modifiers applied, *m* need never be taken less than 1.0.

Table 10-13. Numerical Acceptance Criteria for Linear Procedures—Reinforced Concrete Beams

Conditions			m-Factors[a]				
			Performance Level				
				Component Type			
				Primary		Secondary	
			IO	LS	CP	LS	CP
Condition i. Beams controlled by flexure[b]							
$\frac{\rho-\rho'}{\rho_{bal}}$	Transverse reinforcement[c]	$\frac{V}{b_w d\sqrt{f'_c}}$[d]					
≤0.0	C	≤3 (0.25)	3	6	7	6	10
≤0.0	C	≥6 (0.5)	2	3	4	3	5
≥0.5	C	≤3 (0.25)	2	3	4	3	5
≥0.5	C	≥6 (0.5)	2	2	3	2	4
≤0.0	NC	≤3 (0.25)	2	3	4	3	5
≤0.0	NC	≥6 (0.5)	1.25	2	3	2	4
≥0.5	NC	≤3 (0.25)	2	3	3	3	4
≥0.5	NC	≥6 (0.5)	1.25	2	2	2	3
Condition ii. Beams controlled by shear[b]							
Stirrup spacing ≤ $d/2$			1.25	1.5	1.75	3	4
Stirrup spacing > $d/2$			1.25	1.5	1.75	2	3
Condition iii. Beams controlled by inadequate development or splicing along the span[b]							
Stirrup spacing ≤ $d/2$			1.25	1.5			4
Stirrup spacing > $d/2$			1.25	1.5			3
Condition iv. Beams controlled by inadequate embedment into beam–column joint[b]							
			2	2	3	3	4

use lowest m-factor for concrete diaphragm chord analysis

m-factors for concrete diaphragm shear

NOTE: f'_c in lb/in.^{2} (MPa) units.

[a] Values between those listed in the table should be determined by linear interpolation.

[b] Where more than one of conditions i, ii, iii, and iv occurs for a given component, use the minimum appropriate numerical value from the table.

[c] "C" and "NC" are abbreviations for conforming and nonconforming transverse reinforcement. Transverse reinforcement is conforming if, within the flexural plastic hinge region, hoops are spaced at ≤ $d/3$, and if, for components of moderate and high ductility demand, the strength provided by the hoops (V_s) is at least 3/4 of the design shear. Otherwise, the transverse reinforcement is considered nonconforming.

[d] V is the design shear force calculated using limit-state analysis procedures in accordance with Section 10.4.2.4.1.

2. Posttensioning existing beams, columns, or joints using external posttensioning reinforcement. Posttensioned reinforcement should be unbonded within a distance equal to twice the effective depth from sections where inelastic action is expected. Anchorages should be located away from regions where inelastic action is anticipated and should be designed with consideration of possible force variations from seismic forces;
3. Modifying the element by selective material removal from the existing element. Examples include (a) where nonstructural components interfere with the frame, eliminating this interference by removing or separating the nonstructural component from the frame; (b) weakening from concrete removal or severing longitudinal reinforcement to change the response from a nonductile to a more ductile mode, for example, weakening beams to promote formation of a strong-column, weak-beam system; and (c) segmenting walls to change stiffness and strength;
4. Improving deficient existing reinforcement details. Removal of cover concrete to modify existing reinforcement details should avoid damage to core concrete and the bond between existing reinforcement and core concrete. New cover concrete should be designed and constructed to achieve fully composite action with the existing materials (FEMA 547 Sections 12.4.4, 12.4.5, and 12.4.6);
5. Changing the building system to reduce demands on the existing elements. Examples include addition of supplementary seismic-force-resisting elements, such as walls or buttresses, seismic isolation, and mass reduction (FEMA 547 Chapter 24); and
6. Changing the frame element to a shear wall, infilled frame, or braced frame element by adding new material. Connections between new and existing materials should be designed to transfer the anticipated forces based on the design-load combinations. Where the existing concrete frame columns and beams act as boundary components and collectors for the new shear wall or braced frame, these should be checked for adequacy, considering strength, reinforcement development, and deformability. Diaphragms, including ties and collectors, should be evaluated and if necessary, rehabilitated to ensure a complete load path to the new shear wall or braced frame element (FEMA 547 Sections 12.4.1 and 12.4.2).

10.4.3 Posttensioned Concrete Beam–Column Moment Frames

10.4.3.1 General The analytical model for a posttensioned concrete beam–column frame element shall be established as specified in Section 10.4.2.1 for reinforced concrete beam–

TABLE 28 – ALLOWABLE DIAPHRAGM STRENGTH, q (plf), AND FLEXIBILITY FACTORS, F, FOR TYPE HSB®-36 DECK ATTACHED WITH WELDS TO SUPPORTS AND SIDELAPS FASTENED WITH BUTTON PUNCHES (BP) OR 1½" TOP SEAM WELDS (TSW) AT SIDELAPS[1,2,3,4,5,6,7,8]

DECK GAGE	SIDELAP ATTACH-MENT		SPAN (ft-in.)								
			4'-0"	5'-0"	6'-0"	7'-0"	8'-0"	9'-0"	10'-0"	11'-0"	12'-0"
			36/4 ARC SPOT AND ARC SEAM WELD PATTERN AT SUPPORTS								
22	BP @ 24"	q	282	234	190	169	144	135	121	–	–
		F	-1.3+267R	4.2+212R	9.1+174R	12.6+148R	16.3+127R	18.9+112R	22.1+98R		
	BP @ 12"	q	318	262	226	199	180	167	157	–	–
		F	-2.3+267R	3.1+212R	7.2+175R	10.5+149R	13.3+129R	15.7+114R	17.9+101R		
	TSW @ 24"	q	628	649	562	588	526	552	505	–	–
		F	-9.4+271R	-6.3+217R	-3.5+181R	-2.2+155R	-0.5+135R	0.1+120R	1.2+108R		
	TSW @ 18"	q	763	756	663	673	681	622	633	–	–
		F	-10.2+271R	-6.9+217R	-4.2+181R	-2.8+155R	-1.7+136R	-0.4+121R	0.2+108R		
	TSW @ 12"	q	871	846	828	815	805	798	791	–	–
		F	-10.7+272R	-7.3+217R	-5.1+181R	-3.5+155R	-2.3+136R	-1.3+121R	-0.6+109R		
	TSW @ 6"	q	1117	1107	1101	1096	1092	1089	1001	–	–
		F	-11.6+272R	-8.2+217R	-6+181R	-4.4+155R	-3.2+136R	-2.3+121R	-1.5+109R		
20	BP @ 24"	q	403	336	275	246	211	195	175	169	155
		F	3.1+167R	7.2+132R	11.1+108R	13.8+91R	16.9+78R	19+68R	21.7+59R	23.4+53R	25.8+47R
	BP @ 12"	q	454	378	326	290	262	241	227	216	206
		F	2.2+168R	6.2+133R	9.3+109R	11.9+93R	14.2+80R	16.1+70R	17.8+62R	19.4+55R	20.8+50R
	TSW @ 24"	q	824	846	733	764	685	715	654	683	634
		F	-4.2+171R	-2.3+137R	-0.4+114R	0.3+98R	1.5+86R	1.9+76R	2.7+68R	2.8+62R	3.4+57R
	TSW @ 18"	q	993	981	861	872	879	804	818	829	774
		F	-5+172R	-2.9+137R	-1.1+114R	-0.2+98R	0.5+86R	1.4+76R	1.8+69R	2.1+62R	2.6+57R
	TSW @ 12"	q	1127	1093	1069	1051	1037	1026	1018	1010	912
		F	-5.5+172R	-3.3+137R	-1.9+115R	-0.8+98R	0+86R	0.6+76R	1+69R	1.4+62R	1.8+57R
	TSW @ 6"	q	1435	1422	1412	1406	1400	1396	1313	1085	912
		F	-6.2+172R	-4.1+138R	-2.7+115R	-1.7+98R	-0.9+86R	-0.3+76R	0.1+69R	0.5+63R	0.8+57R
18	BP @ 24"	q	704	592	487	438	379	353	314	300	275
		F	6.3+80R	9.1+63R	11.9+51R	13.9+42R	16.3+35R	17.8+30R	20+26R	21.3+22R	23.3+19R
	BP @ 12"	q	794	666	579	517	470	434	405	383	366
		F	5.5+81R	8.2+63R	10.4+52R	12.2+43R	13.9+37R	15.3+32R	16.7+28R	17.9+24R	19+22R
	TSW @ 24"	q	1272	1293	1121	1160	1040	1081	989	1028	955
		F	0+84R	0.8+67R	1.9+56R	2.2+48R	2.9+42R	3+37R	3.5+33R	3.5+30R	3.9+28R
	TSW @ 18"	q	1513	1486	1306	1316	1323	1210	1227	1241	1160
		F	-0.7+84R	0.3+67R	1.3+56R	1.7+48R	2+42R	2.6+37R	2.7+33R	2.9+30R	3.2+28R
	TSW @ 12"	q	1705	1648	1607	1577	1554	1535	1520	1508	1394
		F	-1.1+84R	-0.1+67R	0.7+56R	1.2+48R	1.6+42R	1.9+37R	2.1+34R	2.3+30R	2.5+28R
	TSW @ 6"	q	2150	2127	2111	2099	2090	2083	2007	1659	1394
		F	-1.8+84R	-0.8+67R	-0.1+56R	0.4+48R	0.8+42R	1.1+37R	1.3+34R	1.5+31R	1.7+28R
16	BP @ 24"	q	912	778	641	584	506	477	425	408	371
		F	7.1+44R	9.2+34R	11.5+27R	13.1+22R	15.1+18R	16.4+15R	18.3+12R	19.4+10R	21.2+8R
	BP @ 12"	q	1041	893	784	707	649	604	568	538	514
		F	6.4+45R	8.4+35R	10.1+28R	11.6+23R	13+19R	14.2+16R	15.3+14R	16.3+12R	17.3+10R
	TSW @ 24"	q	1643	1679	1460	1515	1361	1417	1299	1352	1257
		F	1.4+48R	1.8+38R	2.6+32R	2.7+27R	3.2+24R	3.2+21R	3.6+19R	3.5+17R	3.8+16R
	TSW @ 18"	q	1957	1929	1702	1718	1731	1586	1610	1630	1525
		F	0.8+48R	1.3+38R	2.1+32R	2.3+27R	2.4+24R	2.8+21R	2.9+19R	2.9+17R	3.2+16R
	TSW @ 12"	q	2203	2136	2088	2053	2026	2004	1986	1971	1941
		F	0.4+48R	1+38R	1.5+32R	1.8+27R	2+24R	2.2+21R	2.3+19R	2.4+17R	2.5+16R
	TSW @ 6"	q	2753	2727	2710	2696	2686	2678	2671	2310	1941
		F	-0.2+48R	0.4+38R	0.8+32R	1.1+27R	1.3+24R	1.5+21R	1.6+19R	1.7+17R	1.8+16R

See Page 107 for footnotes.

(continued)

General Notes (Cont'd.)

Sidelap Deck-to-Deck Panel Attachments Parallel to the Flutes:

16. Provisions of specific UL Fire-Rated Assemblies may reduce the maximum allowable sidelap fastener spacing.
17. Deck panel side seams (sidelaps) may be connected with the Verco PunchLok II VSC2 connections, welds, screws, or button punches, as illustrated in Figure 1 and as indicated in the evaluation report.

FIGURE 1 - SIDELAP OPTIONS

Standard Sidelap
Used with the PunchLok® II (VSC2), Top Seam Weld (TSW), or Button Punch (BP). Available on deck types: B, N3, N, W2, W3

"SS" Sidelap Screw
Used with Self-Drilling Screws. Available on deck types: B, N3, N, W2, W3

"NS" Nested Sidelap
Used with Self-Drilling Screws. Available on deck type: HSN3-NS

Nested Sidelap
Used with Self-Drilling Screws. Available on deck type: 1-5/16" (Deep) VERCOR or 9/16" (Shallow) VERCOR

Diaphragm Shear and Flexibility:

18. The shear strength and flexibility factors for roof decks and FORMLOK decks without concrete fill listed in this report are based on an F_u = 62 ksi, and a continuous 3-span condition for span lengths 4 feet and greater. For span lengths less than 4 feet, the allowable diaphragm shear values are based on a sheet length of 12 feet or a maximum of 7 spans. Deck panels longer than 12 feet or with more than 7 spans may be used with the tabulated values.
19. The allowable values for composite decks shown in the tables are applicable to either phosphatized/painted or galvanized decks. The allowable values shown for roof deck panels are applicable to either painted, mill-finished, or galvanized decks.
20. The allowable diaphragm shear strength listed in the tables are in pounds per linear foot. The flexibility factors listed in the tables are in micro inches a diaphragm web will deflect in a span of 1 ft under a shear load of 1 lb/ft.
21. Where individual panels are cut, the partial panel shall be fastened in a manner to fully transfer the shears at the point of the diaphragm to the adjacent full panels for the values specified in the tables.
22. Verco's published allowable diaphragm shear strength tables (except tables 47 and 48) utilize the ASD factors of safety for Earthquake loading from AISI S100, Table D5, excerpt below.
    a. To convert from Earthquake loading to Wind loading, utilizing ASD, the published allowable diaphragm shear strength may be multiplied by Ω_d (Earthquake), and then divided by Ω_d (Wind):
    As an example:
    Welds: 3.00/2.35 = 1.27
    Mechanical Fasteners: 2.5/2.35 = 1.06
    b. To convert from ASD to LRFD for each connection type, the published allowable diaphragm shear values may be multiplied by the applicable conversion factor, $C = \Omega_d \times \Phi_d$
    The following examples are for Earthquake loading:
    For welds: C_{WELD} = 3.00 x 0.55 = 1.65
    For mechanical fasteners: $C_{MECHANICAL\ FASTENER}$ = 2.5 x 0.65 = 1.625
    For deck panel buckling*: $C_{BUCKLING}$ = 2.00 x 0.80 = 1.60
    * The shaded areas in the allowable diaphragm shear tables indicate where buckling is the limit state rather than the connections.

AISI S100 TABLE D5 - SAFETY FACTORS AND RESISTANCE FACTORS FOR DIAPHRAGMS

Load Type or Combinations Including	Connection Type [1]	Limit State					
		Connection Related			Panel Buckling [2]		
		USA and Mexico		Canada	USA and Mexico		Canada
		Ω_d (ASD)	Φ_d (LRFD)	Φ_d (LSD)	Ω_d (ASD)	Φ_d (LRFD)	Φ_d (LSD)
Earthquake	Welds	3.00	0.55	0.50	2.00	0.80	0.75
	Screws	2.50	0.65	0.60			
Wind	Welds	2.35	0.70	0.65			
	Screws						
All Others	Welds	2.65	0.60	0.55			
	Screws	2.50	0.65	0.60			

[1] For mechanical fasteners - such as Power Actuated Fasteners or Forced Entry Fasteners, the factors of safety for screws may be used.

[2] Panel buckling is considered out-of-plane deck buckling and not local buckling at fasteners.

(continued)

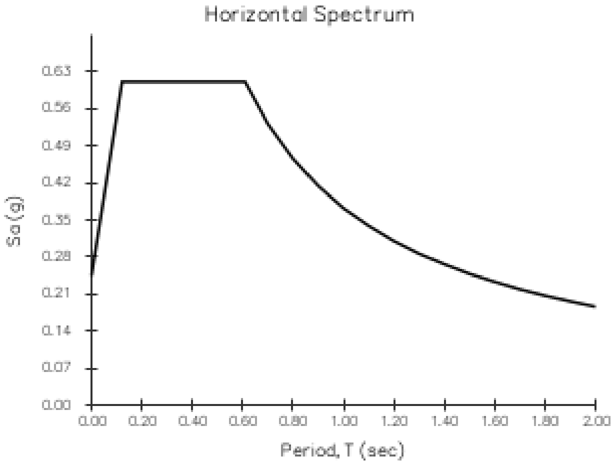
USGS Design Maps Summary Report

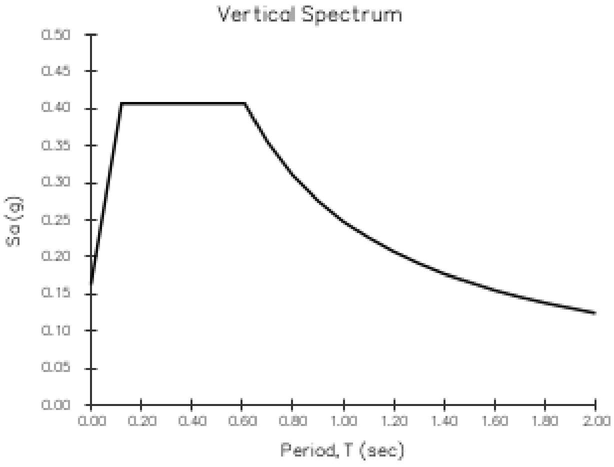
User–Specified Input

Report Title	Willamete River WTP Wed September 6, 2017 20:16:49 UTC
Building Code Reference Document	ASCE 41-13 Retrofit Standard, BSE-1E (which utilizes USGS hazard data available in 2008)
Site Coordinates	45.295°N, 122.783°W
Site Soil Classification	Site Class E – “Soft Clay Soil”

USGS–Provided Output

$\mathbf{S}_{S,20/50}$	0.283 g	$\mathbf{S}_{XS,BSE\text{-}1E}$	0.611 g
$\mathbf{S}_{1,20/50}$	0.107 g	$\mathbf{S}_{X1,BSE\text{-}1E}$	0.372 g





USGS Design Maps Detailed Report

ASCE 41-13 Retrofit Standard, BSE-1E (45.295°N, 122.783°W)

Site Class E – “Soft Clay Soil”

Section 2.4.1 – General Procedure for Hazard Due to Ground Shaking

20%/50-year maximum direction spectral response acceleration for 0.2s and 1.0s periods, respectively:

From Section 2.4.1.4	$S_{S,20/50} = 0.283$ g
From Section 2.4.1.4	$S_{1,20/50} = 0.107$ g

Section 2.4.1.6 – Adjustment for Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class E, based on the site soil properties in accordance with Section 2.4.1.6.1.

SITE CLASS	**SOIL PROFILE NAME**	**Soil shear wave velocity, $\bar{v}_s$, (ft/s)**	**Standard penetration resistance, $\bar{N}$**	**Soil undrained shear strength, $\bar{s}_u$, (psf)**
A	Hard rock	$\bar{v}_s > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_s \le 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \le 2{,}500$	$\bar{N} > 50$	>2,000 psf
D	Stiff soil profile	$600 \le \bar{v}_s < 1{,}200$	$15 \le \bar{N} \le 50$	1,000 to 2,000 psf
E	Stiff soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	<1,000 psf
E	—	Any profile with more than 10 ft of soil having the characteristics: 1. Plasticity index *PI* > 20, 2. Moisture content *w* ≥ 40%, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays (*H* > 10 feet of peat and/or highly organic clay where *H* = thickness of soil) 3. Very high plasticity clays (*H* > 25 feet with plasticity index *PI* > 75) 4. Very thick soft/medium stiff clays (*H* > 120 feet)		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Table 2–3. Values of F_a as a Function of Site Class and Mapped Short-Period Spectral Response Acceleration S_s

Site Class	Mapped Spectral Acceleration at Short-Period S_s				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Site-specific geotechnical and dynamic site response analyses shall be performed				

Note: Use straight–line interpolation for intermediate values of S_S

For Site Class = E and S_S = 0.283 g, F_a = 2.394

Table 2–4. Values of F_v as a Function of Site Class and Mapped Spectral Response Acceleration at 1 s Period S_1

Site Class	Mapped Spectral Acceleration at 1 s Period S_1				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	Site-specific geotechnical and dynamic site response analyses shall be performed				

Note: Use straight–line interpolation for intermediate values of S_1

For Site Class = E and S_1 = 0.107 g, F_v = 3.479

Provided as a reference for Equation (2-4): $F_aS_{S,20/50}$ = 2.394 x 0.283 g = 0.678 g

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Provided as a reference for Equation (2-5): $F_vS_{1,20/50}$ = 3.479 x 0.107 g = 0.372 g

---

Provided as a reference for Equation (2-4): $S_{XS,BSE\text{-}1N}$ = ⅔ x $S_{XS,BSE\text{-}2N}$ = ⅔ x $F_aS_{S,BSE\text{-}2N}$ = 0.611 g

---

Provided as a reference for Equation (2-5): $S_{X1,BSE\text{-}1N}$ = ⅔ x $S_{X1,BSE\text{-}2N}$ = ⅔ x $F_vS_{1,BSE\text{-}2N}$ = 0.656 g

---

Equation (2–4): $S_{XS,BSE\text{-}1E}$ = MIN[$F_aS_{S,20/50}$, $S_{XS,BSE\text{-}1N}$] = MIN[0.678g, 0.611g] = 0.611g

---

Equation (2–5): $S_{X1,BSE\text{-}1E}$ = MIN[$F_vS_{S,20/50}$, $S_{X1,BSE\text{-}1N}$] = MIN[0.372g, 0.656g] = 0.372g

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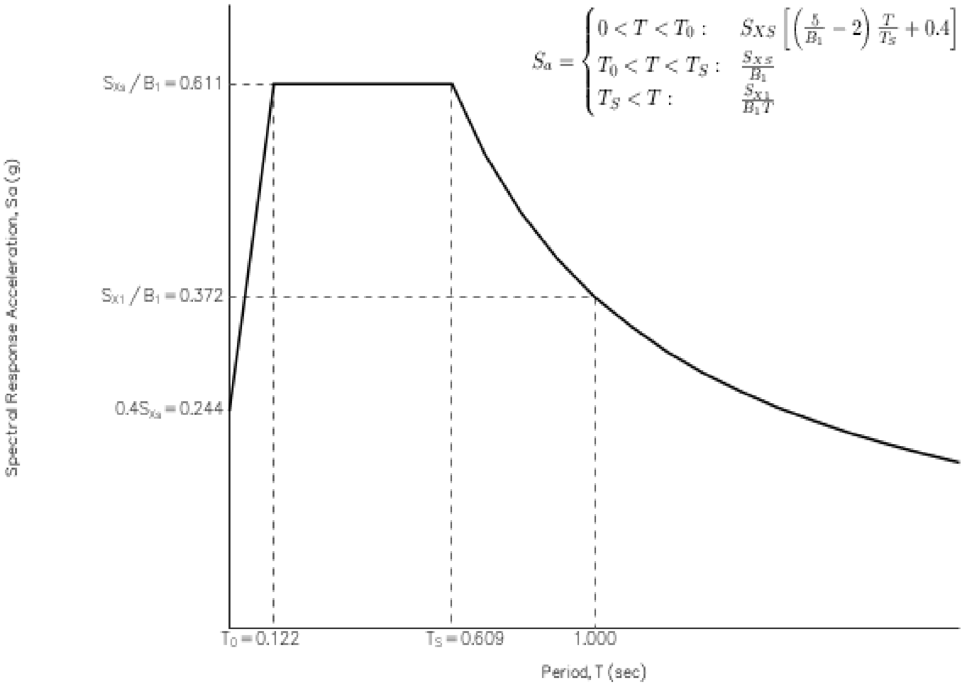
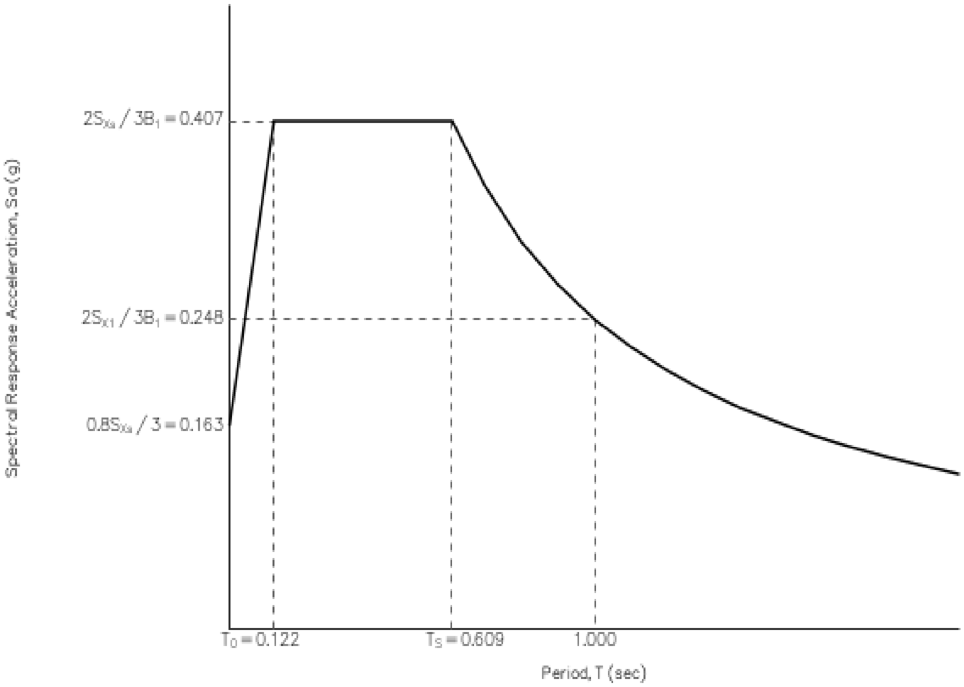
Section 2.4.1.7.1 — General Horizontal Response Spectrum

Figure 2-1. General Horizontal Response Spectrum



Section 2.4.1.7.2 — General Vertical Response Spectrum

The General Vertical Response Spectrum is determined by multiplying the General Horizontal Response Spectrum by ⅔.



USGS Design Maps Summary Report

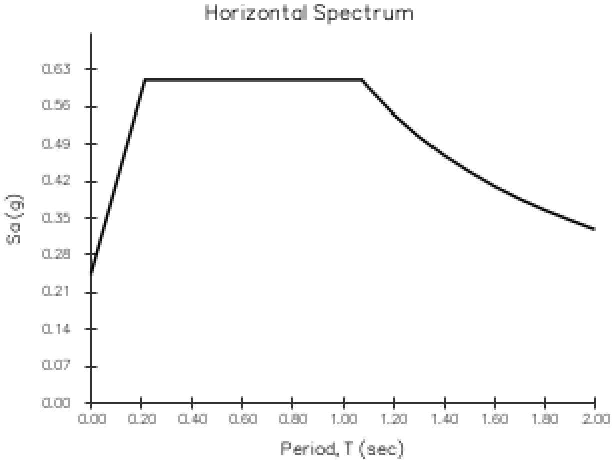
User–Specified Input

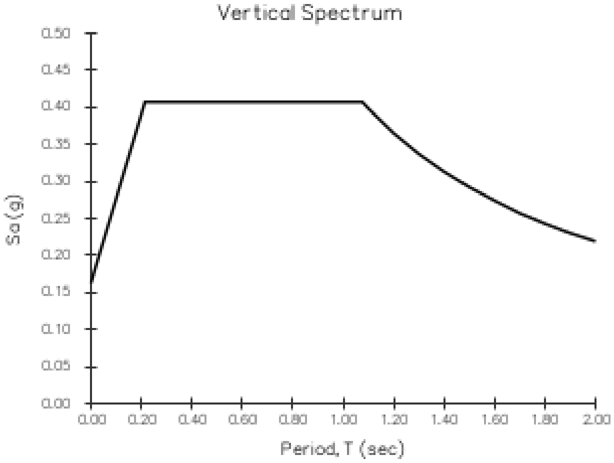
Report Title	Willamete River WTP Wed September 6, 2017 20:41:26 UTC
Building Code Reference Document	ASCE 41-13 Retrofit Standard, BSE-1N (which utilizes USGS hazard data available in 2008)
Site Coordinates	45.295°N, 122.783°W
Site Soil Classification	Site Class E – “Soft Clay Soil”

USGS–Provided Output

$S_{XS,BSE-1N}$ 0.611 g

$S_{X1,BSE-1N}$ 0.656 g





Design Maps Detailed Report

ASCE 41-13 Retrofit Standard, BSE-1N (45.295°N, 122.783°W)

Site Class E – "Soft Clay Soil"

Section 2.4.1 – General Procedure for Hazard Due to Ground Shaking

Provided as a reference for Equation (2-4) and Equation (2-5), respectively:

From Section 2.4.1.1 $S_{S,BSE\text{-}2N} = 0.924$ g

From Section 2.4.1.1 $S_{1,BSE\text{-}2N} = 0.410$ g

Section 2.4.1.6 – Adjustment for Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class E, based on the site soil properties in accordance with Section 2.4.1.6.1.

SITE CLASS	SOIL PROFILE NAME	Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_S > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_S \le 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_S \le 2{,}500$	$\bar{N} > 50$	>2,000 psf
D	Stiff soil profile	$600 \le \bar{v}_S < 1{,}200$	$15 \le \bar{N} \le 50$	1,000 to 2,000 psf
E	Stiff soil profile	$\bar{v}_S < 600$	$\bar{N} < 15$	<1,000 psf
E	—	Any profile with more than 10 ft of soil having the characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \ge 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Table 2–3. Values of F_a as a Function of Site Class and Mapped Short-Period Spectral Response Acceleration S_s

Site Class	Mapped Spectral Acceleration at Short-Period S_s				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Site-specific geotechnical and dynamic site response analyses shall be performed				

Note: Use straight–line interpolation for intermediate values of S_S

For Site Class = E and S_S = 0.924 g, F_a = 0.992

Table 2–4. Values of F_v as a Function of Site Class and Mapped Spectral Response Acceleration at 1 s Period S_1

Site Class	Mapped Spectral Acceleration at 1 s Period S_1				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	Site-specific geotechnical and dynamic site response analyses shall be performed				

Note: Use straight–line interpolation for intermediate values of S_1

For Site Class = E and S_1 = 0.410 g, F_v = 2.400

Provided as a reference for Equation (2-4): $S_{XS,BSE\text{-}2N} = F_a S_{S,BSE\text{-}2N} = 0.992 \times 0.924\text{ g} = 0.916\text{ g}$

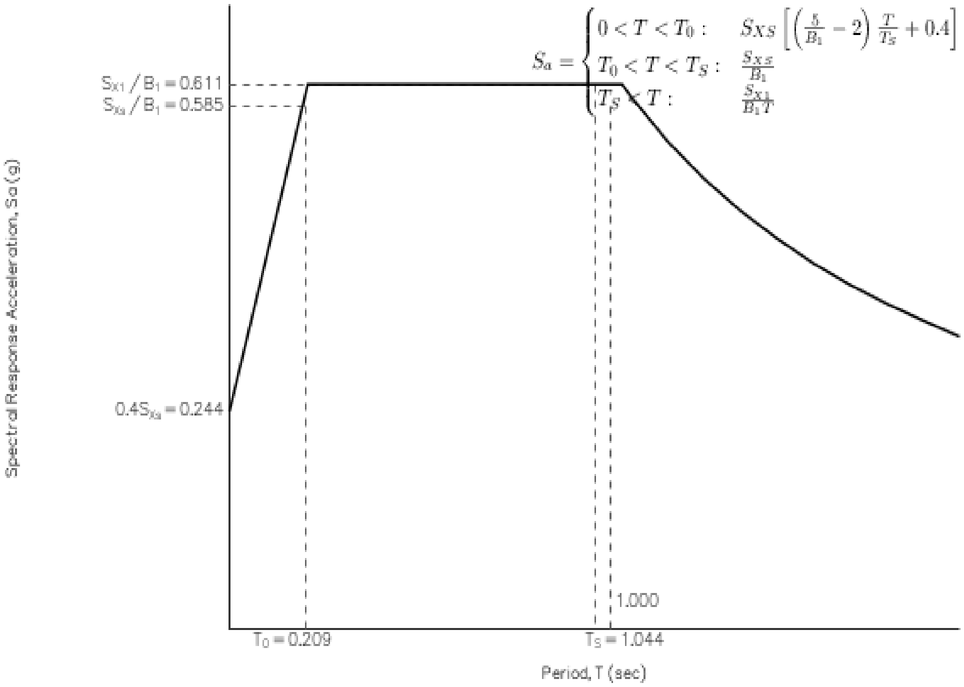
Provided as a reference for Equation (2-5): $S_{X1,BSE\text{-}2N} = F_v S_{1,BSE\text{-}2N} = 2.400 \times 0.410\text{ g} = 0.985\text{ g}$

Equation (2–4): $S_{XS,BSE\text{-}1N} = ⅔ \times S_{XS,BSE\text{-}2N} = ⅔ \times 0.916\text{ g} = 0.611\text{ g}$

Equation (2–5): $S_{X1,BSE\text{-}1N} = ⅔ \times S_{X1,BSE\text{-}2N} = ⅔ \times 0.985\text{ g} = 0.657\text{ g}$

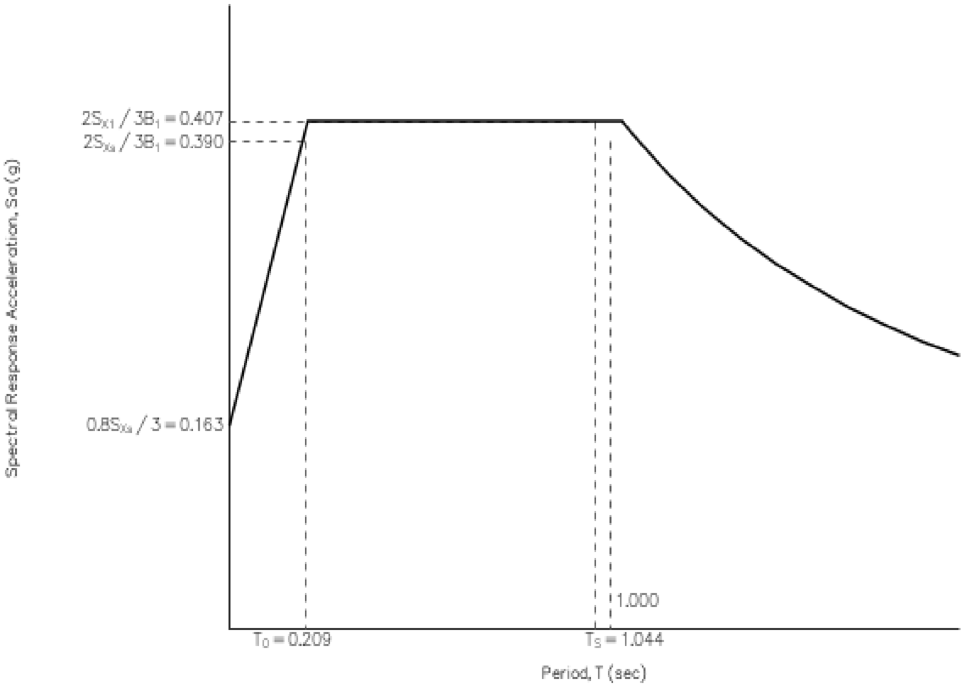
Section 2.4.1.7.1 — General Horizontal Response Spectrum

Figure 2-1. General Horizontal Response Spectrum



Section 2.4.1.7.2 — General Vertical Response Spectrum

The General Vertical Response Spectrum is determined by multiplying the General Horizontal Response Spectrum by ⅔.



ACI 350 - EXISTING CONCRETE STRUCTURES CRITERIA & PARAMETERS

CODE

$$U = 1.4(D + F) \tag{9-1}$$

$$U = 1.2(D + F + T) + 1.6(L + H) + 0.5(L_r \text{ or } S \text{ or } R) \tag{9-2}$$

$$U = 1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (1.0L \text{ or } 0.8W) \tag{9-3}$$

$$U = 1.2D + 1.6W + 1.0L + 0.5(L_r \text{ or } S \text{ or } R) \tag{9-4}$$

$$U = 1.2D + 1.2F + 1.0E + 1.6H + 1.0L + 0.2S \tag{9-5}$$

$$U = 0.9D + 1.2F + 1.6W + 1.6H \tag{9-6}$$

$$U = 0.9D + 1.2F + 1.0E + 1.6H \tag{9-7}$$

except as follows:

(a) The load factor on L in Eq. (9-3) to (9-5) shall be permitted to be reduced to 0.5 where it can be justified that no greater than 50 percent of the design live load is expected to be present during normal operating conditions. Reduction of the load factor shall not be permitted in areas occupied as places of public assembly, and areas where the live load L is greater than 100 lb/ft^2;

(b) Where wind load W has not been reduced by a directionality factor, it shall be permitted to use $1.3W$ in place of $1.6W$ in Eq. (9-4) and (9-6);

(c) Where earthquake load E is based on service-level seismic forces, $1.4E$ shall be used in place of $1.0E$ in Eq. (9-5) and (9-7);

(d) The load factor on H shall be reduced to 0.6 where H reduces the effect of D, L, or F. Earth pressure shall be permitted to be used to reduce other load effects only if investigation and analysis shows that structure movement and soil characteristics are appropriate to develop that pressure;

(e) Both the full value and the zero value of L and F shall be used in the above load combinations to determine the most severe condition.

9.2.2 — If resistance to impact effects is taken into account in design, such effects shall be included with live load L.

9.2.3 — Estimations of differential settlement, creep, shrinkage, expansion of shrinkage-compensating concrete, or temperature change shall be based on a realistic assessment of such effects occurring in service.

9.2.4 — For a structure in a flood zone, the flood load and load combinations of ASCE 7 shall be used.

9.2.5 — For post-tensioned anchorage zone design, a load factor of 1.2 shall be applied to the maximum prestressing steel jacking force.

COMMENTARY

be applied to H as noted, and the magnitude of earth pressure used should be developed conservatively by a geotechnical engineer.

Both L and F are considered to be transient loads, so designs must consider the effects for such loads being present or absent.

R9.2.2 — If the live load is applied rapidly, as may be the case for vehicle loads, cranes, etc., impact effects should be considered. In all equations, substitute (L + impact) for L when impact should be considered.

R9.2.3 — The designer should consider the effects of differential settlement, creep, shrinkage, temperature, and shrinkage-compensating concrete. The term realistic assessment is used to indicate that the most probable values rather than the upper bound values of the variables should be used.

R9.2.4 — Areas subject to flooding are defined by flood hazard maps, usually maintained by local governmental jurisdictions.

R9.2.5 — The load factor of 1.2 applied to the maximum tendon jacking force results in a design load of about 113 percent of the specified prestressing steel yield strength, but

CODE

9.2.6 — Required strength ***U*** for other than compression-controlled sections, as defined in 10.3.3, shall be multiplied by the following environmental durability factor (***S_d***) in portions of an environmental engineering concrete structure where durability, liquid-tightness, or similar serviceability are considerations. In the case of shear design, this factor is applied to the excess shear strength carried by shear reinforcement only. This durability factor shall not be used for designs using service loads and permissible service load stresses. For applicable use of the environmental durability factor (***S_d***) in conjunction with load combinations that include earthquake loads, see Section 21.2.1.8.

$$S_d = \frac{\phi f_y}{\gamma f_s} \geq 1.0 \tag{9-8}$$

where $\gamma = \frac{\text{factored load}}{\text{unfactored load}}$

and where ***f_s*** is the permissible tensile stress in reinforcement as given below:

9.2.6.1 — Flexural stress: See 10.6.4.

9.2.6.2 — Direct and hoop tensile stress in normal environmental exposures

$$f_s = 20{,}000 \text{ psi}$$

9.2.6.3 — Direct and hoop tensile stress in severe environmental exposures

$$f_s = 17{,}000 \text{ psi}$$

9.2.6.4 — Shear stress carried by shear reinforcement in normal environmental exposures

$$f_s = 24{,}000 \text{ psi}$$

9.2.6.5 — Shear stress carried by shear reinforcement in severe environmental exposures

$$f_s = 20{,}000 \text{ psi}$$

COMMENTARY

not more than 96 percent of the nominal ultimate strength of the prestressing steel. This compares well with the maximum attainable jacking force, which is limited by the anchor efficiency factor.

R9.2.6 — In environmental engineering concrete structures, durability and long-term service life are paramount. The resulting stresses in nonprestressed reinforcement using normal building code load factors are higher than would be desirable in environmental engineering concrete structures. The intent of the environmental durability factor is to reduce the effective stress in nonprestressed reinforcement under service load conditions, such that stress levels are considered to be in an acceptable range for control of cracking. The environmental durability factor in Eq. (9-8) will vary with individual load combinations and with applicable ϕ factors (for example, flexure versus shear). As a conservative simplification, the ϕ factor may be taken as the maximum ϕ factor (0.90) in Eq. (9-8).

The limitation of $S_d \geq 1.0$ is to ensure that the strength requirements of 318 are always met as a minimum regardless of crack control considerations. This limitation will likely control where bars of relatively low yield strength are used.

10.3.4

In effect, for tension-controlled sections and shear strength contributed by reinforcement, Eq. (9-8) eliminates the effects of code-prescribed load factors and ϕ factors and applies an effective load factor equal to f_y/f_s with ϕ factors set to 1.0. Thus, where the environmental durability factor is applicable in these types of sections, the following design procedure will achieve the same results:

1. Multiply the unfactored loads by a uniform load factor equal to f_y/f_s ($\geq$1.0);

2. Use a value of 1.0 for applicable design ϕ factors.

The normal load factors would still be applicable to some design conditions, such as shear strength from concrete and compression-controlled members.

R9.2.6.1 — Required flexural strength $\geq S_dU$.

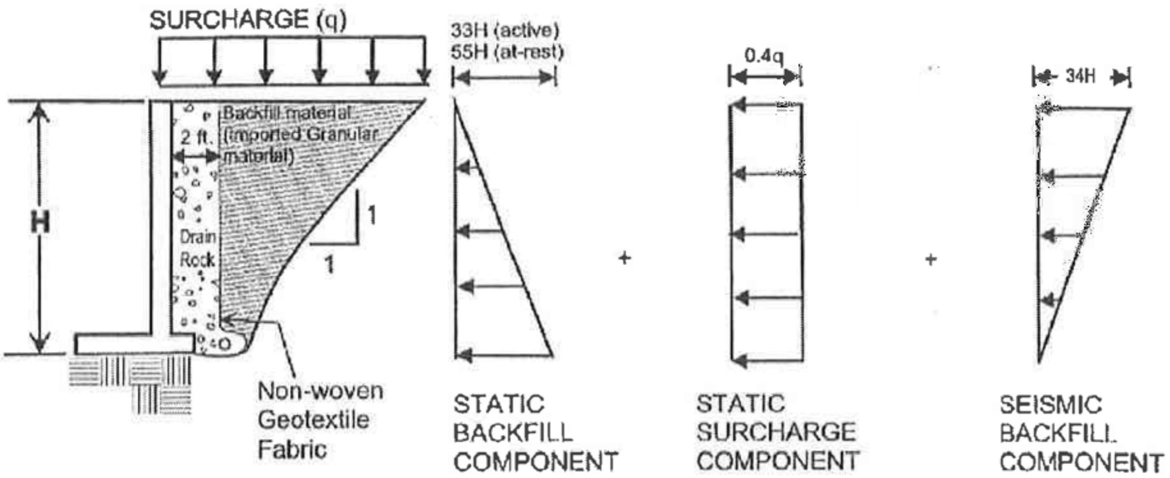
R9.2.6.2 and R9.2.6.3 — Required strength in direct and hoop tension $\geq S_dU$.

Some designers prefer to use a maximum steel stress equal to 14,000 psi for hoop tension. This practice is based on an earlier version of the PCA publication, "Circular Concrete Tanks without Prestressing."[9.7]

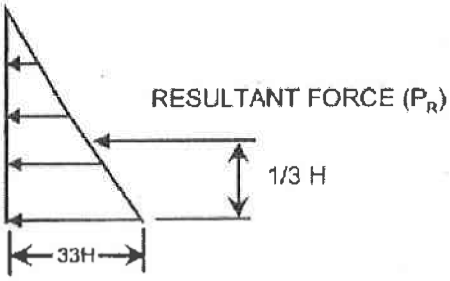
R9.2.6.4 and R9.2.6.5 — Shear stress carried by the shear reinforcing is defined as the excess shear strength required in addition to the design shear strength provided by the concrete ϕV_c

$$\phi V_s \geq S_d (V_u - \phi V_c)$$

TOTAL LATERAL PRESSURE

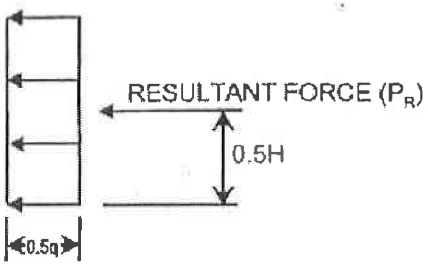


STATIC BACKFILL COMPONENT



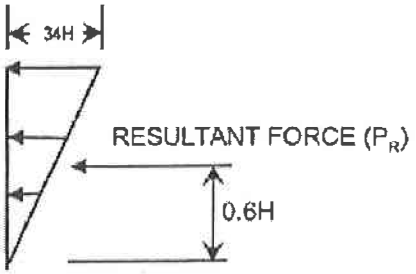
$$P_R = [\text{PRESSURE VALUE}] \times \frac{H}{2}$$

STATIC SURCHARGE COMPONENT



$$P_R = [\text{PRESSURE VALUE}] \times H$$

SEISMIC BACKFILL COMPONENT



$$P_R = [\text{PRESSURE VALUE}] \times \frac{H}{2}$$

WILSONVILLE WATER TREATMENT PLANT
WILSONVILLE, OREGON

LATERAL PRESSURE DISTRIBUTION AND RESULTANT LOCATION

SQUIER ASSOCIATES

FIGURE 6

Drawn by: RP	Checked by:	Graphics Check:		File: DRAWINGS\LATERAL.DSF	Date: 2/2/00	Job. No. 200510

USGS Design Maps Summary Report

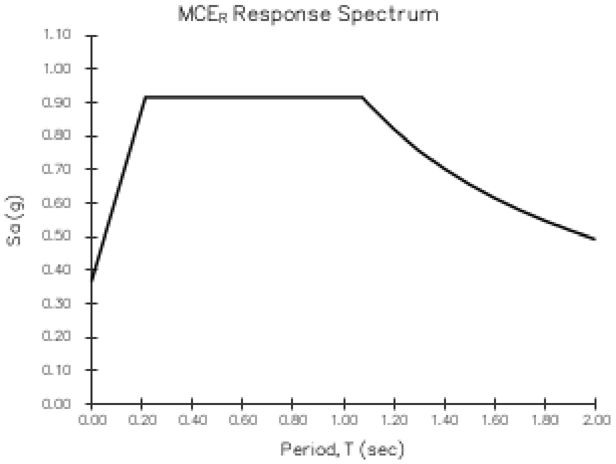
User–Specified Input

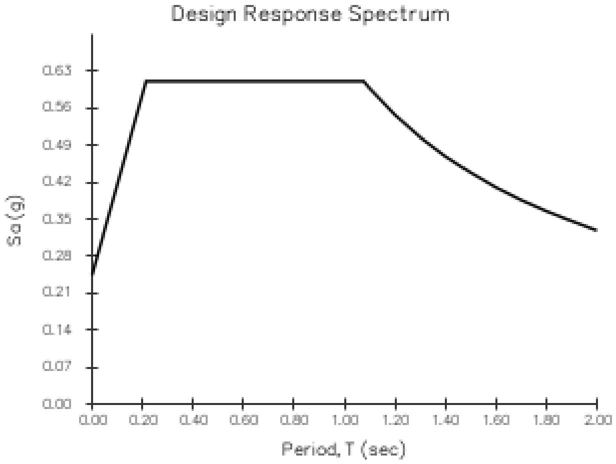
Report Title	Willamete River WTP Wed September 6, 2017 20:19:38 UTC
Building Code Reference Document	ASCE 7-10 Standard (which utilizes USGS hazard data available in 2008)
Site Coordinates	45.295°N, 122.783°W
Site Soil Classification	Site Class E – “Soft Clay Soil”
Risk Category	I/II/III

USGS–Provided Output

$S_S =$	0.924 g	$S_{MS} =$	0.916 g	$S_{DS} =$	0.611 g
$S_1 =$	0.410 g	$S_{M1} =$	0.985 g	$S_{D1} =$	0.656 g

For information on how the SS and S1 values above have been calculated from probabilistic (risk-targeted) and deterministic ground motions in the direction of maximum horizontal response, please return to the application and select the “2009 NEHRP” building code reference document.





For PGA_M, T_L, C_{RS}, and C_{R1} values, please view the detailed report.

Design Maps Detailed Report

ASCE 7-10 Standard (45.295°N, 122.783°W)

Site Class E – "Soft Clay Soil", Risk Category I/II/III

Section 11.4.1 — Mapped Acceleration Parameters

Note: Ground motion values provided below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_S) and 1.3 (to obtain S_1). Maps in the 2010 ASCE-7 Standard are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

From Figure 22-1 [1] $S_S = 0.924$ g

From Figure 22-2 [2] $S_1 = 0.410$ g

Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class E, based on the site soil properties in accordance with Chapter 20.

Table 20.3–1 Site Classification

Site Class	$\bar{v}_s$	$\bar{N}$ **or** $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index *PI* > 20, • Moisture content *w* ≥ 40%, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients and Risk–Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Table 11.4–1: Site Coefficient F_a

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at Short Period				
	$S_S \leq 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_S

For Site Class = E and S_S = 0.924 g, F_a = 0.992

Table 11.4–2: Site Coefficient F_v

Site Class	Mapped MCE_R Spectral Response Acceleration Parameter at 1–s Period				
	$S_1 \leq 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \geq 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_1

For Site Class = E and S_1 = 0.410 g, F_v = 2.400

Equation (11.4–1): $S_{MS} = F_aS_S = 0.992 \times 0.924 = 0.916$ g

Equation (11.4–2): $S_{M1} = F_vS_1 = 2.400 \times 0.410 = 0.985$ g

Section 11.4.4 — Design Spectral Acceleration Parameters

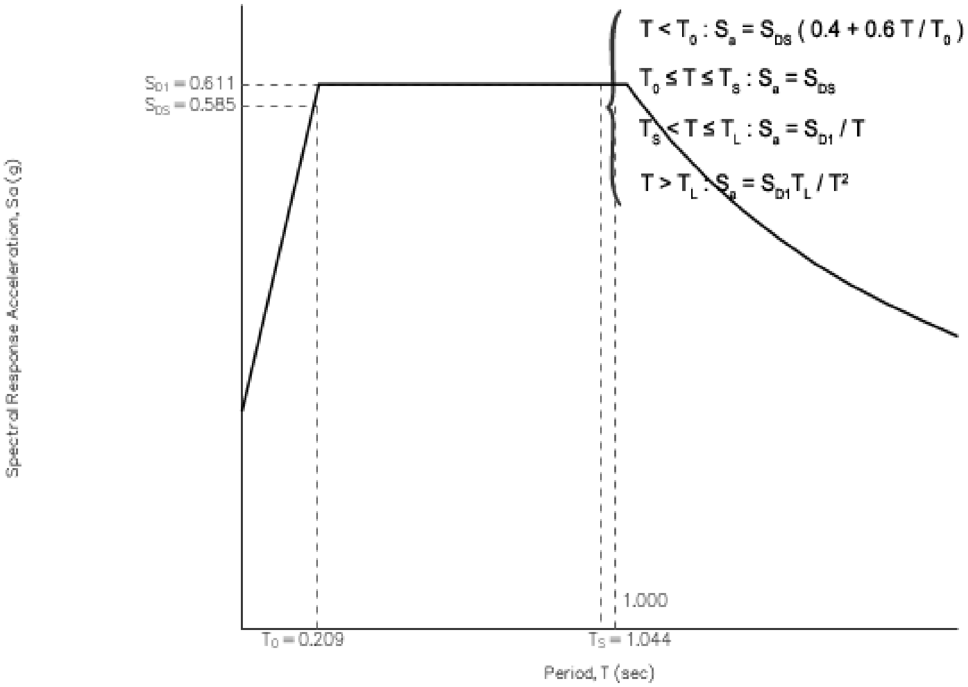
Equation (11.4–3): $S_{DS} = ⅔\ S_{MS} = ⅔ \times 0.916 = 0.611$ g

Equation (11.4–4): $S_{D1} = ⅔\ S_{M1} = ⅔ \times 0.985 = 0.656$ g

Section 11.4.5 — Design Response Spectrum

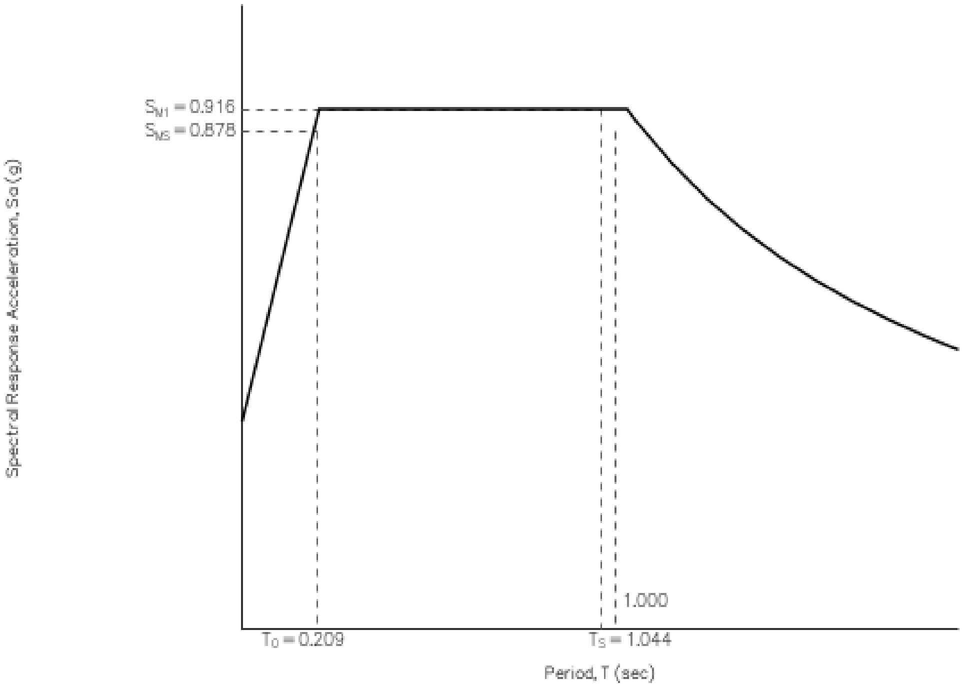
From Figure 22-12 [3] $T_L = 16$ seconds

Figure 11.4–1: Design Response Spectrum



Section 11.4.6 — Risk-Targeted Maximum Considered Earthquake (MCE_R) Response Spectrum

The MCE_R Response Spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

From Figure 22-7 [4]	PGA = 0.406
Equation (11.8–1):	$PGA_M = F_{PGA}PGA = 0.900 \text{ x } 0.406 = 0.366 \text{ g}$

Table 11.8–1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of PGA

For Site Class = E and PGA = 0.406 g, F_{PGA} = 0.900

Section 21.2.1.1 — Method 1 (from Chapter 21 – Site-Specific Ground Motion Procedures for Seismic Design)

From Figure 22-17 [5]	C_{RS} = 0.898
From Figure 22-18 [6]	C_{R1} = 0.871

Section 11.6 — Seismic Design Category

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

VALUE OF S_{DS}	**RISK CATEGORY**		
	I or II	**III**	**IV**
$S_{DS} < 0.167g$	A	A	A
$0.167g \leq S_{DS} < 0.33g$	B	B	C
$0.33g \leq S_{DS} < 0.50g$	C	C	D
$0.50g \leq S_{DS}$	D	D	D

For Risk Category = I and S_{DS} = 0.611 g, Seismic Design Category = D

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

VALUE OF S_{D1}	**RISK CATEGORY**		
	I or II	**III**	**IV**
$S_{D1} < 0.067g$	A	A	A
$0.067g \leq S_{D1} < 0.133g$	B	B	C
$0.133g \leq S_{D1} < 0.20g$	C	C	D
$0.20g \leq S_{D1}$	D	D	D

For Risk Category = I and S_{D1} = 0.656 g, Seismic Design Category = D

Note: When S_1 is greater than or equal to 0.75g, the Seismic Design Category is **E** for buildings in Risk Categories I, II, and III, and **F** for those in Risk Category IV, irrespective of the above.

Seismic Design Category ≡ “the more severe design category in accordance with Table 11.6-1 or 11.6-2” = D

Note: See Section 11.6 for alternative approaches to calculating Seismic Design Category.

References

1. *Figure 22-1*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-1.pdf
2. *Figure 22-2*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-2.pdf
3. *Figure 22-12*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-12.pdf
4. *Figure 22-7*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-7.pdf
5. *Figure 22-17*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-17.pdf
6. *Figure 22-18*: https://earthquake.usgs.gov/hazards/designmaps/downloads/pdfs/2010_ASCE-7_Figure_22-18.pdf

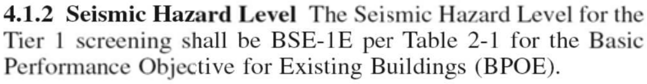
Area 4 - ActiFlo Building
ASCE 41 Evaluation

carollo
Engineers...Working Wonders With Water™

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
CHKD BY		**DESCRIPTION**	Area 4 - ActiFlo	**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 (Tier 1 Screening) - Seismic		**SHEET**	

SEISMIC HAZARD LEVEL & BASIC PERFORMANCE OBJECTIVE

Note:



4.1.2 Seismic Hazard Level The Seismic Hazard Level for the Tier 1 screening shall be BSE-1E per Table 2-1 for the Basic Performance Objective for Existing Buildings (BPOE).

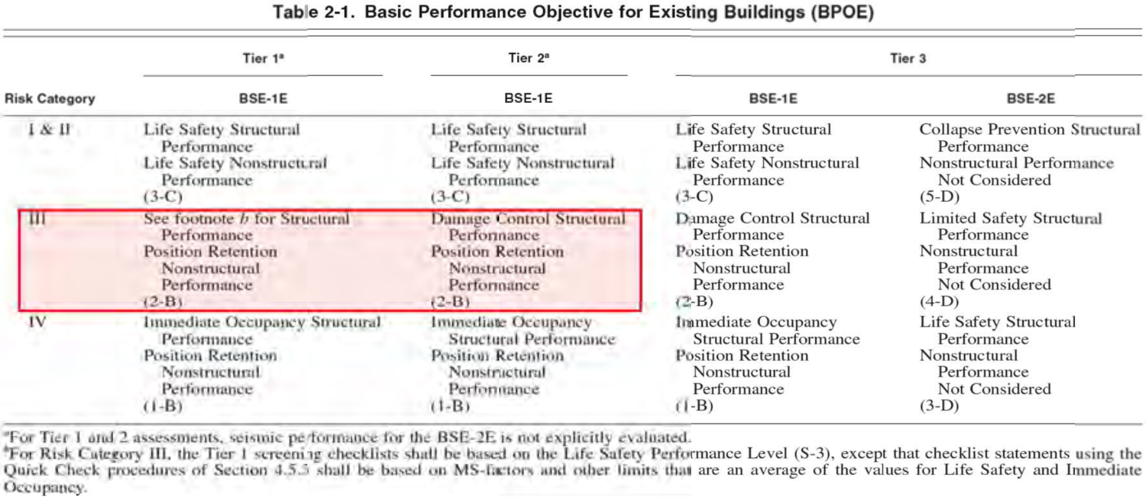


Table 2-1. Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1[a]	Tier 2[a]	Tier 3	
Risk Category	BSE-1E	BSE-1E	BSE-1E	BSE-2E
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III	See footnote *b* for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

[a] For Tier 1 and 2 assessments, seismic performance for the BSE-2E is not explicitly evaluated.

[b] For Risk Category III, the Tier 1 screening checklists shall be based on the Life Safety Performance Level (S-3), except that checklist statements using the Quick Check procedures of Section 4.5.3 shall be based on MS-factors and other limits that are an average of the values for Life Safety and Immediate Occupancy.

BUILDING PERIOD (SECTION 4.5.2.4)

building height, h_n = 11.00 ft

building period adjustment factor, C_t = 0.020

effective viscous damping ratio, β = 0.75

fundamental building period, T = 0.121 sec

SEISMIC PARAMETERS

Building Type = RM1 Table 3-1

modification factor, C = 1.00 Table 4-8

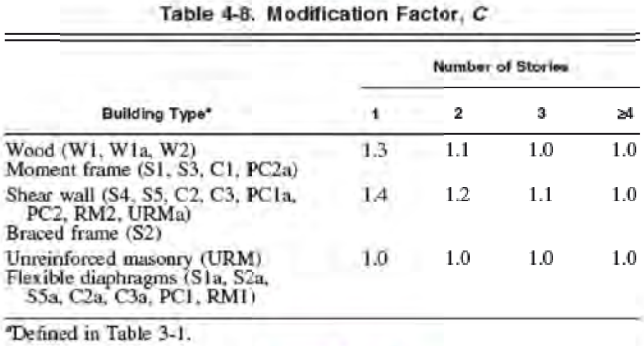


Table 4-8. Modification Factor, *C*

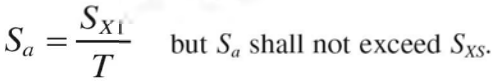
	Number of Stories			
Building Type[a]	1	2	3	≥4
Wood (W1, W1a, W2) Moment frame (S1, S3, C1, PC2a)	1.3	1.1	1.0	1.0
Shear wall (S4, S5, C2, C3, PC1a, PC2, RM2, URMa) Braced frame (S2)	1.4	1.2	1.1	1.0
Unreinforced masonry (URM) Flexible diaphragms (S1a, S2a, S5a, C2a, C3a, PC1, RM1)	1.0	1.0	1.0	1.0

[a] Defined in Table 3-1.

spectral acceleration at 1-sec for BSE-1E, S_{x1} = 0.372 g USGS Seismic Map

spectral acceleration at short period for BSE-1E, S_{xs} = 0.611 g USGS Seismic Map

spectral acceleration, S_a = 0.611 g



$S_a = \dfrac{S_{X1}}{T}$ but S_a shall not exceed S_{XS}.

base shear coefficient, V = 0.611 W Eq 4-1

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
SHEET					
CHKD BY		**DESCRIPTION**	Area 4 - ActiFlo	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening) - Building Weight & Base Shear				

DEAD LOAD (Seismic Weight)

Roof Weight

Roofing	=	5.00	psf
Metal Roof Deck	=	3.00	psf
Steel Joist	=	7.00	psf
Miscellaneous (MEP)	=	5.00	psf
	Total =	20.00	psf

Roof Length	=	19.33	ft
Roof Width	=	18.67	ft
	Total Roof Weight =	7.22	kips

	UW (in)	Trib Ht (ft)	Length (ft)			
Parapet Wall	84.00	1.00	58.66	=	4.93	kips
Wall Below	84.00	5.50	58.66	=	27.10	kips
				Roof Seismic Weight =	***39.25***	***kips***

Seismic Weight & Base Shear

Base Shear Coefficient	=	0.611	g
Total Seismic Weight	=	39	kips
Design Base Shear	=	24	kips

LIVE LOAD

Roof Live Load	=	20.0	psf

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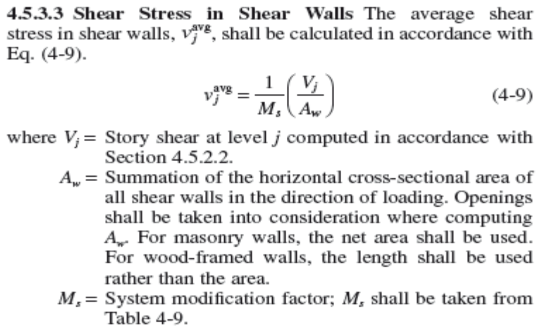
BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 4 - ActiFlo **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Shear Stress

SEISMIC LOAD VERTICAL DISTRIBUTION

Wall Shear Stress Check



4.5.3.3 Shear Stress in Shear Walls The average shear stress in shear walls, v_j^{avg}, shall be calculated in accordance with Eq. (4-9).

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{A_w}\right) \qquad (4\text{-}9)$$

where V_j = Story shear at level j computed in accordance with Section 4.5.2.2.
A_w = Summation of the horizontal cross-sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration where computing A_w. For masonry walls, the net area shall be used. For wood-framed walls, the length shall be used rather than the area.
M_s = System modification factor; M_s shall be taken from Table 4-9.

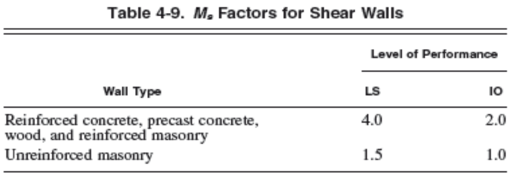


Table 4-9. M_s Factors for Shear Walls

Wall Type	Level of Performance	
	LS	IO
Reinforced concrete, precast concrete, wood, and reinforced masonry	4.0	2.0
Unreinforced masonry	1.5	1.0

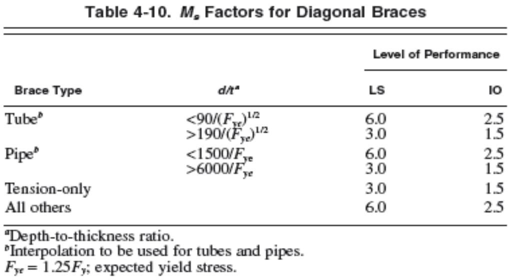


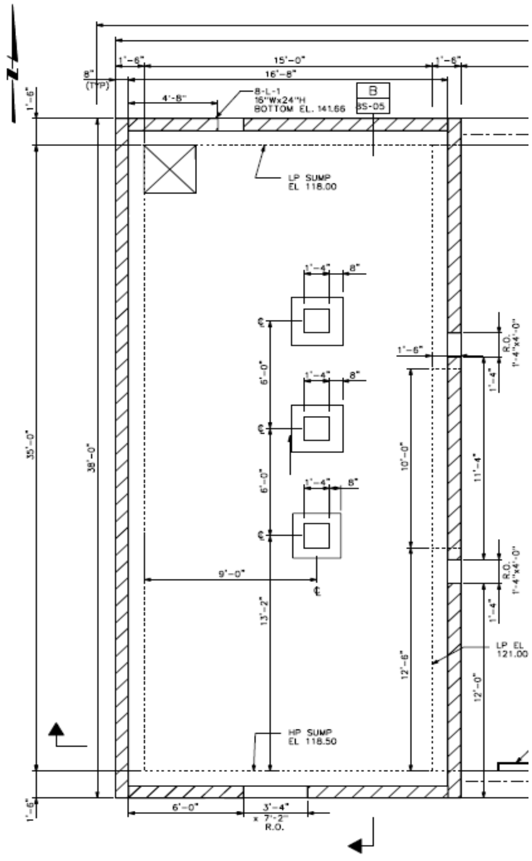
Table 4-10. M_s Factors for Diagonal Braces

Brace Type	d/t[a]	Level of Performance	
		LS	IO
Tube[b]	$<90/(F_{ye})^{1/2}$	6.0	2.5
	$>190/(F_{ye})^{1/2}$	3.0	1.5
Pipe[b]	$<1500/F_{ye}$	6.0	2.5
	$>6000/F_{ye}$	3.0	1.5
Tension-only		3.0	1.5
All others		6.0	2.5

[a] Depth-to-thickness ratio.
[b] Interpolation to be used for tubes and pipes.
$F_{ye} = 1.25F_y$; expected yield stress.

$v_{s,allow}$ = 70 psi
M_s = 3.0 <-- Damage Control (between "LS" & "IO")

	t_{wall} (in)	$L_{net,\ wall}$ (ft)	A_{wall} (in^2)	*V* *(kips)*	*v shear* *(psi)*	
Walls in NS-Dir	7.63	40.00	3660	*24.00*	*2.19*	*<= OK*
Walls in EW-Dir	7.63	31.99	2927	*24.00*	*2.73*	*<= OK*



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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 4 - ActiFlo	**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 - Damage Control - Diaphragm Shear in Transverse Direction					

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, K = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 18.67 ft
diaphragm depth, L_{diaph} = 19.33 ft

spectral acceleration, S_a = 0.611 g
building seismic weight, W = 39 kips

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 33 kips
diaph shear, $Q_{UD} = F_d / (2^*L_{diaph})$ = 863 plf

allowable diaphragm shear = 1069 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1710 plf
$m_1{}^*K^*Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

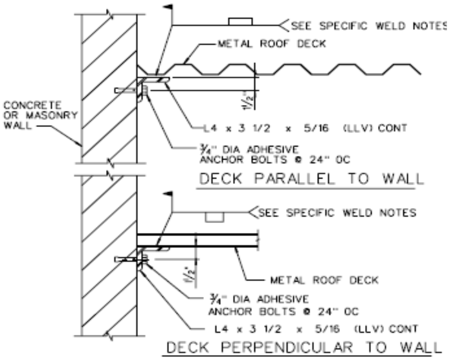
Chord Force (Tier 2 - Deformation Controlled)

chord force, $Q_{UD} = (F_d{}^*L_{span}) / (8^*L_{diaph})$ = 4028 lbs

strength reduction factor, ϕ = 1.00
Number of Bars = 4 bars
Bar Size = #4
Yield Stress f_y = 60,000 psi
$A_{s,total}$ = 0.80 in^2
Tensile Capacity at Opng, ϕT_n = 48000 lbs
$m_2{}^*K^*Q_{CE}$ = 174000 lbs

Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in



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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
SHEET					
CHKD BY		**DESCRIPTION**	Area 4 - ActiFlo	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 - Damage Control - Diaphragm Shear in Transverse Direction				

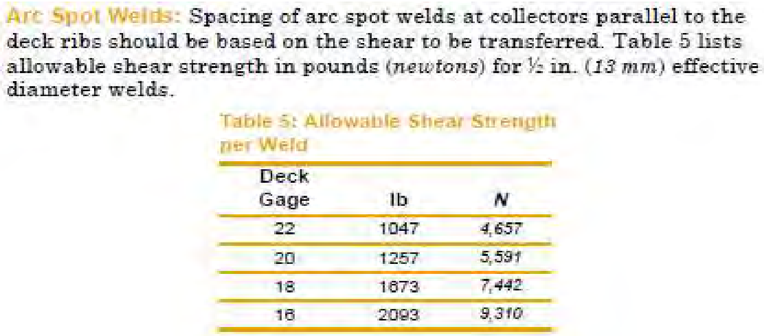
anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

anchor bolt shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 1726 lbs /bolt
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 616 lbs /bolt

projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt
cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

strength reduction factor, ϕ = 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y$ = 15904 lbs /bolt steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddle weld shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 863 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 308 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, C_{WELD} = 1.65 per IAPMO-ER #0217
KQ_{CL} = 2074 lbs /weld

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.31	<--	***OK***	diaphragm shear
demand capcity ratio, DCR =	*0.02*	<--	***OK***	diaphragm chord
demand capcity ratio, DCR =	*0.10*	<--	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.12*	<--	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.03*	<--	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.04*	<--	***OK***	steel yielding
demand capcity ratio, DCR =	0.15	<--	***OK***	puddle weld strength

BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 4 - ActiFlo **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in Longitudinal Direction

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, K = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 19.33 ft
diaphragm depth, L_{diaph} = 18.67 ft

spectral acceleration, S_a = 0.611 g
building seismic weight, W = 39 kips

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 33 kips
diaph shear, $Q_{UD} = F_d / (2^*L_{diaph})$ = 893 plf

allowable diaphragm shear = 1069 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1710 plf
$m_1{}^*K^*Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

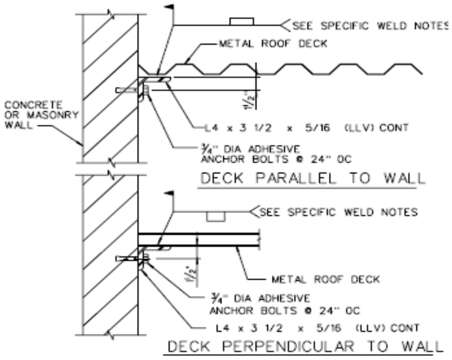
Chord Force (Tier 2 - Deformation Controlled)

chord force, $Q_{UD} = (F_d{}^*L_{span}) / (8^*L_{diaph)}$ = 4317 lbs

strength reduction factor, ϕ = 1.00
Number of Bars = 4 bars
Bar Size = #4
Yield Stress f_y = 60,000 psi
$A_{s,total}$ = 0.80 in^2
Tensile Capacity at Opng, ϕT_n = 48000 lbs
$m_2{}^*K^*Q_{CE}$ = 174000 lbs

Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in



BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 4 - ActiFlo **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in Longitudinal Direction

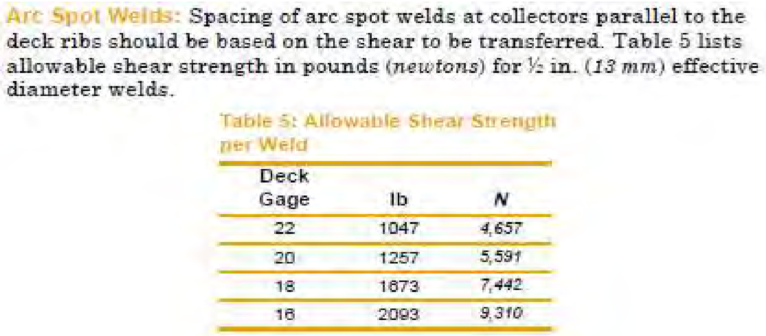
anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

anchor bolt shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 1787 lbs /bolt
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 638 lbs /bolt

projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt
cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

strength reduction factor, ϕ = 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt **OK** masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt **OK** masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt **OK** anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y$ = 15904 lbs /bolt **OK** steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddle weld shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 893 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 319 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, C_{WELD} = 1.65 per IAPMO-ER #0217
KQ_{CL} = 2074 lbs /weld

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = 0.32 <-- ***OK*** diaphragm shear
demand capcity ratio, DCR = *0.02* <-- ***OK*** diaphragm chord
demand capcity ratio, DCR = *0.11* <-- ***OK*** masonry breakout
demand capcity ratio, DCR = *0.12* <-- ***OK*** masonry crushing
demand capcity ratio, DCR = *0.03* <-- ***OK*** anchor bolt pryout
demand capcity ratio, DCR = *0.04* <-- ***OK*** steel yielding
demand capcity ratio, DCR = 0.15 <-- ***OK*** puddle weld strength

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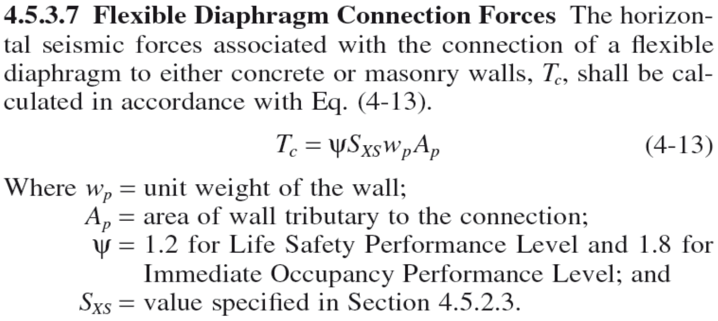
BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 4 - ActiFlo	**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Joist Supports					

WALL ANCHORAGE FORCE


4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \qquad (4\text{-}13)$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

wall height to diaphragm, h_w = 11.00 ft
parapet height, h_p = 1.00 ft

unit weight of wall, w_p = 84.00 psf
Ψ ("IO") = 1.50 <-- Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

beam spacing = 6.22 ft
wall out-of-plane load = 500 lbs/ ft

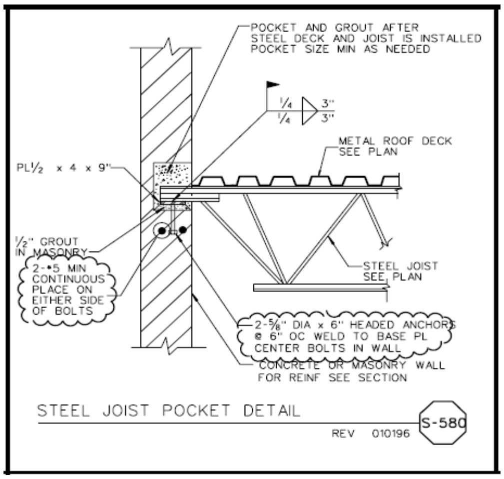
wall anchorage force, T_c = 3114 lbs

Masonry & Steel Strength

number of anchor bolts = 2
anchor bolt size = 0.625 in
anchor bolt embed = 6.00 in
anchor bolt edge distance = 3.81 in
anchorage spacing = 6.00 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

projected area of anchor bolt shear, A_{pv} = 46 in^2
projected area of anchor bolt tension, A_{pt} = 137 in^2
cross section area of anchor bolt, A_b = 0.31 in^2



$\phi B_{vnb} = 1.0*4*A_{pv}*(f'_m)^{0.5}$ = 7,074 lbs masonry breakout
$\phi B_{vnpry} = 1.0*1050*(f'_m*A_b)^{1/4}$ = 9,726 lbs masonry crushing
$\phi B_{vnpry} = 1.0*8*A_{pt}*(f'_m)^{0.5}$ = 42,525 lbs anchor bolt pryout
$\phi B_{vns} = 1.0*0.6*A_b*f_y$ = 13,254 lbs steel yielding

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = *0.44* <-- ***OK*** masonry breakout
demand capcity ratio, DCR = *0.32* <-- ***OK*** masonry crushing
demand capcity ratio, DCR = *0.07* <-- ***OK*** anchor bolt pryout
demand capcity ratio, DCR = *0.23* <-- ***OK*** steel yielding

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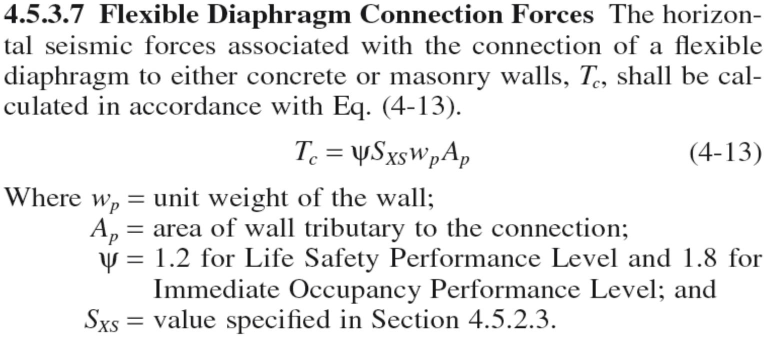
CHKD BY		**DESCRIPTION**			Area 4 - ActiFlo	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger						

WALL ANCHORAGE FORCE



4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \qquad (4\text{-}13)$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

wall height to diaphragm, h_w = 11.00 ft
parapet height, h_p = 1.00 ft

unit weight of wall, w_p = 84.00 psf
Ψ ("IO") = 1.50 <-- Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

anchor bolts spacing = 24.00 in
wall out-of-plane load = 500 lbs/ ft

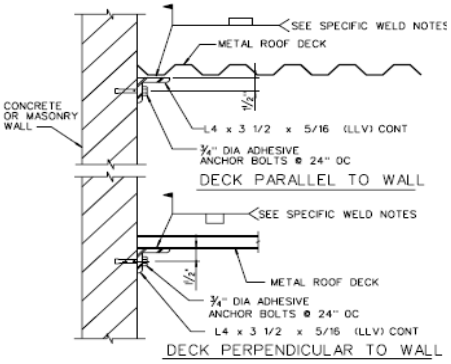
wall anchorage force, T_c = 1001 lbs /bolt

Masonry & Steel Strength

anchor bolt size = 0.750 in
anchor bolt embed = 3.50 in
anchor bolt edge distance = 3.81 in
anchorage spacing = 6.00 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

projected area of anchor bolt tension, A_{pt} = 38 in^2
cross section area of anchor bolt, A_b = 0.44 in^2



$\phi B_{vnpry} = 1.0*4*A_{pt}*(f'_m)^{0.5}$ = 5,962 lbs anchor bolt pryout
$\phi B_{vns} = 1.0*A_b*f_y$ = 15,904 lbs steel yielding

Ledger Angle

yield strength, f_y = 36,000 psi
ledger angle thick, t = 0.31 in
moment arm, l_{arm} = 1.19 in distance from top of ledger to center of AB
effective width, b = 3.00 in
section modulus, S = 0.0488 in^3

shear stress = 1,068 psi

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DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger						

moment = 1,191 lb-in
flexural stress = 24,391 psi

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	*0.17*	**<--**	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.06*	**<--**	***OK***	steel yielding
demand capcity ratio, DCR =	*0.03*	**<--**	***OK***	ledger shear
demand capcity ratio, DCR =	*0.68*	**<--**	***OK***	ledger flexural

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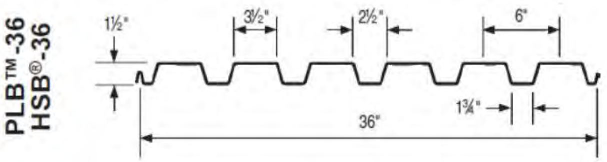
BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 4 - ActiFlo **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck

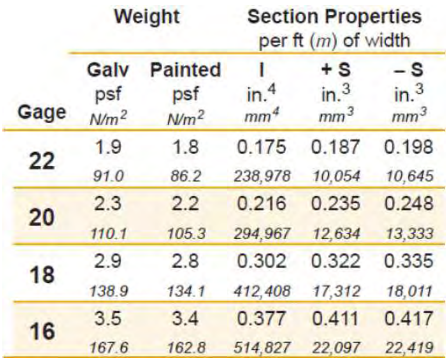
STEEL DECK PROPERTIES (ASTM A653, Grade 33)

Modulus of Elasticity, E = 29500 ksi

Yield Strength, F_y = 38 ksi

Ultimate Strength, F_u = 52 ksi





	Weight		Section Properties per ft (*m*) of width		
Gage	Galv psf *N/m²*	Painted psf *N/m²*	I in.⁴ *mm⁴*	+ S in.³ *mm³*	– S in.³ *mm³*
22	1.9 *91.0*	1.8 *86.2*	0.175 *238,978*	0.187 *10,054*	0.198 *10,645*
20	2.3 *110.1*	2.2 *105.3*	0.216 *294,967*	0.235 *12,634*	0.248 *13,333*
18	2.9 *138.9*	2.8 *134.1*	0.302 *412,408*	0.322 *17,312*	0.335 *18,011*
16	3.5 *167.6*	3.4 *162.8*	0.377 *514,827*	0.411 *22,097*	0.417 *22,419*

Steel Deck = HSB-36

Gage = 20

Deck Span, L = 5.67 ft

DESIGN LOAD (Service Level)

Roof Load, w = 30 psf --- *steel deck gravity*

Wall Out-of-Plane Load, F = 500 lb/ft --- *deck axial load*

Design Flexural Moment :

Neutral Axis, y_b = 0.919 in

M_{roof} = 1.447 kip-in /ft --- *moment due to gravity load = w * L2 / 8*
M_{ecc} = 0.328 kip-in /ft --- *moment due to wall out-of-plane = (F/1.4) * yb*

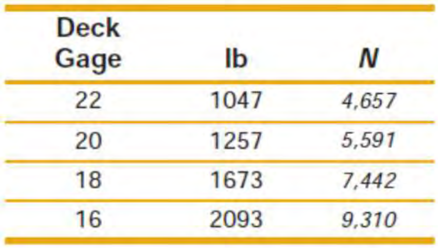
M_{total} = 1.775 kip-in /ft

ARC-SPOT WELD (WALL OUT-OF-PLANE)

Effective Weld Size Dia, d_e = 1/2 in

Weld Pattern = 5 per 36/sheet

Allowable Weld Capacity = 2.10 kip/ft <= OK



Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

Allowable shear strength for 1/2" effective diameter puddle welds.

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SHEET					
CHKD BY		**DESCRIPTION**	Area 4 - ActiFlo	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck				

STEEL DECK ALLOWABLE COMPRESSION

Effective Length Factor, K = 1.00

Deck Thickness, t = 0.0359 in

Width of Top Flange, w = 3.50 in

Gross Section Area, A_g = 0.599 in^2/ft

radius of gyration, r = 0.601 in

KL/r = 113

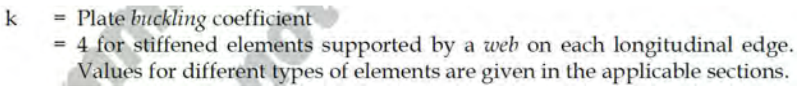
λ_c = 1.29

F_n = 18.85 ksi

Effective Width of Top & Bottom Flange Under Compression
(Assume Bottom Flange Fully Effective)

Ω_c = 1.8 --- *factor of safety*

k = 4



k = Plate *buckling* coefficient
= 4 for stiffened elements supported by a *web* on each longitudinal edge. Values for different types of elements are given in the applicable sections.

Poisson's Ratio = 0.300

F_{cr} = 11.22

λ = 1.296

ρ = 0.641

Effective Flange Width, b = 2.242 in --- *effective flange width = ρw*

Effective Section Area, A_e = 0.554 in^2/ft --- *effective section area*

P_n / Ω_c = 5.80 kip /ft **<= OK** --- $A_e * F_n / \Omega_c$

STEEL DECK ALLOWABLE TENSION

Gross Section Area, A_g = 0.599 in^2/ft

Ω_{T1} = 1.67

T_{n1} / Ω_{T1} = 13.63 kip /ft **<= OK** --- $A_g * F_y / \Omega_{T1}$

Ω_{T2} = 2.00

T_{n2} / Ω_{T2} = 15.57 kip /ft **<= OK** --- $A_g * F_u / \Omega_{T2}$

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
				SHEET	
CHKD BY		**DESCRIPTION**	Area 4 - ActiFlo	**JOB NO.**	10721A.00

DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck

STEEL DECK ALLOWABLE BENDING

Ω_b = 1.67

S_+ = 0.235 in^3/ft --- *positive section modulus*

M_n / Ω_b = 5.35 kip-in /ft **<= OK** --- $S_+ * F_y / \Omega_b$

COMBINED LOAD INTERACTION

Bending-Tension Interaction:

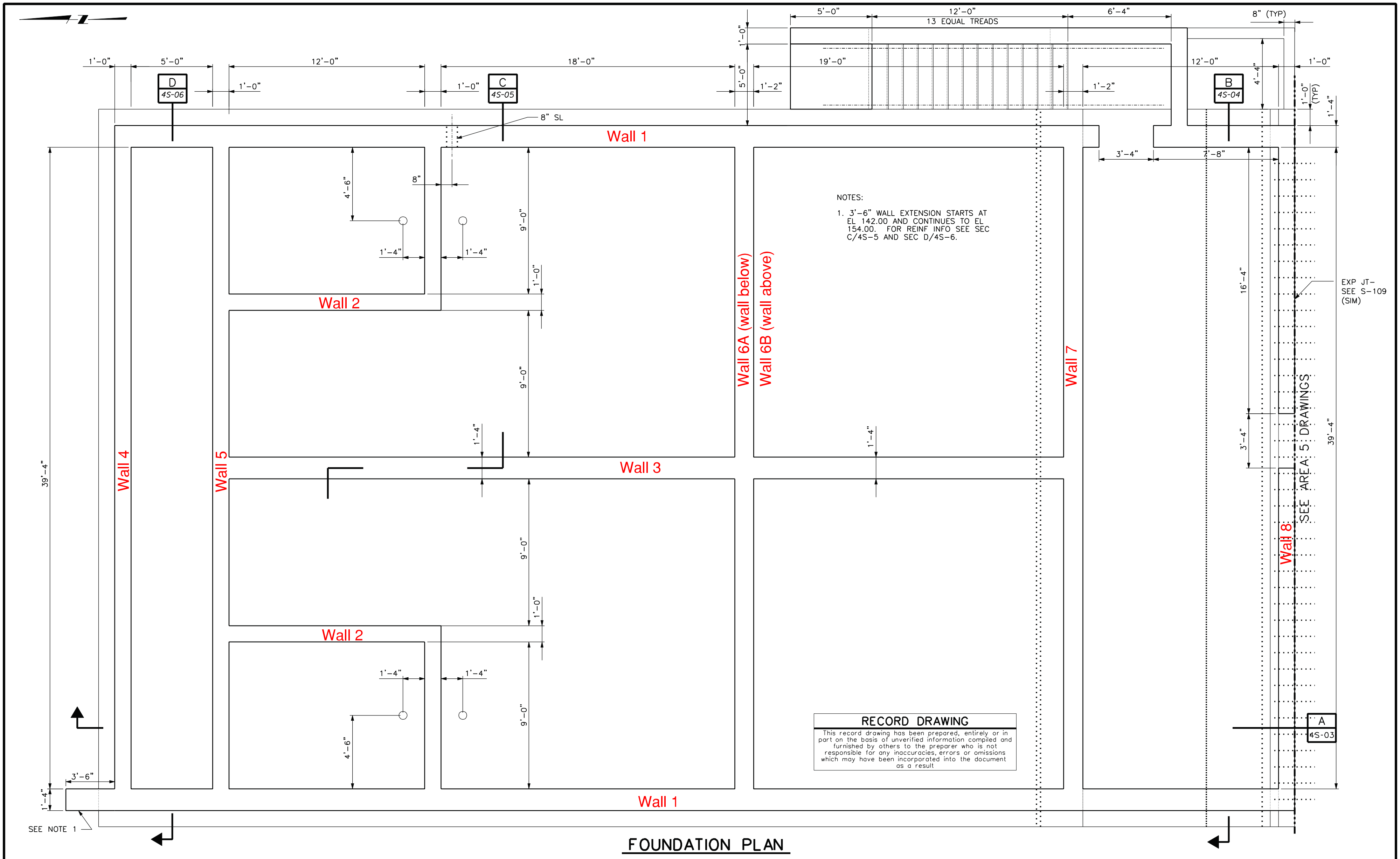
DCR = 0.369 **<= OK**

Bending-Compression Interaction:

DCR = 0.418 **<= OK**

Area 4 - ActiFlo Concrete Structure
ACI 350 Evaluation

WALL IDENTIFICATION



NOTES:

1. 3'-6" WALL EXTENSION STARTS AT EL 142.00 AND CONTINUES TO EL 154.00. FOR REINF INFO SEE SEC C/4S-5 AND SEC D/4S-6.

RECORD DRAWING

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FOUNDATION PLAN

Job No: 1076081 File: P:\Wilsonville, City Of\Willamette WTP D-B\Rcrd Dwgs\str\ustn\wi04s01.dgn Plot Date: 03/28/2003 09:22:05 AM

REV	DATE	BY	DESCRIPTION
R	10/03	BMP	RECORD DRAWING

SCALE 3/8"=1'-0"

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

DESIGNED B. CROOK
DRAWN B. CROOK
CHECKED

SUBMITTED BY
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Oregon

City of
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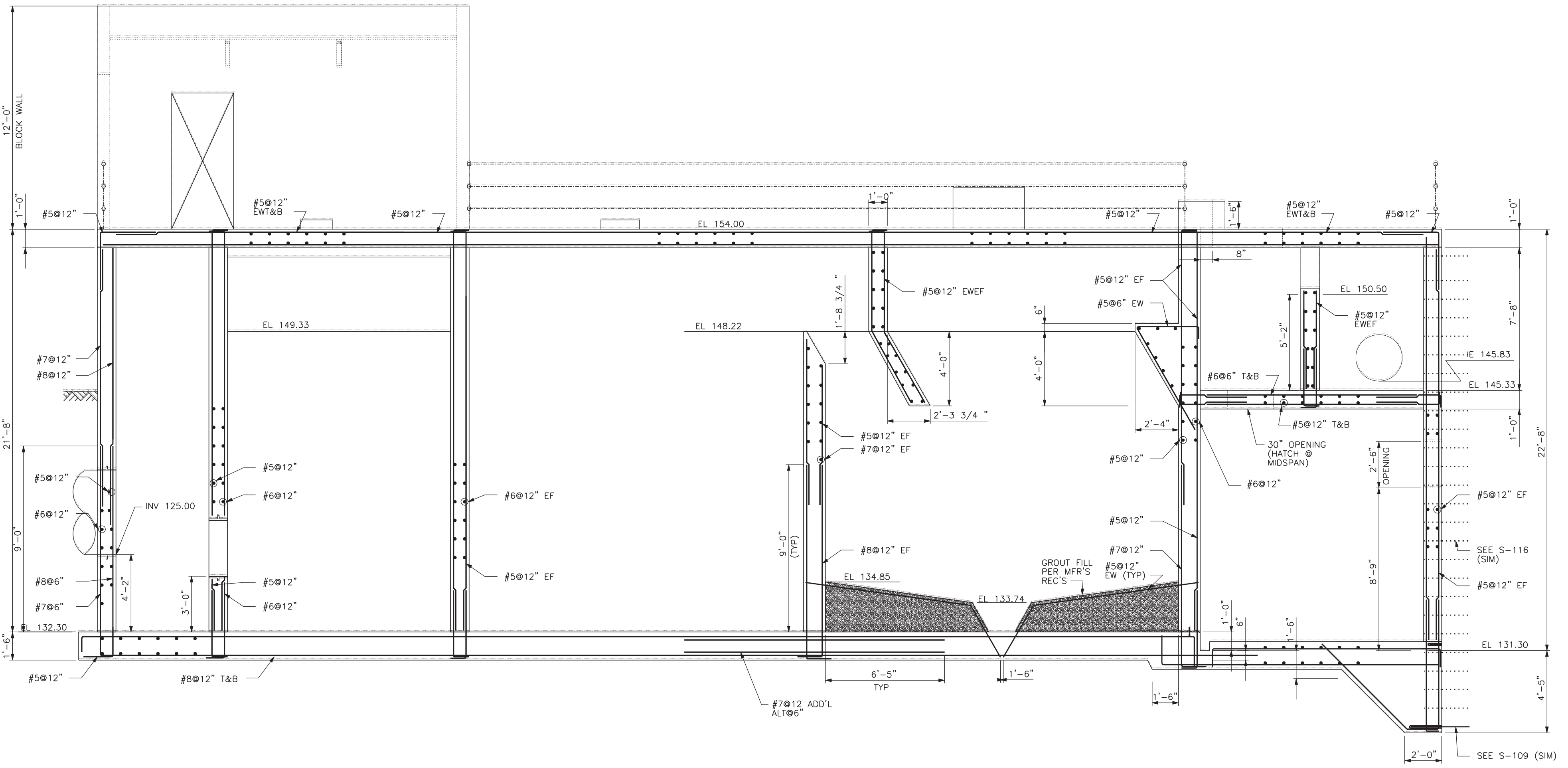
in OREGON

CITY OF WILSONVILLE
WILLAMETTE RIVER WATER TREATMENT PLANT
ACTIFLO
STRUCTURAL
FOUNDATION PLAN

SHEET
4S-01

Job No: 1076081 File: P:\Wilsonville, City Of\Willamette WTP D-B\FILE-TRANSFER\cad_drawings\str\wi04s03.dgn Plot Date: 10/24/2003 11:52:01 AM



NOTE:
FOR CORNER FILLETS
USE #5@12" WITH WIRE
FABRIC NEAR SURFACE

SECTION A
4S-01
4S-02

RECORD DRAWING

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REV	DATE	BY	DESCRIPTION
R	10/03	BAP	RECORD DRAWING

SCALE
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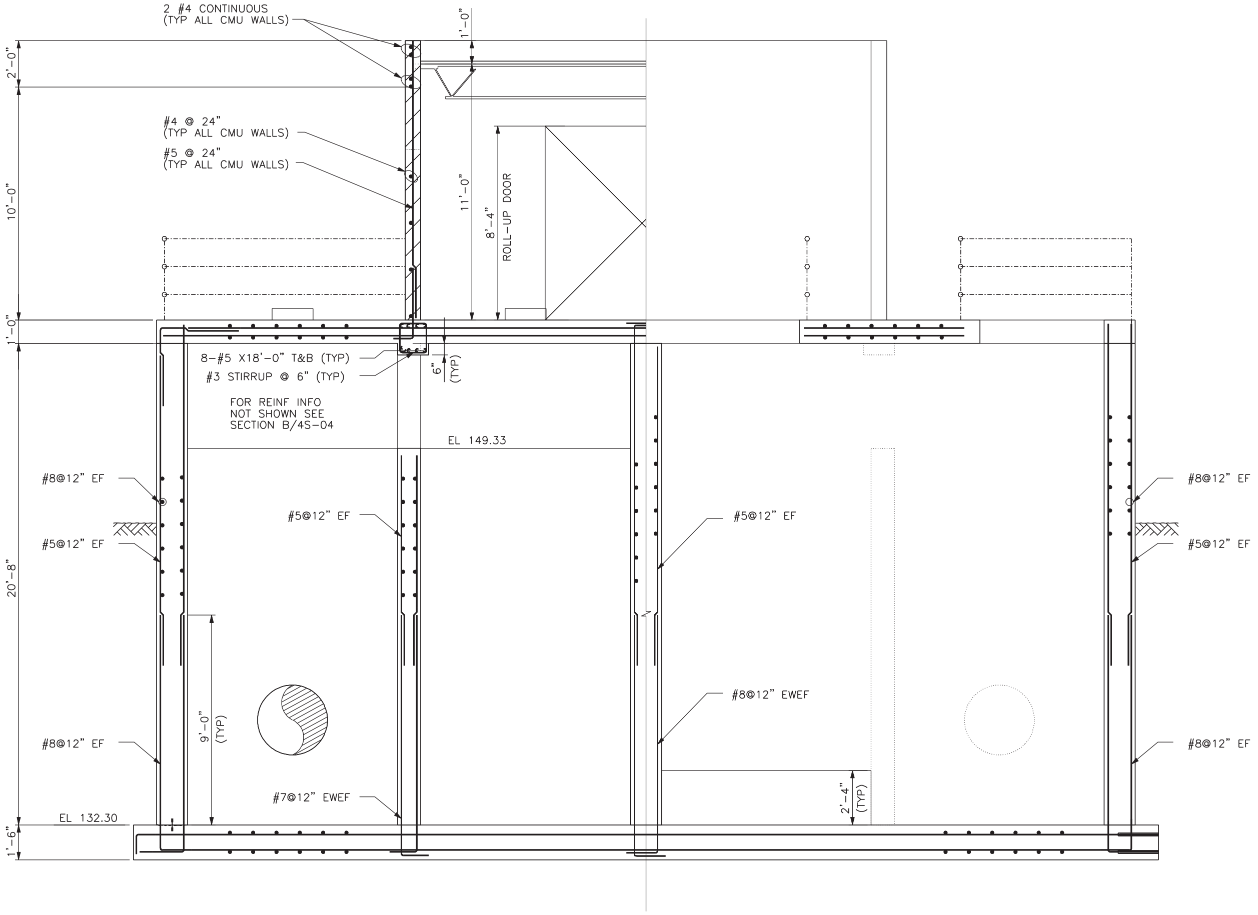
STRUCTURAL
SECTION

SHEET
4S-03



SECTION C
4S-01
4S-02

RECORD DRAWING

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Job No: 1076081
File: P:\Wilsonville, City Of\Willamette WTP D-B\FILE-TRANSFER\cad_drawings\str\wi04s05.dgn
Plot Date: 01/24/2003 11:54:35 AM

REV	DATE	BY	DESCRIPTION
R	10-02	BR	RECORD DRAWING

SCALE
3/8"=1'-0"

WARNING
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SHEET
4S-05

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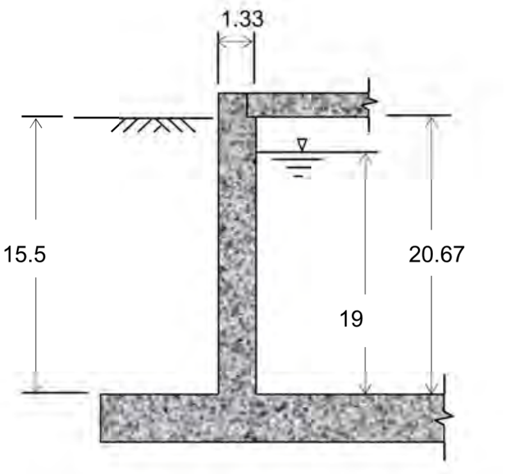
CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 1&3 Pressures		

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **19** ft
tank wall thickness, t_w = **16** inch
wall height to underside of roof, H_w = **20.67** ft

liquid height, H_L = **19** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION
(wall fixity = pinned at roof & fixed at floor)

Soil Data

The site has no groundwater.

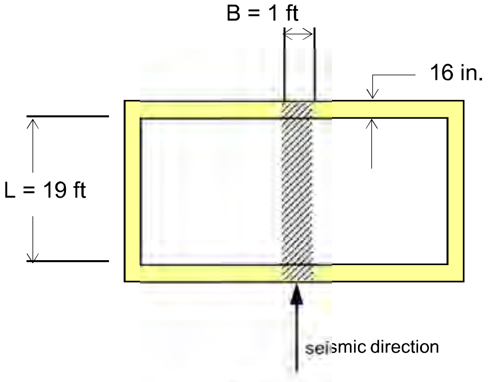
soil height above top of foundation base = **15.5** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf
0

concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.29**
Response modification factor, R_{wc} = **1.39**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 1&3 Pressures		

Weights:

unit 1-ft width wall mass, W_w = (16/12) * (20.67) * 0.15 = 4.13 kip

wall c.g. relative to base, h_w = 20.67 / 2 = 10.335 ft

unit width liquid mass, W_L = (19) * (1) * (19) * 32.17 = 22.53 kip

Seismic:

1). structure stiffness and dynamic property:

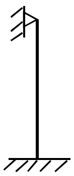
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.12850 k-sec^2/ft^2

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.28267 k-sec^2/ft^2

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 8.537 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 1600.23 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (1600.23 / (0.1285 + 0.2827))\hat{}½ = 62.3846 \text{ rad/sec}$$

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 62.3846 = 0.1007 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = \quad (3.16*32.2*\tanh(3.16*(1)))\hat{}½ = 10.0644$$

$$\omega_c = \frac{\lambda}{\sqrt{L}} = \quad 10.0644 / (19)\hat{}½ = 2.3089 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 2.3089 = 2.7213 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.362 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ , \quad \text{but} \le 1.0 = \quad 0.8453$$

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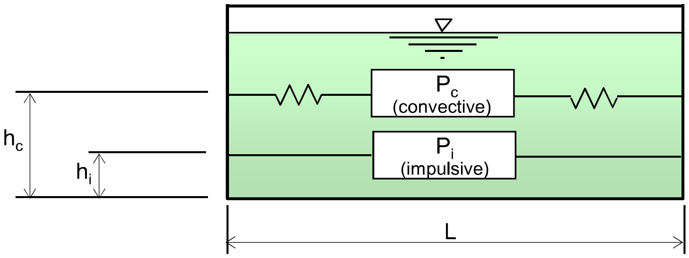
DESIGN TASK:					Wall 1&3 Pressures		



Dynamic Model

$L =$ 19 ft
$B =$ 1 ft
$H_L =$ 19 ft
$W_L =$ 22.53 kip

$L / H_L =$ 1.00000
$H_L / L =$ 1.00000

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L \left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}} \right) =$$

22.53*(tanh(0.866*(1)) / 0.866*(1)) = 18.19 kip

hi (EBP) = HL * (0.5-0.09375*(L/HL)) = 19*(0.5-0.09375*(1)) = 7.719 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 9.389 ft

impulsive force, $P_i = \left(\frac{S_{ai}\ I}{R_{wi}} \right) W_i =$ (0.611 * 1.25 / 2.29)*18.19 = 6.1 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L \left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) =$$

22.53*(0.264*(1)*tanh(3.16*(1))) = 5.93 kip

$$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 13.477 \text{ ft}$$

$$h_{c\ (IBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 13.993 \text{ ft}$$

convective force, $P_c = \left(\frac{S_{ac}\ I}{R_{wc}} \right) W_c =$ (0.3616 * 1.25 / 1.39)*5.93 = 1.9 kip

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DESIGN TASK:					Wall 1&3 Pressures		

5). lateral inertia force of the accelerating wall:

unit width wall mass, $W_w =$ 4.13 kip

wall c.g. relative to base, $h_w =$ 10.335 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (0.611{*}1.25{*}0.8453/2.29)^{*}4.13 = \quad 1.16 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (19/2) * (0.3616 / 1.4 * 1.25) = \quad 3.07 \text{ ft}$$

Wave height is greater than the freeboard of 1.67-ft. Check possible effects on the roof.

7). vertical acceleration:

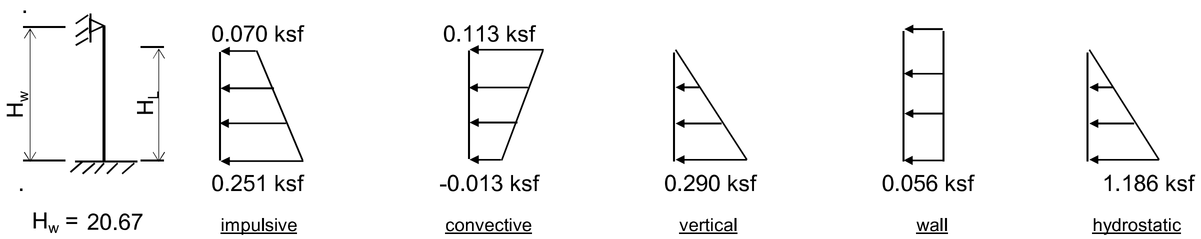
design horizontal accereration, $S_{DS} =$ 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4{*}S_{DS} =$ 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444{*}1{*}1/1 = \quad 0.2444 \text{ g}$$

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



$H_w =$ 20.67

$H_L =$ 19

impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

$P_i =$ 6.10 kip

$h_i =$ 7.719 ft

at $y = H_L$, $p_{iy} =$ 0.070 ksf

at base $y = 0$, $p_{iy} =$ 0.251 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

$P_c =$ 1.90 kip

$h_c =$ 13.477 ft

at $y = H_L$, $p_{cy} =$ 0.113 ksf

at base $y = 0$, $p_{cy} =$ -0.013 ksf

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BY: C.Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 1&3 Pressures

vertical acceleration:

$$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$$

$\ddot{u}$ = 0.2444
at y = H_L, p_{vy} = 0.000 ksf
at base y = 0, p_{vy} = 0.290 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\;I\;\varepsilon\,\gamma_c\,(t_w/12)}{R_{wi}} =$$

p_{wy} = 0.2819 * γ_c * (t_w/12)
at y = H_w, p_{wy} = 0.056 ksf
at base y = 0, p_{wy} = 0.056 ksf

hydrostatic:

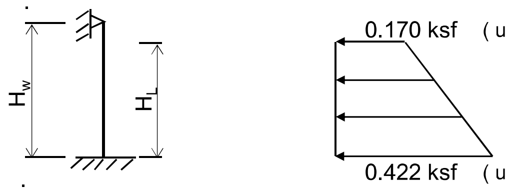
$$q_{hy} = \gamma_L\,(H_L - y) =$$

at y = H_L, q_{hy} = 0.000 ksf
at base y = 0, q_{hy} = 1.186 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y = 0.170 ksf
at base y = 0, p_y = 0.422 ksf



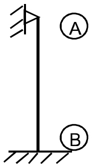
0.170 ksf (unfactored = 0.17 / 1.4 = 0.121 ksf)

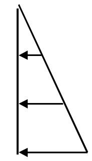
0.422 ksf (unfactored = 0.422 / 1.4 = 0.302 ksf)

resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

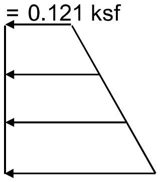
wall height, H_w = 20.67 ft
liquid height, H_L = 19 ft





1.186 ksf
hydrostatic

unfactored load = 0.121 ksf



unfactored load = 0.302 ksf
resultant dynamic pressures

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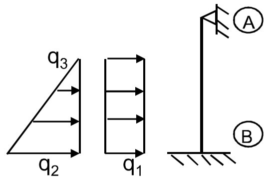
DESIGN TASK:					Wall 1&3 Pressures		

10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 20.67 ft

soil height above top of base = 15.5 ft

groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

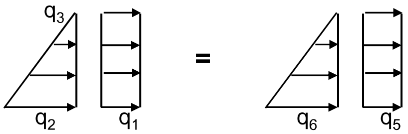
live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:

LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.8525 ksf

unfactored soil, q3 = 0.0000 ksf



equivalent soil loadings:

unfactored q5 = 0.1000 ksf

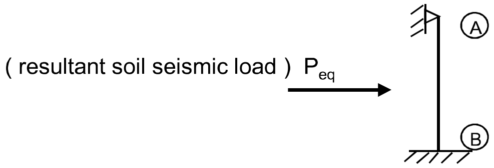
unfactored q6 = 0.8525 ksf

soil seismic:

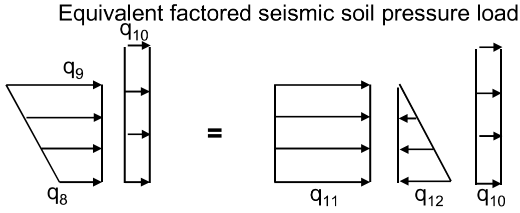
resultant factored soil seismic load per foot of wall width, $P_{u\,(eq)}$ = **4.08** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **10.33** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0003 ksf

equivalent soil seismic, q9 = 0.5261 ksf

wall seismic (see wall page 5), q10 = 0.0564 ksf

equivalent soil seismic, q11 = q9 = 0.5261 ksf

equivalent soil seismic, q12 = q8 - q9 = -0.5258 ksf

unfactored equivalent soil seismic, q8 =0.0003 / 1.4 = 0.0002 ksf

unfactored equivalent soil seismic, q9 =0.5261 / 1.4 = 0.3758 ksf

unfactored wall seismic , q10 = 0.0564 / 1.4 = 0.0403 ksf

unfactored equivalent soil seismic, q11 =0.5261 / 1.4 = 0.3758 ksf

unfactored equivalent soil seismic, q12 =-0.5258 / 1.4 = -0.3756 ksf

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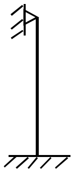
DESIGN TASK:					Wall 1&3 Pressures		

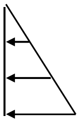
11). **Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:**



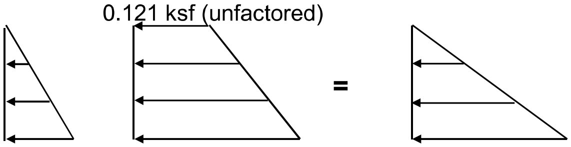
Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

wall height = 20.67 ft
water depth = 19 ft



b). load case 2: hydrostatic + dynamic:



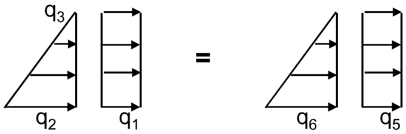
wall height = 20.67 ft
water depth = 19 ft

c). load case 3: static soil + LL surcharge:

wall height = 20.67 ft
soil height on wall = 15.5 ft

equivalent static soil & surcharge loadings...

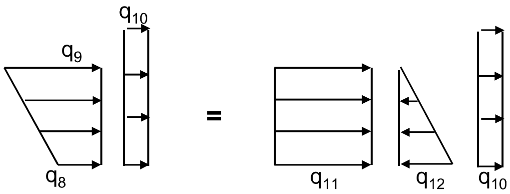
LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.853 ksf
unfactored soil, q3 = 0.000 ksf



equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.853 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.67 ft
soil height on wall = 15.5 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.376 ksf
unfactored equivalent soil seismic, q10 = 0.040 ksf
unfactored equivalent soil seismic, q11 = 0.376 ksf
unfactored equivalent soil seismic, q12 = -0.376 ksf

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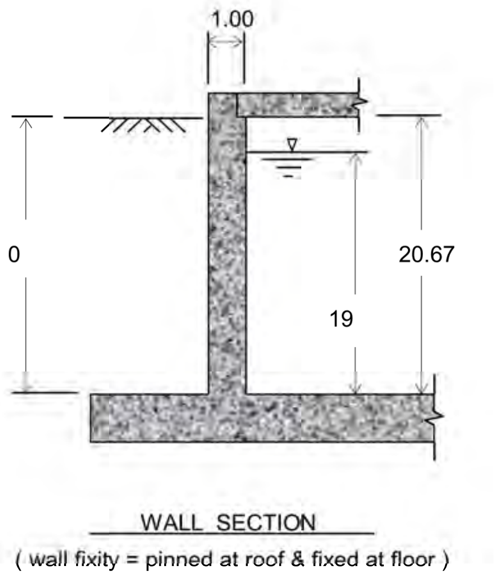
DESIGN TASK:					Wall 2 Pressures		

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **9** ft
tank wall thickness, t_w = **12** inch
wall height to underside of roof, H_w = **20.67** ft

liquid height, H_L = **19** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



(wall fixity = pinned at roof & fixed at floor)

Soil Data

The site has no groundwater.

soil height above top of foundation base = **0** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf

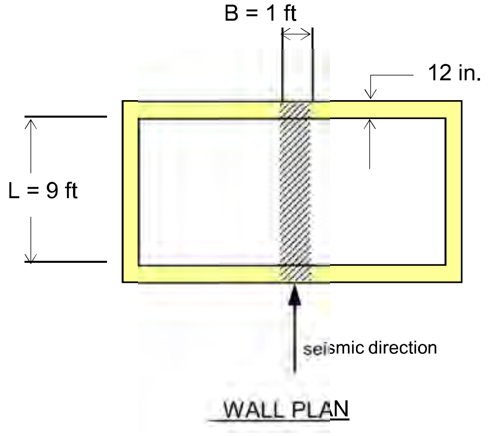
0

concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.44**
Response modification factor, R_{wc} = **1.23**



Load Cases:

case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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DESIGN TASK:					Wall 2 Pressures		

Weights:

unit 1-ft width wall mass, W_w = (12/12) * (20.67) * 0.15 = 3.10 kip
wall c.g. relative to base, h_w = 20.67 / 2 = 10.335 ft

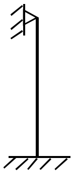
unit width liquid mass, W_L = (9) * (1) * (19) * 32.17 = 10.67 kip

Seismic:

1). structure stiffness and dynamic property:

Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.
wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.09638 k-sec^2/ft^2
liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.15714 k-sec^2/ft^2
centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 9.294 ft



wall fixity condition is pinned at roof & fixed at floor:
wall stiffness is determined using a unit mass load located at the centroidal distance h.
wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 601.30 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (601.3 / (0.0964 + 0.1571))\hat{}½ = 48.7012 \text{ rad/sec}$$

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 48.7012 = 0.1290 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = \quad (3.16*32.2*\tanh(3.16*(2.1111)))\hat{}½ = 10.0825$$

$$\omega_c = \frac{\lambda}{\sqrt{L}} = \quad 10.0825 / (9)\hat{}½ = 3.3608 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 3.3608 = 1.8695 sec
Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec
design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.526 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021 \text{ , but } \le 1.0 = 0.9340$$

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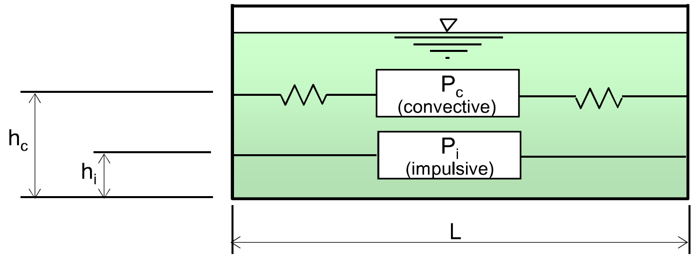
DESIGN TASK:					Wall 2 Pressures		



Dynamic Model

$L =$ 9 ft
$B =$ 1 ft
$H_L =$ 19 ft
$W_L =$ 10.67 kip

$L / H_L =$ 0.47368
$H_L / L =$ 2.11111

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) =$$ 10.67*(tanh(0.866*(0.4737)) / 0.866*(0.4737)) = 10.11 kip

hi (EBP) = HL * (0.5-0.09375*(L/HL)) = 19*(0.5-0.09375*(0.4737)) = 8.656 ft

hi (IBP) = HL * 0.45 = 8.55 ft

impulsive force, $P_i = \left(\frac{S_{ai}\ I}{R_{wi}}\right)W_i =$ (0.611 * 1.25 / 2.44)*10.11 = 3.2 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) =$$ 10.67*(0.264*(0.4737)*tanh(3.16*(2.1111))) = 1.33 kip

$$h_{c\ (EBP)} = H_L\left(1-\frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right)-1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 16.159 ft

$$h_{c\ (IBP)} = H_L\left(1-\frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right)-2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 16.166 ft

convective force, $P_c = \left(\frac{S_{ac}\ I}{R_{wc}}\right)W_c =$ (0.5263 * 1.25 / 1.23)*1.33 = 0.7 kip

5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 3.10 kip

wall c.g. relative to base, h_w = 10.335 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w =$ (0.611*1.25*0.934/2.44)*3.1 = 0.91 kip

6). maximum wave slosh height displacement:

$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) =$ (9 / 2) * (0.5263 / 1.4 * 1.25) = 2.11 ft

Wave height is greater than the freeboard of 1.67-ft. Check possible effects on the roof.

7). vertical acceleration:

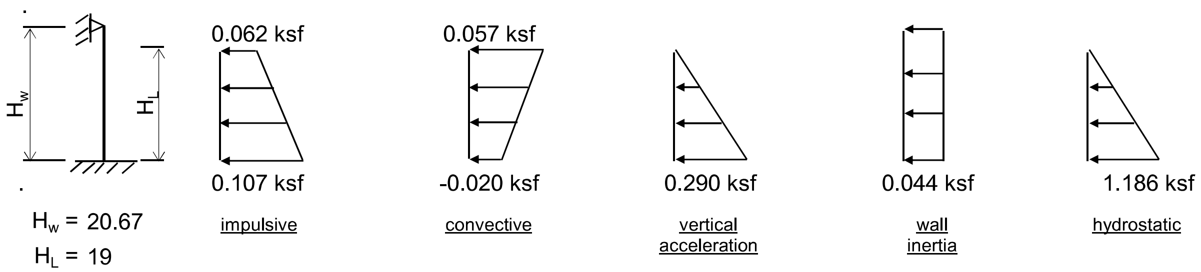
design horizontal accereration, S_{DS} = 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4{*}S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 0.2444*1*1/1 = 0.2444 g

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



H_w = 20.67

H_L = 19

impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 3.20 kip

h_i = 8.656 ft

at $y = H_L$, p_{iy} = 0.062 ksf

at base $y = 0$, p_{iy} = 0.107 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 0.70 kip

h_c = 16.159 ft

at $y = H_L$, p_{cy} = 0.057 ksf

at base $y = 0$, p_{cy} = -0.020 ksf

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vertical acceleration:

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

$\ddot{u}$ = 0.2444
at y = H_L, p_{vy} = 0.000 ksf
at base y = 0, p_{vy} = 0.290 ksf

wall inertia:

$p_{wy} = \dfrac{S_{ai}\ \ I\ \ \varepsilon\,\gamma_c\ (t_w/12)}{R_{wi}} =$

p_{wy} = 0.2924 * γ_c * $(t_w/12)$
at y = H_w, p_{wy} = 0.044 ksf
at base y = 0, p_{wy} = 0.044 ksf

hydrostatic:

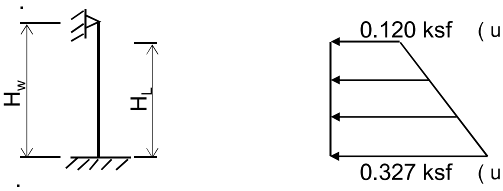
$q_{hy} = \gamma_L\,(H_L - y) =$

at y = H_L, q_{hy} = 0.000 ksf
at base y = 0, q_{hy} = 1.186 ksf

combine the effects of the dynamic pressures on the wall:

$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$

at y = H_w, p_y = 0.120 ksf
at base y = 0, p_y = 0.327 ksf



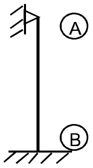
0.120 ksf (unfactored = 0.12 / 1.4 = 0.086 ksf)

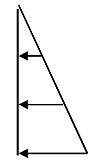
0.327 ksf (unfactored = 0.327 / 1.4 = 0.234 ksf)

resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

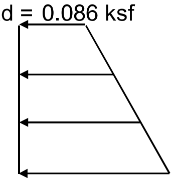
wall height, H_w = 20.67 ft
liquid height, H_L = 19 ft





1.186 ksf
hydrostatic

unfactored load = 0.086 ksf



unfactored load = 0.234 ksf
resultant dynamic pressures

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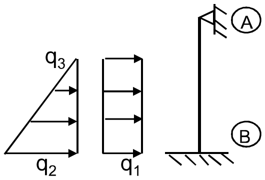
DESIGN TASK:					Wall 2 Pressures		

10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 20.67 ft

soil height above top of base = 0 ft

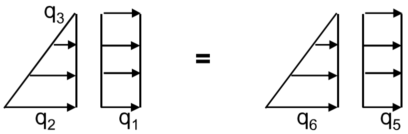
groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:



LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.0000 ksf

unfactored soil, q3 = 0.0000 ksf

0.000

equivalent soil loadings:

unfactored q5 = 0.1000 ksf

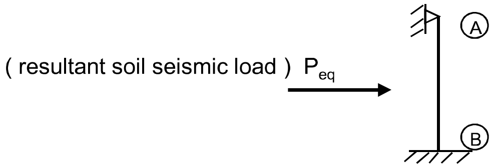
unfactored q6 = 0.0000 ksf

soil seismic:

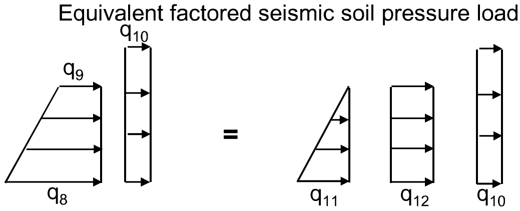
resultant factored soil seismic load per foot of wall width, $P_{u\ (eq)}$ = **0** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **0** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0000 ksf

equivalent soil seismic, q9 = 0.0000 ksf

wall seismic (see wall page 5), q10 = 0.0439 ksf

equivalent soil seismic, q11 = q8 - q9 = 0.0000 ksf

equivalent soil seismic, q12 = q9 = 0.0000 ksf

unfactored equivalent soil seismic, q8 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q9 =0 / 1.4 = 0.0000 ksf

unfactored wall seismic , q10 = 0.0439 / 1.4 = 0.0313 ksf

unfactored equivalent soil seismic, q11 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q12 =0 / 1.4 = 0.0000 ksf

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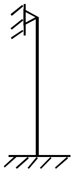
DESIGN TASK: Wall 2 Pressures

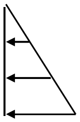
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



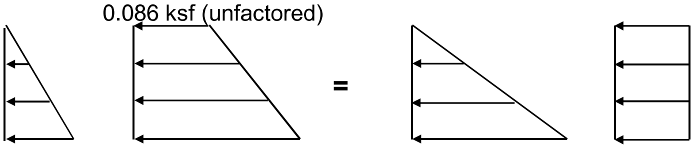
Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

wall height = 20.67 ft
water depth = 19 ft



b). load case 2: hydrostatic + dynamic:

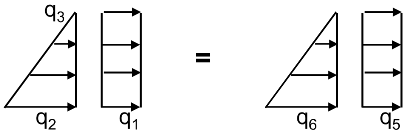


wall height = 20.67 ft
water depth = 19 ft

c). load case 3: static soil + LL surcharge:

wall height = 20.67 ft
soil height on wall = 0 ft

equivalent static soil & surcharge loadings...

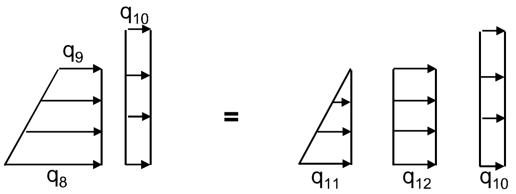


LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.000 ksf
unfactored soil, q3 = 0.000 ksf
0.000

equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.000 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.67 ft
soil height on wall = 0 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.000 ksf
unfactored equivalent soil seismic, q10 = 0.031 ksf
unfactored equivalent soil seismic, q11 = 0.000 ksf
unfactored equivalent soil seismic, q12 = 0.000 ksf

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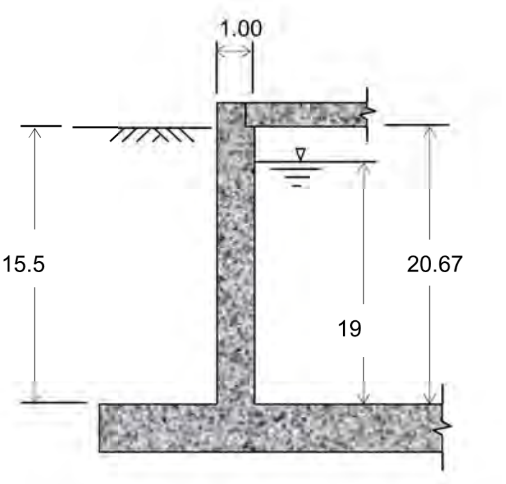
BY: C.Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 4 Pressures

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**
tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **5** ft
tank wall thickness, t_w = **12** inch
wall height to underside of roof, H_w = **20.67** ft

liquid height, H_L = **19** ft
liquid specific gravity = **1**
liquid density, γ_L = (sp.gr.)*γ_w = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION
(wall fixity = pinned at roof & fixed at floor)

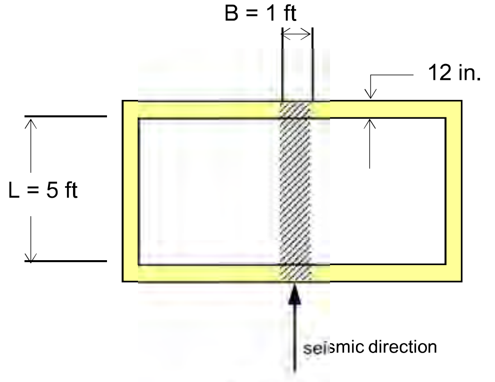
Soil Data

The site has no groundwater.

soil height above top of foundation base = **15.5** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf
0
concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:
Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.5**
Response modification factor, R_{wc} = **1**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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DESIGN TASK:					Wall 4 Pressures		

Weights:

unit 1-ft width wall mass, W_w = (12/12) * (20.67) * 0.15 = 3.10 kip

wall c.g. relative to base, h_w = 20.67 / 2 = 10.335 ft

unit width liquid mass, W_L = (5) * (1) * (19) * 32.17 = 5.93 kip

Seismic:

1). structure stiffness and dynamic property:

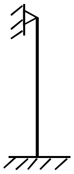
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.09638 k-sec^2/ft^2

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.09058 k-sec^2/ft^2

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 9.703 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 571.75 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} =$$ (571.75 / (0.0964 + 0.0906))ˆ½ = 55.3006 rad/sec

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 55.3006 = 0.1136 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} =$$ (3.16*32.2*tanh(3.16*(3.8)))ˆ½ = 10.0825

$$\omega_c = \frac{\lambda}{\sqrt{L}} =$$ 10.0825 / (5)ˆ½ = 4.5090 rad/sec,

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 4.509 = 1.3935 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.706 g

effective mass coeff., $\varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021$, but $\leq$ 1.0 = 0.9718

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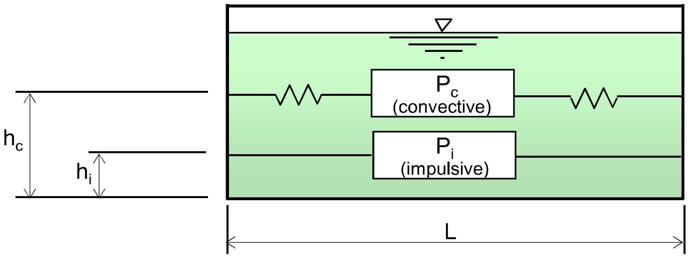
DESIGN TASK:					Wall 4 Pressures		



Dynamic Model

$L =$	5	ft
$B =$	1	ft
$H_L =$	19	ft
$W_L =$	5.93	kip
$L / H_L =$	0.26316	
$H_L / L =$	3.80000	

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L \left(\frac{\tanh\left(0.866 \frac{L}{H_L}\right)}{0.866 \frac{L}{H_L}} \right) =$$ 5.93*(tanh(0.866*(0.2632)) / 0.866*(0.2632)) = 5.83 kip

hi (EBP) = HL * (0.5-0.09375*(L/HL)) = 19*(0.5-0.09375*(0.2632)) = 9.031 ft

hi (IBP) = HL * 0.45 = 8.55 ft

impulsive force, $P_i = \left(\frac{S_{ai} \;\; I}{R_{wi}} \right) W_i =$ (0.611 * 1.25 / 2.5)*5.83 = 1.8 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L \left(0.264 \left(\frac{L}{H_L} \right) \tanh\left(3.16 \left(\frac{H_L}{L} \right) \right) \right) =$$ 5.93*(0.264*(0.2632)*tanh(3.16*(3.8))) = 0.41 kip

$$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 17.418 \text{ ft}$$

$$h_{c\ (IBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 17.418 \text{ ft}$$

convective force, $P_c = \left(\frac{S_{ac} \; I}{R_{wc}} \right) W_c =$ (0.7062 * 1.25 / 1)*0.41 = 0.4 kip

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5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 3.10 kip

wall c.g. relative to base, h_w = 10.335 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w =$ (0.611*1.25*0.9718/2.5)*3.1 = 0.92 kip

6). maximum wave slosh height displacement:

$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) =$ (5 / 2) * (0.7062 / 1.4 * 1.25) = 1.58 ft

7). vertical acceleration:

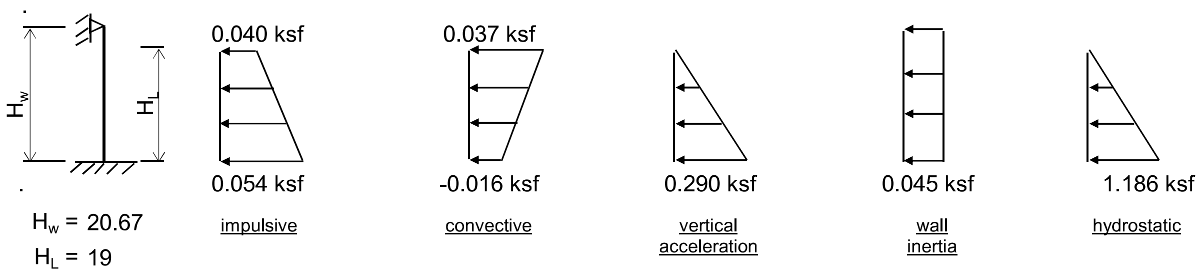
design horizontal accereration, S_{DS} = 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4{*}S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 0.2444*1*1/1 = 0.2444 g

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 1.80 kip

h_i = 9.031 ft

at y = H_L, p_{iy} = 0.040 ksf

at base y = 0, p_{iy} = 0.054 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 0.40 kip

h_c = 17.418 ft

at y = H_L, p_{cy} = 0.037 ksf

at base y = 0, p_{cy} = -0.016 ksf

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vertical acceleration:

$$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$$

$\ddot{u} =$ 0.2444

at $y = H_L$, $p_{vy} =$ 0.000 ksf

at base $y = 0$, $p_{vy} =$ 0.290 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ \ I\ \ \varepsilon\,\gamma_c\ (t_w/12)}{R_{wi}} =$$

$p_{wy} =$ 0.2969 $* \gamma_c * (t_w/12)$

at $y = H_w$, $p_{wy} =$ 0.045 ksf

at base $y = 0$, $p_{wy} =$ 0.045 ksf

hydrostatic:

$$q_{hy} = \gamma_L\,(H_L - y) =$$

at $y = H_L$, $q_{hy} =$ 0.000 ksf

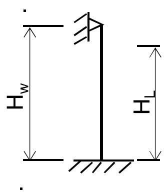
at base $y = 0$, $q_{hy} =$ 1.186 ksf

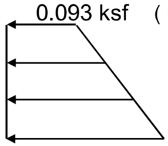
combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at $y = H_w$, $p_y =$ 0.093 ksf

at base $y = 0$, $p_y =$ 0.307 ksf





0.093 ksf (unfactored = 0.093 / 1.4 = 0.066 ksf)

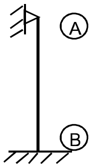
0.307 ksf (unfactored = 0.307 / 1.4 = 0.219 ksf)

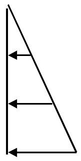
resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

wall height, $H_w =$ 20.67 ft

liquid height, $H_L =$ 19 ft

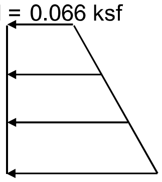




1.186 ksf

hydrostatic

unfactored load = 0.066 ksf



unfactored load = 0.219 ksf

resultant dynamic pressures

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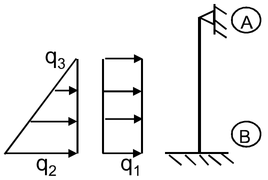
10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 20.67 ft

soil height above top of base = 15.5 ft

groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

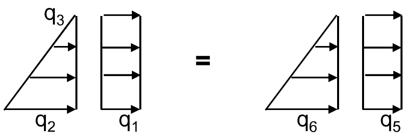
live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:

LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.8525 ksf

unfactored soil, q3 = 0.0000 ksf



equivalent soil loadings:

unfactored q5 = 0.1000 ksf

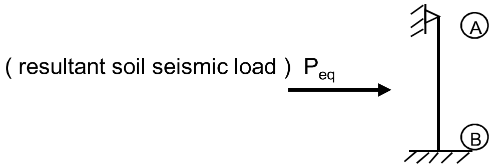
unfactored q6 = 0.8525 ksf

soil seismic:

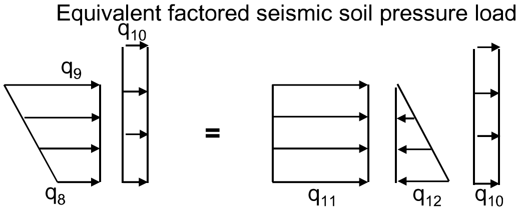
resultant factored soil seismic load per foot of wall width, $P_{u\,(eq)}$ = **4.08** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **10.33** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0003 ksf

equivalent soil seismic, q9 = 0.5261 ksf

wall seismic (see wall page 5), q10 = 0.0445 ksf

equivalent soil seismic, q11 = q9 = 0.5261 ksf

equivalent soil seismic, q12 = q8 - q9 = -0.5258 ksf

unfactored equivalent soil seismic, q8 =0.0003 / 1.4 = 0.0002 ksf

unfactored equivalent soil seismic, q9 =0.5261 / 1.4 = 0.3758 ksf

unfactored wall seismic , q10 = 0.0445 / 1.4 = 0.0318 ksf

unfactored equivalent soil seismic, q11 =0.5261 / 1.4 = 0.3758 ksf

unfactored equivalent soil seismic, q12 =-0.5258 / 1.4 = -0.3756 ksf

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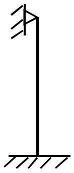
DESIGN TASK:					Wall 4 Pressures		

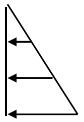
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

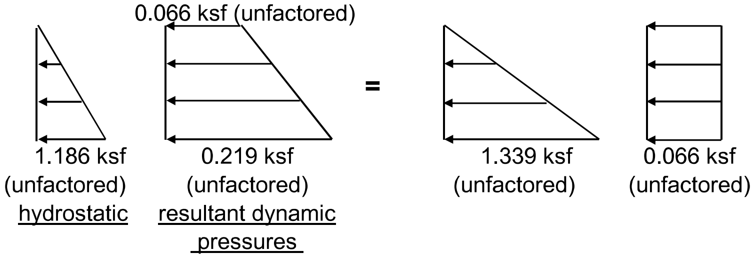
a). load case 1: hydrostatic water

wall height = 20.67 ft
water depth = 19 ft



b). load case 2: hydrostatic + dynamic:

wall height = 20.67 ft
water depth = 19 ft

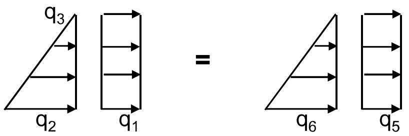


c). load case 3: static soil + LL surcharge:

wall height = 20.67 ft
soil height on wall = 15.5 ft

equivalent static soil & surcharge loadings...

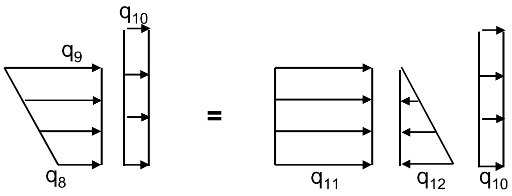
LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.853 ksf
unfactored soil, q3 = 0.000 ksf



equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.853 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.67 ft
soil height on wall = 15.5 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.376 ksf
unfactored equivalent soil seismic, q10 = 0.032 ksf
unfactored equivalent soil seismic, q11 = 0.376 ksf
unfactored equivalent soil seismic, q12 = -0.376 ksf

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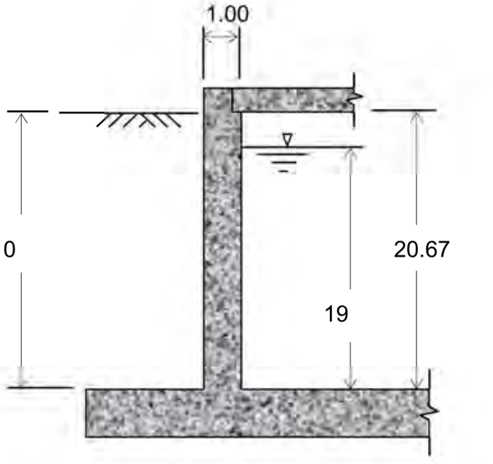
DESIGN TASK:					Wall 5 Pressures		

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**
tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **36** ft
tank wall thickness, t_w = **12** inch
wall height to underside of roof, H_w = **20.67** ft

liquid height, H_L = **19** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION
(wall fixity = pinned at roof & fixed at floor)

Soil Data

The site has no groundwater.

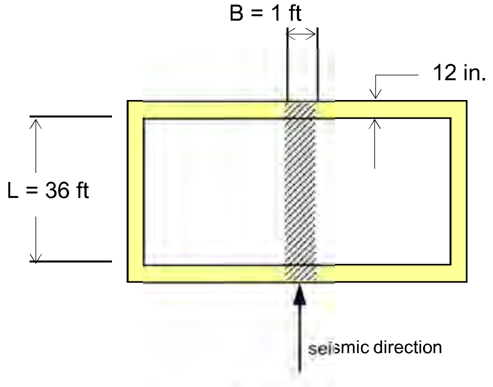
soil height above top of foundation base = **0** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf
0

concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.37**
Response modification factor, R_{wc} = **1.07**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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DESIGN TASK:					Wall 5 Pressures		

Weights:

unit 1-ft width wall mass, W_w =	(12/12) * (20.67) * 0.15 =	3.10	kip
wall c.g. relative to base, h_w =	20.67 / 2 =	10.335	ft
unit width liquid mass, W_L =	(36) * (1) * (19) * 32.17 =	42.68	kip

Seismic:

1). structure stiffness and dynamic property:

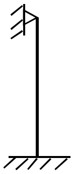
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.09638 k-sec^2/ft^2

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.37505 k-sec^2/ft^2

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 7.781 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 782.11 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (782.11 / (0.0964 + 0.3751))\hat{}½ = 40.7310 \text{ rad/sec}$$

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 40.731 = 0.1543 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = \quad (3.16*32.2*\tanh(3.16*(0.5278))\ )\hat{}½ = 9.7298$$

$$\omega_c = \frac{\lambda}{\sqrt{L}} = \quad 9.7298 / (36)\hat{}½ = 1.6216 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 1.6216 = 3.8746 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.254 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021 \text{ , but } \le 1.0 = 0.7137$$

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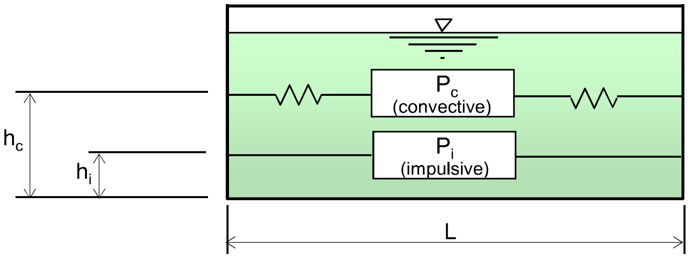
DESIGN TASK: Wall 5 Pressures



Dynamic Model

$L =$ 36 ft
$B =$ 1 ft
$H_L =$ 19 ft
$W_L =$ 42.68 kip

$L / H_L =$ 1.89474
$H_L / L =$ 0.52778

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) =$$ 42.68*(tanh(0.866*(1.8947)) / 0.866*(1.8947)) = 24.13 kip

hi (EBP) = HL * 0.375 = 19 * 0.375 = 7.125 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 14.43 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_{wi}}\right)W_i =$$ (0.611 * 1.25 / 2.37)*24.13 = 7.8 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) =$$ 42.68*(0.264*(1.8947)*tanh(3.16*(0.5278))) = 19.88 kip

$$h_{c\ (EBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 11.224 ft

$$h_{c\ (IBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 15.726 ft

$$\text{convective force, } P_c = \left(\frac{S_{ac}\ I}{R_{wc}}\right)W_c =$$ (0.254 * 1.25 / 1.07)*19.88 = 5.9 kip

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5). lateral inertia force of the accelerating wall:

unit width wall mass, $W_w =$ 3.10 kip

wall c.g. relative to base, $h_w =$ 10.335 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (\,0.611*1.25*0.7137/2.37\,)*3.1 = \quad 0.71 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (\,36 / 2) * (\,0.254 / 1.4 * 1.25\,) = \quad 4.08 \text{ ft}$$

Wave height is greater than the freeboard of 1.67-ft. Check possible effects on the roof.

7). vertical acceleration:

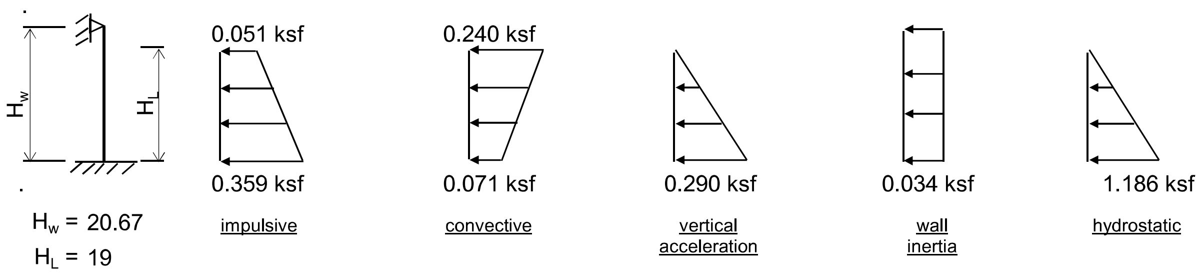
design horizontal accereration, $S_{DS} =$ 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4*S_{DS} =$ 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444*1*1/1 = \quad 0.2444 \text{ g}$$

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



$H_w =$ 20.67

$H_L =$ 19

impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

$P_i =$ 7.80 kip

$h_i =$ 7.125 ft

at $y = H_L$, $p_{iy} =$ 0.051 ksf

at base $y = 0$, $p_{iy} =$ 0.359 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

$P_c =$ 5.90 kip

$h_c =$ 11.224 ft

at $y = H_L$, $p_{cy} =$ 0.240 ksf

at base $y = 0$, $p_{cy} =$ 0.071 ksf

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vertical acceleration:

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

$\ddot{u} =$ 0.2444
at $y = H_L$, $p_{vy} =$ 0.000 ksf
at base $y = 0$, $p_{vy} =$ 0.290 ksf

wall inertia:

$p_{wy} = \dfrac{S_{ai}\ \ I\ \ \varepsilon\,\gamma_c\,(t_w/12)}{R_{wi}} =$

$p_{wy} =$ 0.2300 $* \gamma_c * (t_w/12)$
at $y = H_w$, $p_{wy} =$ 0.034 ksf
at base $y = 0$, $p_{wy} =$ 0.034 ksf

hydrostatic:

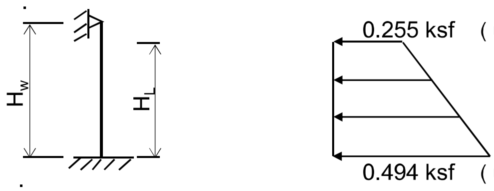
$q_{hy} = \gamma_L\,(H_L - y) =$

at $y = H_L$, $q_{hy} =$ 0.000 ksf
at base $y = 0$, $q_{hy} =$ 1.186 ksf

combine the effects of the dynamic pressures on the wall:

$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$

at $y = H_w$, $p_y =$ 0.255 ksf
at base $y = 0$, $p_y =$ 0.494 ksf



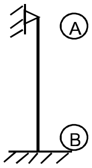
0.255 ksf (unfactored = 0.255 / 1.4 = 0.182 ksf)

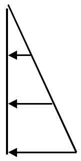
0.494 ksf (unfactored = 0.494 / 1.4 = 0.353 ksf)

resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

wall height, $H_w =$ 20.67 ft
liquid height, $H_L =$ 19 ft

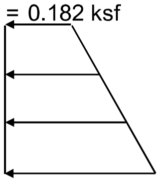




1.186 ksf

hydrostatic

unfactored load = 0.182 ksf



unfactored load = 0.353 ksf

resultant dynamic pressures

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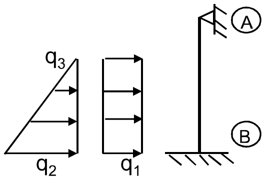
10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 20.67 ft

soil height above top of base = 0 ft

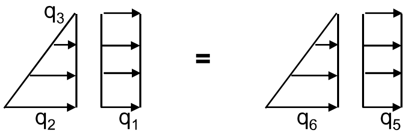
groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:



LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.0000 ksf

unfactored soil, q3 = 0.0000 ksf

0.000

equivalent soil loadings:

unfactored q5 = 0.1000 ksf

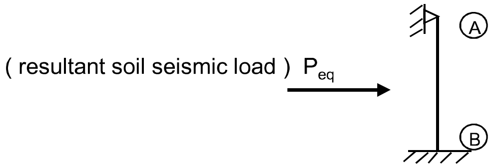
unfactored q6 = 0.0000 ksf

soil seismic:

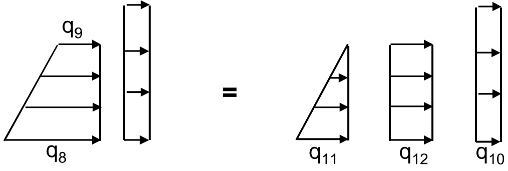
resultant factored soil seismic load per foot of wall width, $P_{u\ (eq)}$ = **0** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **0** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0000 ksf

equivalent soil seismic, q9 = 0.0000 ksf

wall seismic (see wall page 5), q10 = 0.0345 ksf

equivalent soil seismic, q11 = q8 - q9 = 0.0000 ksf

equivalent soil seismic, q12 = q9 = 0.0000 ksf

unfactored equivalent soil seismic, q8 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q9 =0 / 1.4 = 0.0000 ksf

unfactored wall seismic , q10 = 0.0345 / 1.4 = 0.0246 ksf

unfactored equivalent soil seismic, q11 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q12 =0 / 1.4 = 0.0000 ksf

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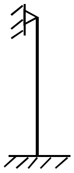
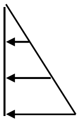
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

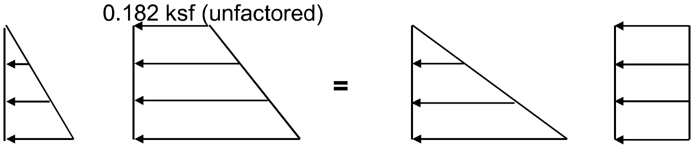
wall height = 20.67 ft
water depth = 19 ft



(unfactored) 1.186 ksf

b). load case 2: hydrostatic + dynamic:

0.182 ksf (unfactored)



1.186 ksf (unfactored) hydrostatic

0.353 ksf (unfactored) resultant dynamic pressures

1.357 ksf (unfactored)

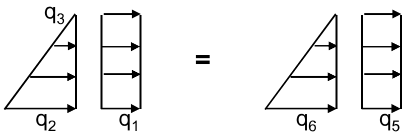
0.182 ksf (unfactored)

wall height = 20.67 ft
water depth = 19 ft

c). load case 3: static soil + LL surcharge:

wall height = 20.67 ft
soil height on wall = 0 ft

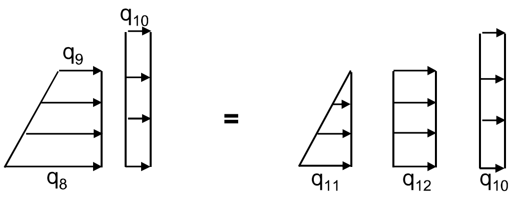
equivalent static soil & surcharge loadings...



LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.000 ksf
unfactored soil, q3 = 0.000 ksf
0.000
equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.000 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.67 ft
soil height on wall = 0 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.000 ksf
unfactored equivalent soil seismic, q10 = 0.025 ksf
unfactored equivalent soil seismic, q11 = 0.000 ksf
unfactored equivalent soil seismic, q12 = 0.000 ksf

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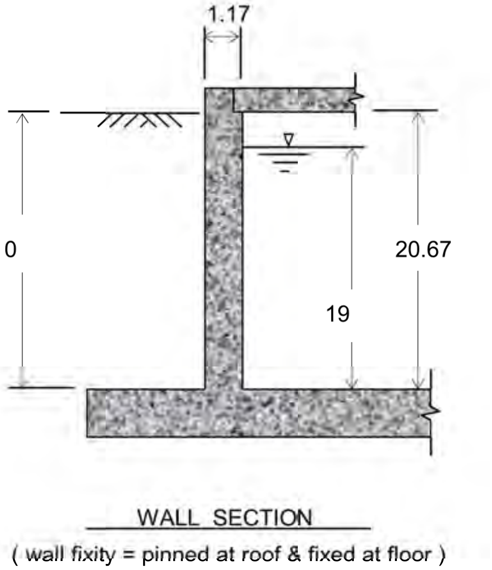
Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity =	**pinned at roof & fixed at floor**	
tank unit width perpendicular to EQ., B =	1	ft
tank inside length in direction of seismic, L =	**31**	ft
tank wall thickness, t_w =	**14**	inch
wall height to underside of roof, H_w =	**20.67**	ft
liquid height, H_L =	**19**	ft
liquid specific gravity =	**1**	
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ =	0.0624	k/ft^3
acceleration due to gravity, g =	32.17	ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ =	0.00194	$k\text{-}sec^2/ft^4$



WALL SECTION

(wall fixity = pinned at roof & fixed at floor)

Soil Data

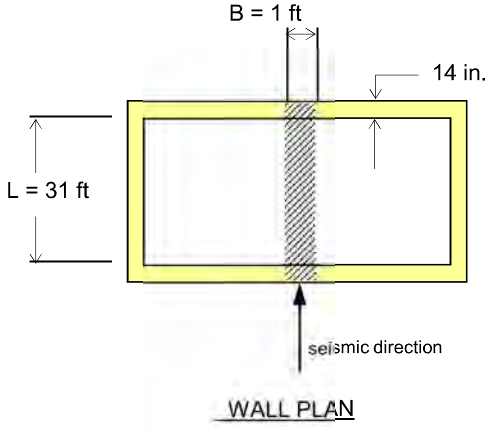
The site has no groundwater.

soil height above top of foundation base =	**0**	ft
groundwater ht. above foundation base =	**0**	ft
dry soil lateral pressure =	**0.055**	k/ft^3
saturated soil lateral pressure =	**0**	k/ft^3
dry soil unit weight =	**0.11**	k/ft^3
live load lateral surcharge =	**0.100**	ksf
	0	
concrete strength, f'_c =	**4**	ksi
concrete density, γ_c =	0.150	k/ft^3
concrete modulus of elasticity, E_c =	3605.0	ksi
concrete mass density, $\rho_c = \gamma_c / g$ =	0.004663	$k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} =	**0.611**	*g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} =	**0.656**	*g

Structure Risk Category =	**3**
Importance factor, I =	**1.25**
Response modification factor, R_{wi} =	**2.37**
Response modification factor, R_{wc} =	**1.08**



Load Cases:

case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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Weights:

unit 1-ft width wall mass, W_w = (14/12) * (20.67) * 0.15 = 3.62 kip

wall c.g. relative to base, h_w = 20.67 / 2 = 10.335 ft

unit width liquid mass, W_L = (31) * (1) * (19) * 32.17 = 36.75 kip

Seismic:

1). structure stiffness and dynamic property:

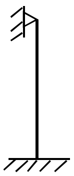
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.11244 k-sec^2/ft^2

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.35907 k-sec^2/ft^2

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 7.89 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 1213.37 k/ft/ft

$\omega_i = \sqrt{\dfrac{k}{m_w + m_i}} =$ (1213.37 / (0.1124 + 0.3591))ˆ½ = 50.7285 rad/sec

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 50.7285 = 0.1239 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\dfrac{H_L}{L}\right)\right)} =$ (3.16*32.2*tanh(3.16*(0.6129)))ˆ½ = 9.8751

$\omega_c = \dfrac{\lambda}{\sqrt{L}} =$ 9.8751 / (31)ˆ½ = 1.7736 rad/sec,

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 1.7736 = 3.5426 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.278 g

effective mass coeff., $\varepsilon = 0.0151\left(\dfrac{L}{H_L}\right)^2 - 0.1908\left(\dfrac{L}{H_L}\right) + 1.021$, but $\leq$ 1.0 = 0.7499

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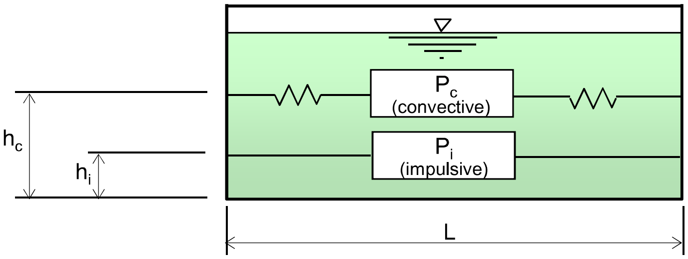

Dynamic Model

$L =$ 31 ft
$B =$ 1 ft
$H_L =$ 19 ft
$W_L =$ 36.75 kip

$L / H_L =$ 1.63158
$H_L / L =$ 0.61290

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) =$$ 36.75*(tanh(0.866*(1.6316)) / 0.866*(1.6316)) = 23.1 kip

hi (EBP) = HL * 0.375 = 19 * 0.375 = 7.125 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 12.739 ft

impulsive force, $P_i = \left(\frac{S_{ai}\ I}{R_{wi}}\right)W_i =$ (0.611 * 1.25 / 2.37)*23.1 = 7.4 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) =$$ 36.75*(0.264*(1.6316)*tanh(3.16*(0.6129))) = 15.18 kip

$$h_{c\ (EBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 11.662 ft

$$h_{c\ (IBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 14.58 ft

convective force, $P_c = \left(\frac{S_{ac}\ I}{R_{wc}}\right)W_c =$ (0.2778 * 1.25 / 1.08)*15.18 = 4.9 kip

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5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 3.62 kip
wall c.g. relative to base, h_w = 10.335 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (\,0.611*1.25*0.7499/2.37\,)*3.62 = \quad 0.87 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (\,31 / 2\,) * (\,0.2778 / 1.4 * 1.25\,) = \quad 3.84 \text{ ft}$$

Wave height is greater than the freeboard of 1.67-ft. Check possible effects on the roof.

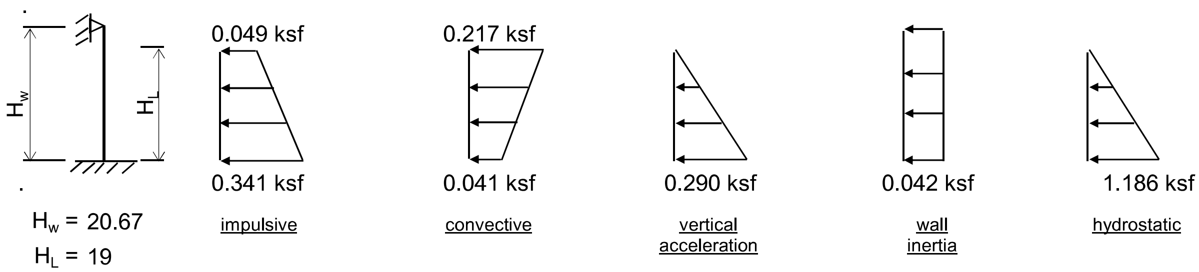
7). vertical acceleration:

design horizontal accereration, S_{DS} = 0.611 *g
vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4*S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444*1*1/1 = \quad 0.2444 \text{ g}$$

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 7.40 kip
h_i = 7.125 ft
at $y = H_L$, p_{iy} = 0.049 ksf
at base $y = 0$, p_{iy} = 0.341 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 4.90 kip
h_c = 11.662 ft
at $y = H_L$, p_{cy} = 0.217 ksf
at base $y = 0$, p_{cy} = 0.041 ksf

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vertical acceleration:

$p_{vy} = \ddot{u}\, \gamma_L\ (H_L - y) =$

$\ddot{u} =$ 0.2444

at $y = H_L$, p_{vy} = 0.000 ksf

at base $y = 0$, p_{vy} = 0.290 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ \ I\ \ \varepsilon\, \gamma_c\ (t_w/12)}{R_{wi}} =$$

p_{wy} = 0.2417 * γ_c * $(t_w/12)$

at $y = H_w$, p_{wy} = 0.042 ksf

at base $y = 0$, p_{wy} = 0.042 ksf

hydrostatic:

$q_{hy} = \gamma_L\ (H_L - y) =$

at $y = H_L$, q_{hy} = 0.000 ksf

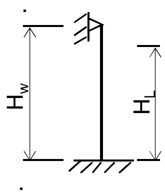
at base $y = 0$, q_{hy} = 1.186 ksf

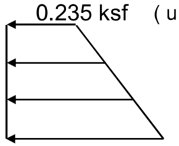
combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{\left(p_{iy} + p_{wy}\right)^2 + p_{cy}^2 + p_{vy}^2} =$$

at $y = H_w$, p_y = 0.235 ksf

at base $y = 0$, p_y = 0.482 ksf





(unfactored = 0.235 / 1.4 = 0.168 ksf)

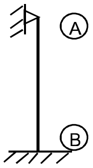
(unfactored = 0.482 / 1.4 = 0.344 ksf)

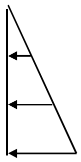
resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

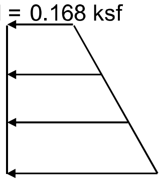
wall height, H_w = 20.67 ft

liquid height, H_L = 19 ft





hydrostatic

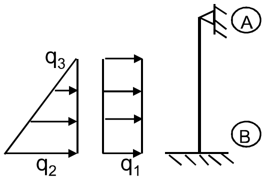


resultant dynamic pressures

BY:	C.Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 6 Pressures		

10). wall design pressures for external soil loading:

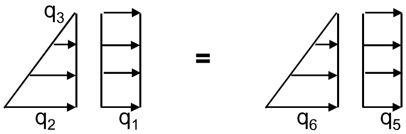
static soil:



The site has no groundwater.

wall height =	20.67	ft
soil height above top of base =	0	ft
groundwater ht. above base =	0	ft
dry soil lateral pressure =	0.055	k/ft^3
sat. soil lateral pressure =	0.000	k/ft^3
live load lateral surcharge =	0.100	ksf

equivalent static soil loadings:



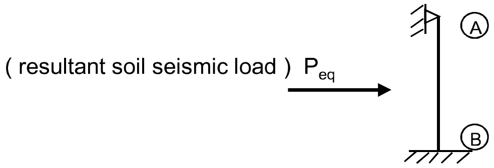
LL lateral surcharge, q1 =	0.1000	ksf
unfactored soil, q2 =	0.0000	ksf
unfactored soil, q3 =	0.0000	ksf
	0.000	
equivalent soil loadings:		
unfactored q5 =	0.1000	ksf
unfactored q6 =	0.0000	ksf

soil seismic:

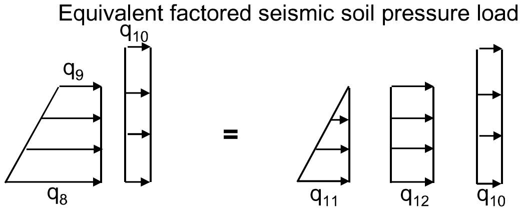
resultant factored soil seismic load per foot of wall width, $P_{u\,(eq)}$ = **0** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **0** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…

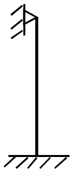


equivalent soil seismic, q8 =	0.0000	ksf
equivalent soil seismic, q9 =	0.0000	ksf
wall seismic (see wall page 5), q10 =	0.0423	ksf
equivalent soil seismic, q11 = q8 - q9 =	0.0000	ksf
equivalent soil seismic, q12 = q9 =	0.0000	ksf

unfactored equivalent soil seismic, q8 =0 / 1.4 =	0.0000	ksf
unfactored equivalent soil seismic, q9 =0 / 1.4 =	0.0000	ksf
unfactored wall seismic , q10 = 0.0423 / 1.4 =	0.0302	ksf
unfactored equivalent soil seismic, q11 =0 / 1.4 =	0.0000	ksf
unfactored equivalent soil seismic, q12 =0 / 1.4 =	0.0000	ksf

BY:	C.Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:	Wall 6 Pressures				

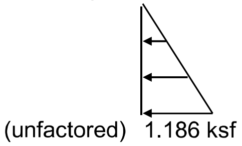
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



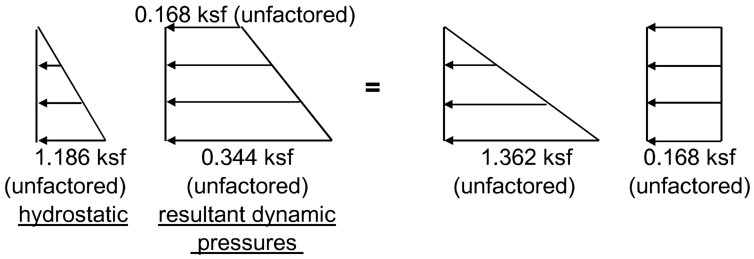
Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

wall height = 20.67 ft
water depth = 19 ft



b). load case 2: hydrostatic + dynamic:

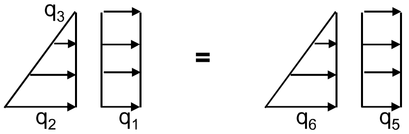


wall height = 20.67 ft
water depth = 19 ft

c). load case 3: static soil + LL surcharge:

wall height = 20.67 ft
soil height on wall = 0 ft

equivalent static soil & surcharge loadings...

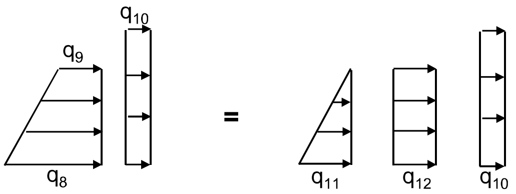


LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.000 ksf
unfactored soil, q3 = 0.000 ksf
0.000

equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.000 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.67 ft
soil height on wall = 0 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.000 ksf
unfactored equivalent soil seismic, q10 = 0.030 ksf
unfactored equivalent soil seismic, q11 = 0.000 ksf
unfactored equivalent soil seismic, q12 = 0.000 ksf

Area 4 - Actiflo™
Wall 1 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	11.90	19.16	47.00	***0.41***	62	126	***0.49***	***<- OK***
1.2F+1.4E	1.00	14.50	14.50	47.00	***0.31***	77	126	***0.61***	***<- OK***
1.6(H+L)	1.41	9.80	13.82	47.00	***0.29***	50	126	***0.40***	***<- OK***
1.6H+1.4E	1.00	13.20	13.20	47.00	***0.28***	70	126	***0.55***	***<- OK***

Vertical Span (Mid-Height)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	7.00	11.27	20.50	***0.55***	0	126	***0.00***	***<- OK***
1.2F+1.4E	1.00	8.40	8.40	20.50	***0.41***	0	126	***0.00***	***<- OK***
1.6(H+L)	1.41	5.96	8.40	20.50	***0.41***	0	126	***0.00***	***<- OK***
1.6H+1.4E	1.00	7.50	7.50	20.50	***0.37***	0	126	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	17.40	28.01	51.00	***0.55***	62	126	***0.49***	***<- OK***
1.2F+1.4E	1.00	20.70	20.70	51.00	***0.41***	76	126	***0.60***	***<- OK***
1.6(H+L)	1.41	14.10	19.88	51.00	***0.39***	52	126	***0.41***	***<- OK***
1.6H+1.4E	1.00	17.80	17.80	51.00	***0.35***	69	126	***0.54***	***<- OK***

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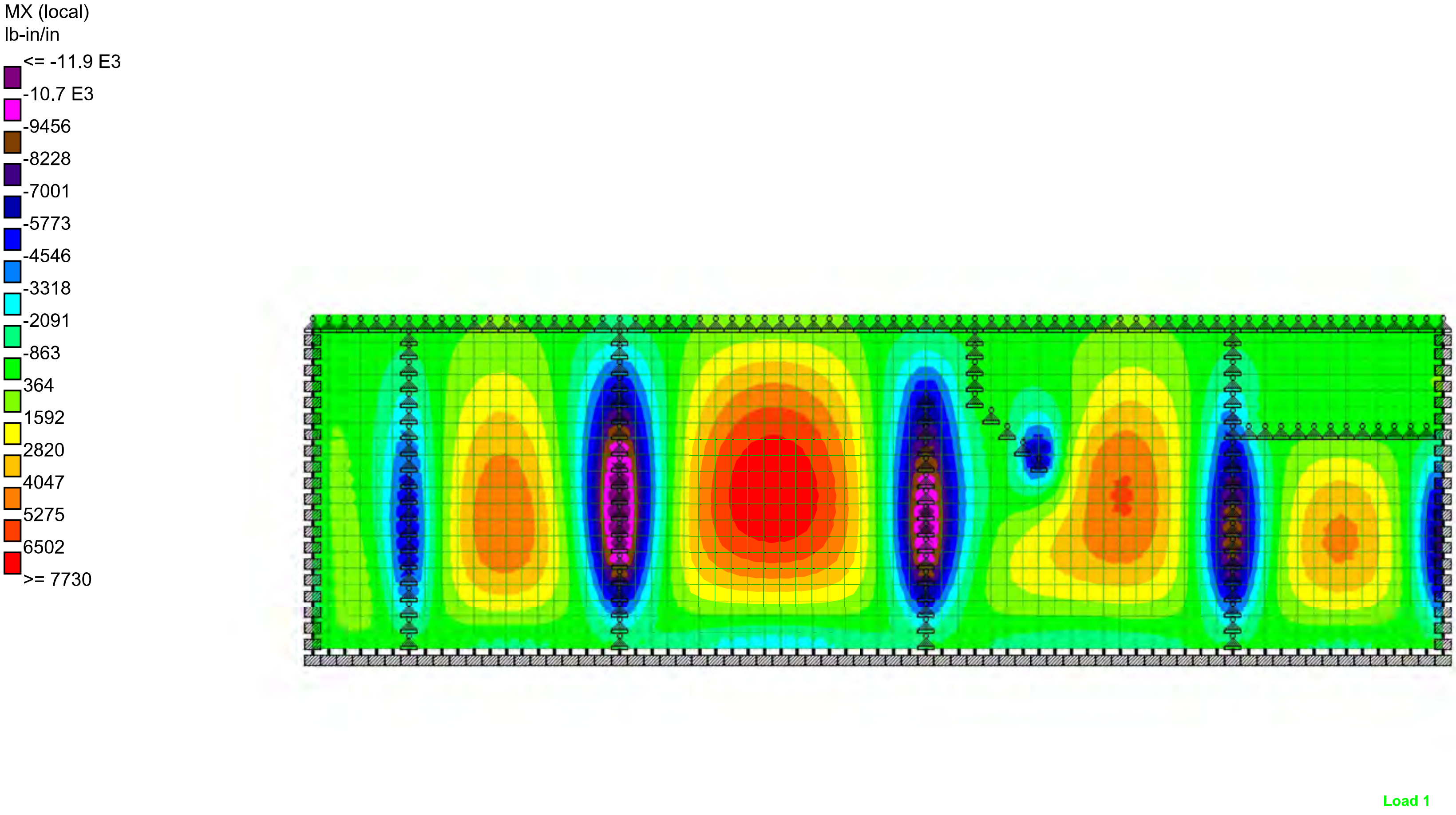
	Part Wall 1		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4H	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Aug-2017 14:52	



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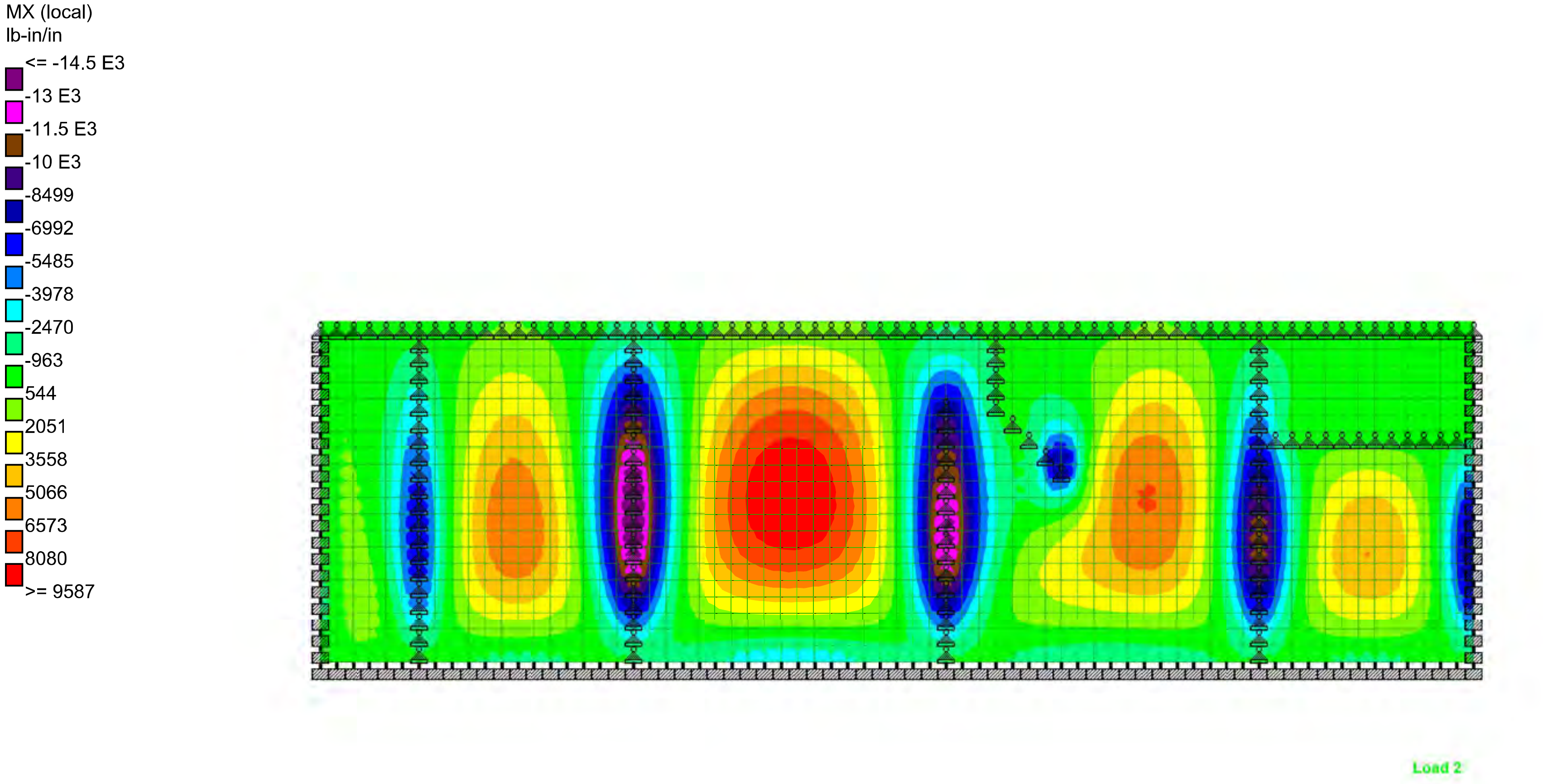
	Part Wall 1		
Job Title Area 4 - ActiFlo Load Case: 1.2F+1.4E	Ref		
	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Sep-2017 08:15	



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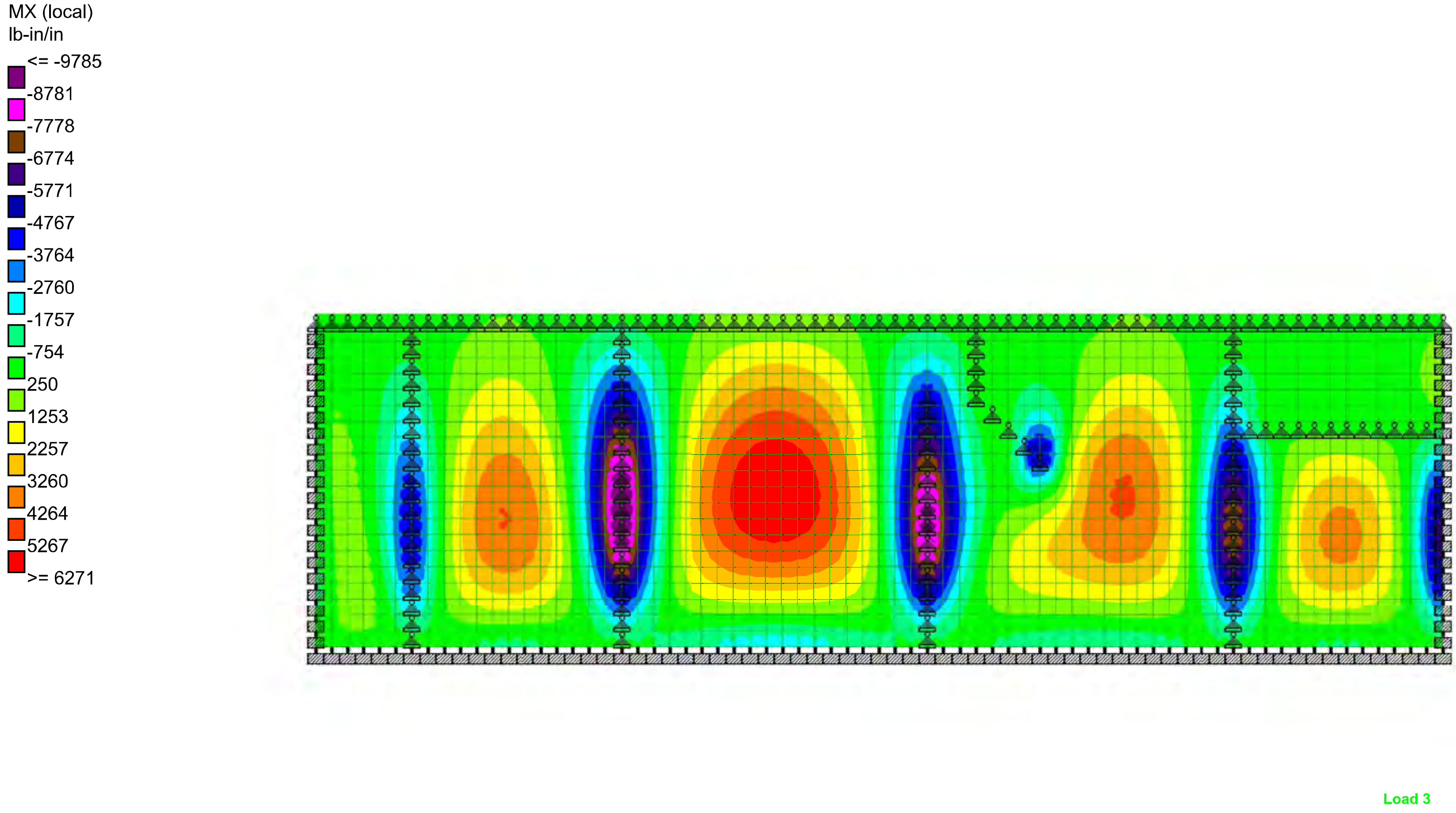
Job Title	Area 4 - ActiFlo Load Case: 1.6(H+L)	Part	Wall 1		
		Ref			
		By	CC	Date 04-Aug-17	Chd
Client	Willamette River WTP	File	Wall 1.std	Date/Time	09-Aug-2017 14:52



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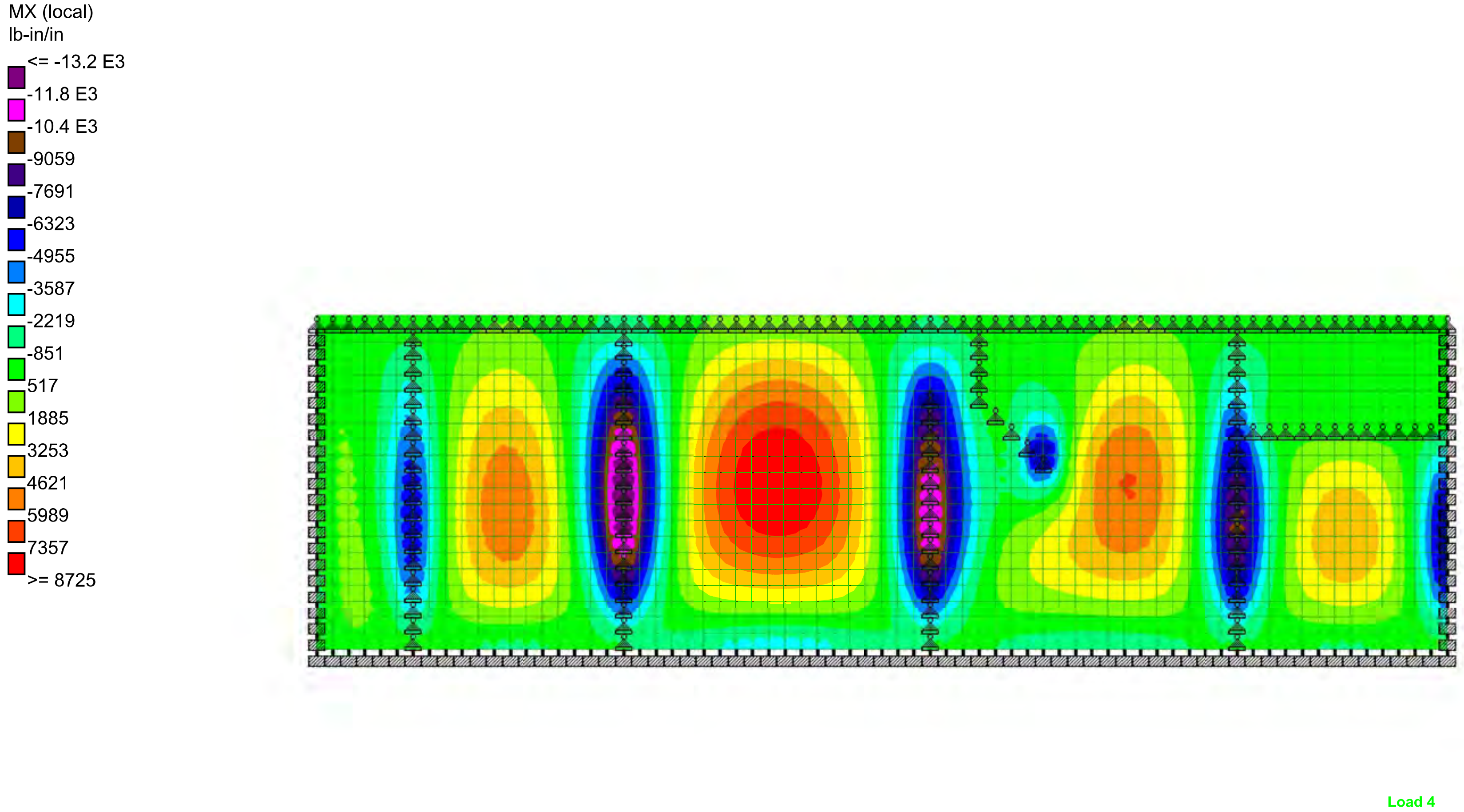
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.6H+1.4E	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Aug-2017 14:52	



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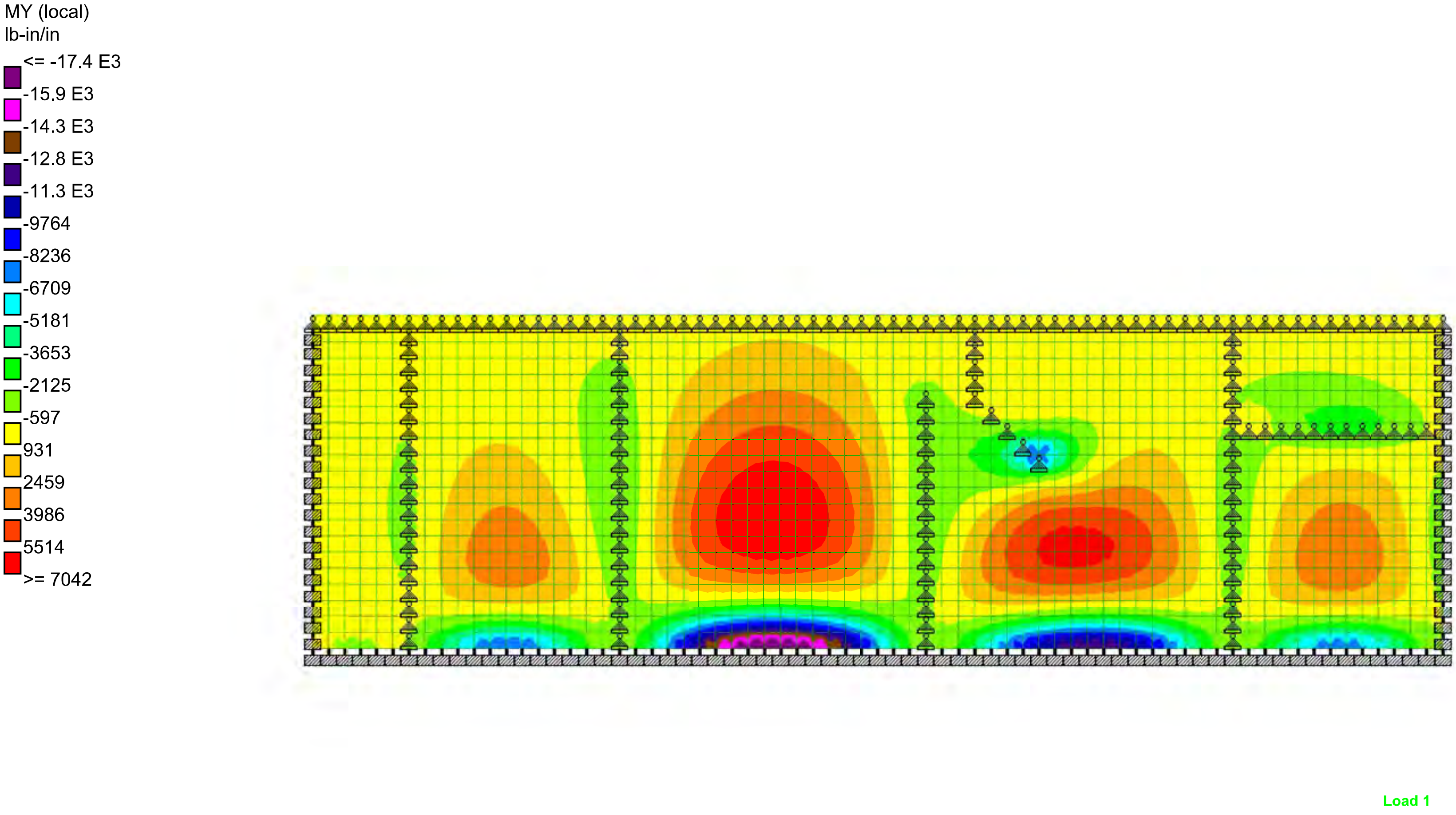
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4H	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Aug-2017 14:52	



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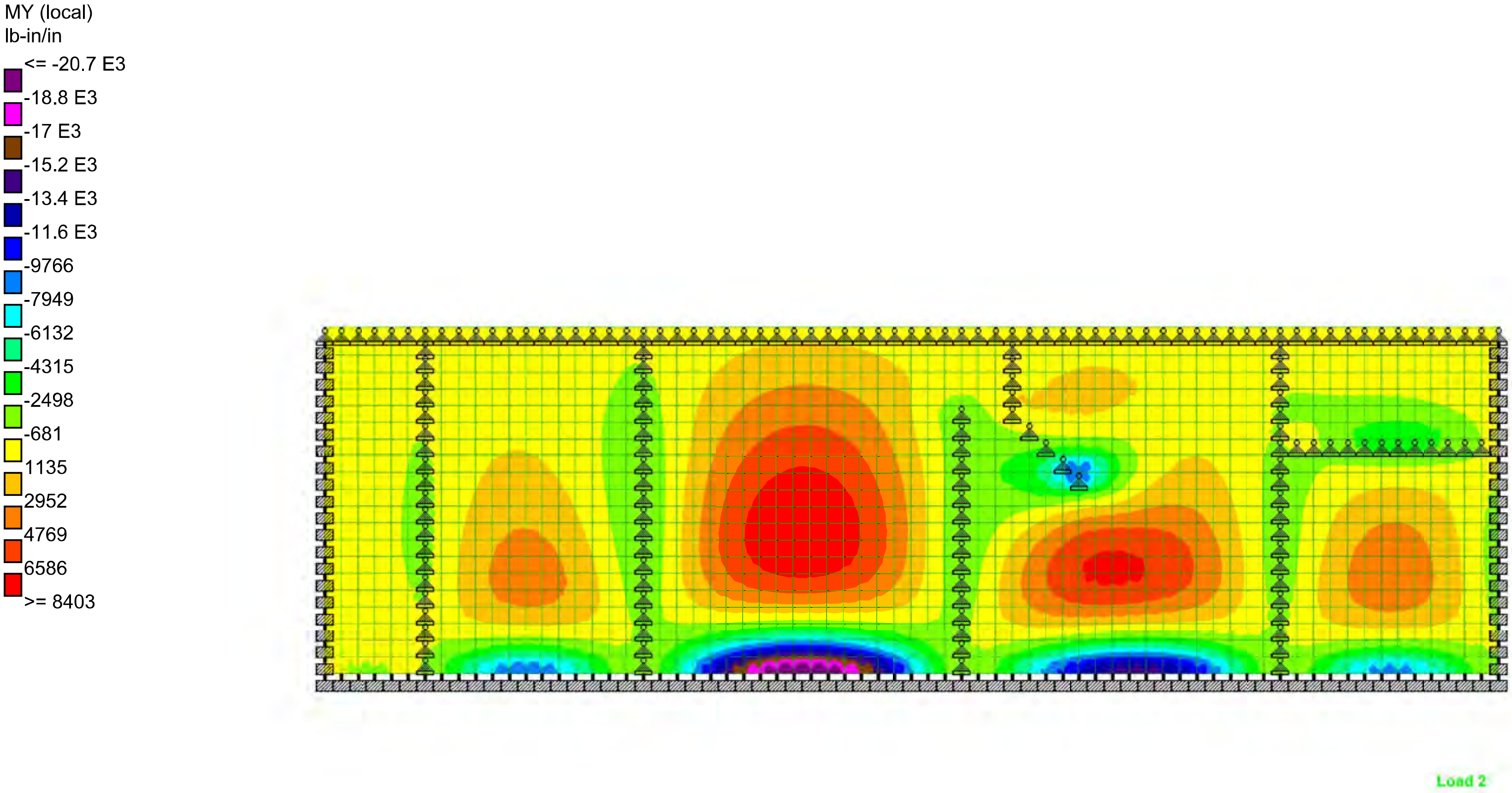
	Part Wall 1		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.2F+1.4E	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Sep-2017 08:15	



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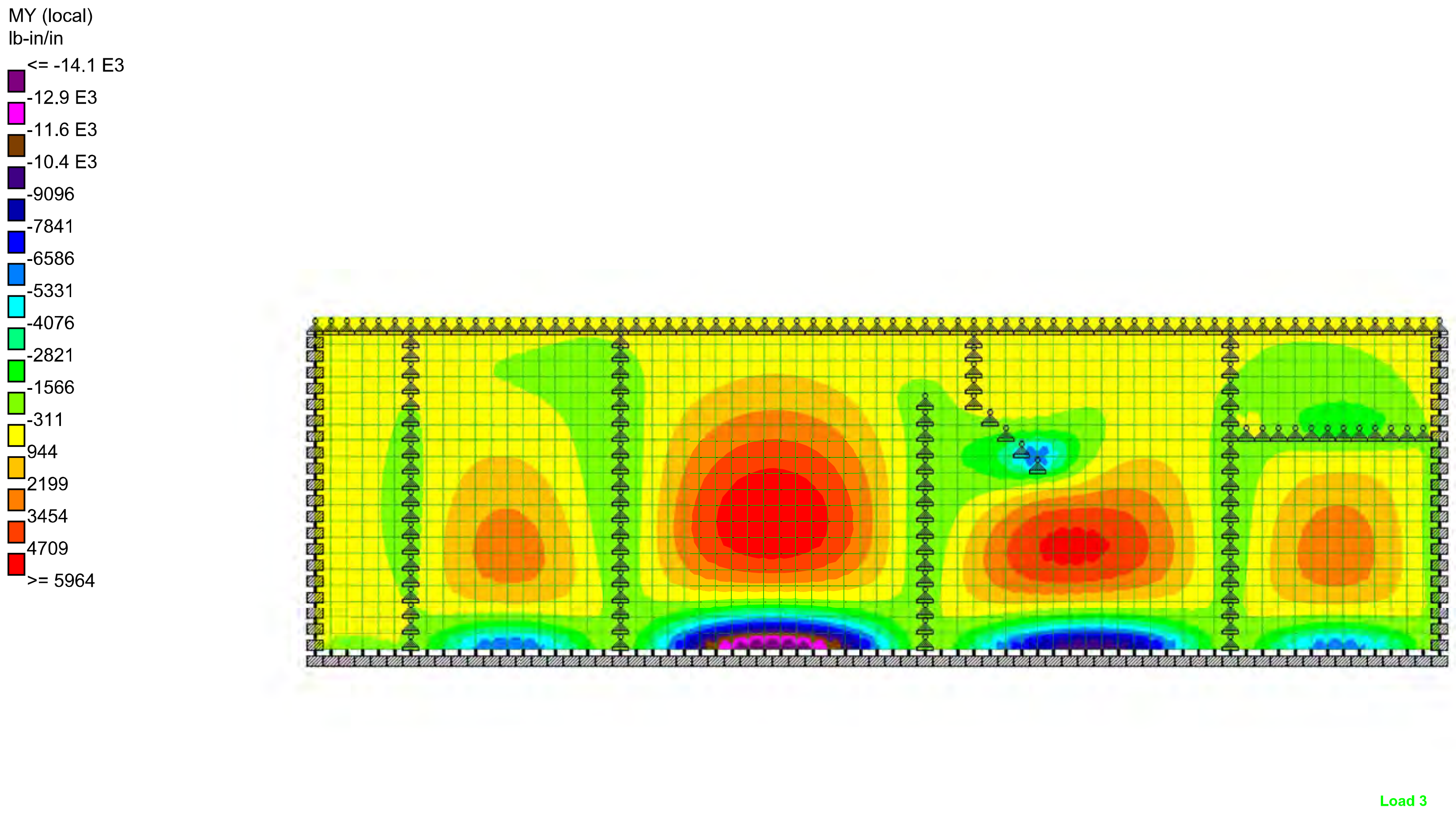
	Ref		
Load Case: 1.6(H+L)	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Aug-2017 14:52	



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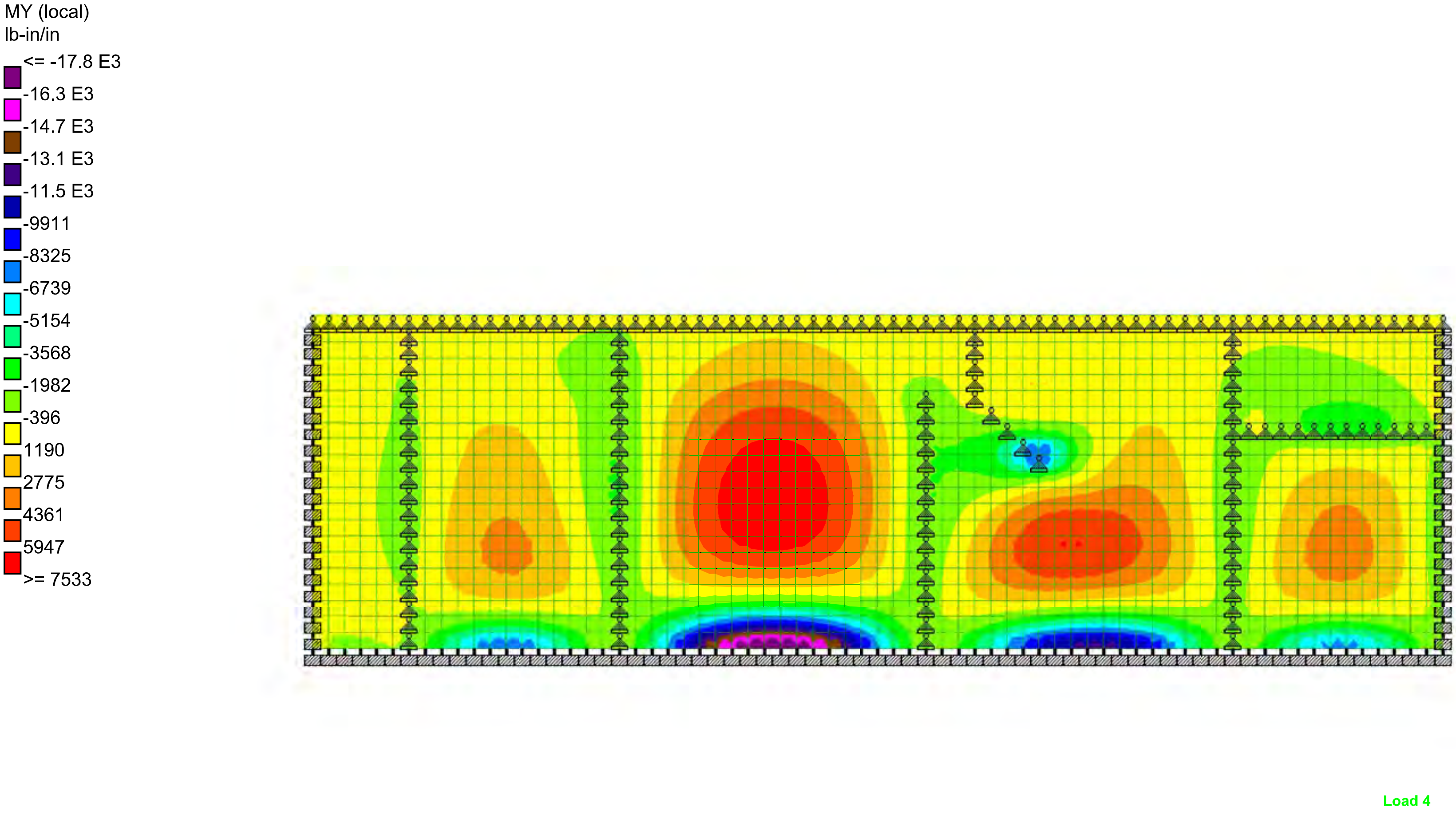
Load Case: 1.6H+1.4E	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Aug-2017 14:52	



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Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4H	By CC	Date 04-Aug-17	Chd
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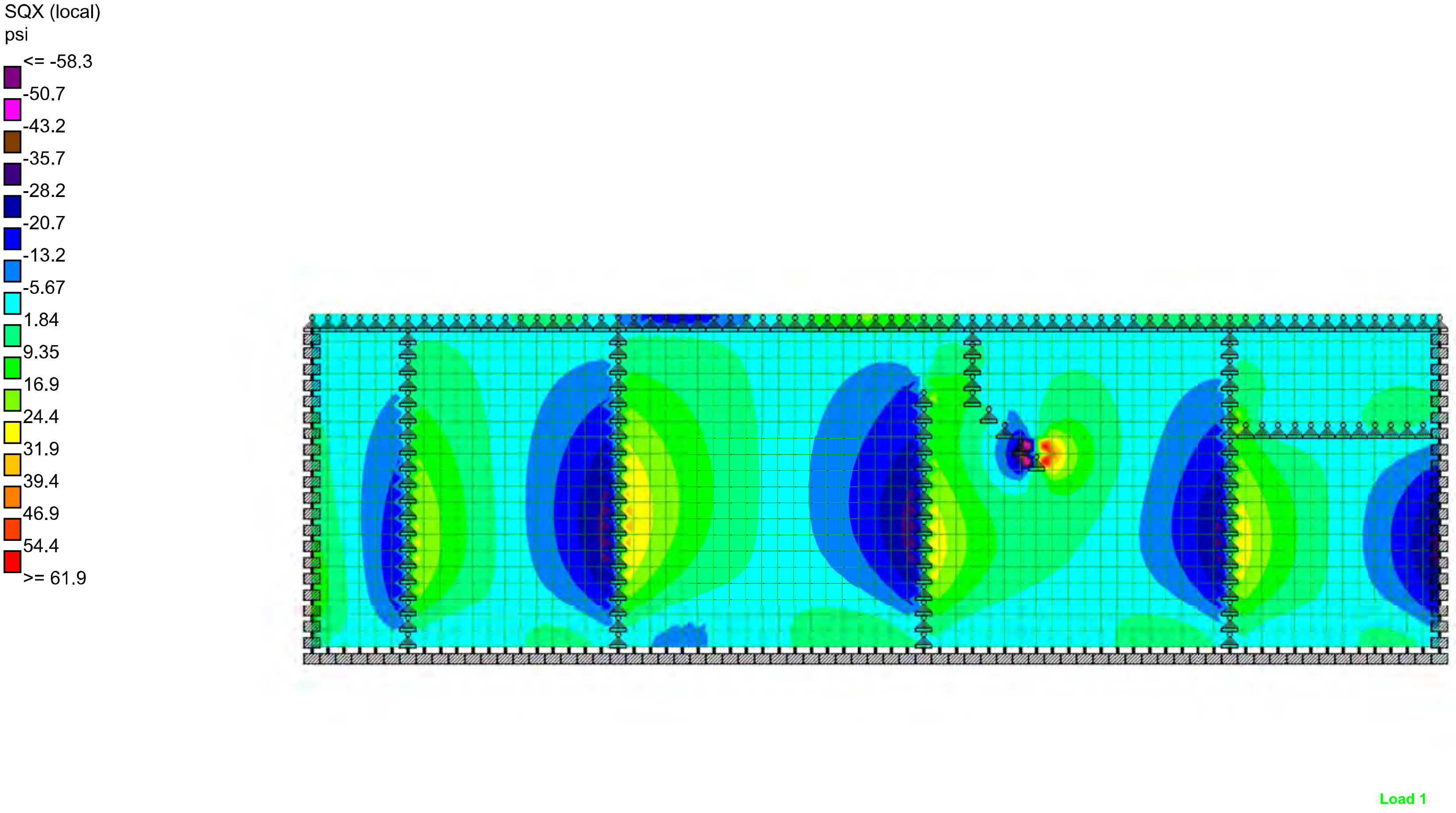

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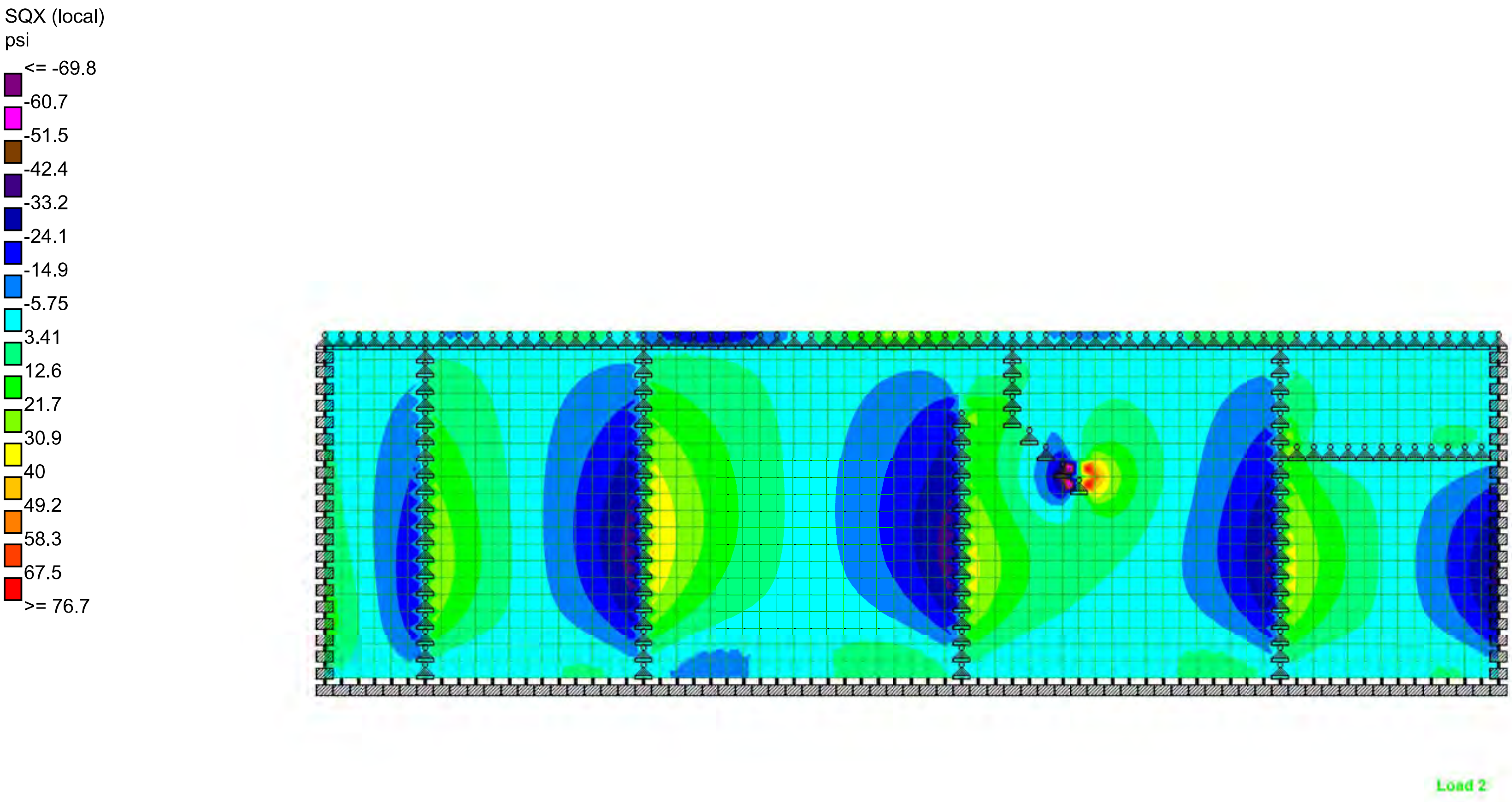
Job Title Area 4 - ActiFlo Load Case: 1.2F+1.4E	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
	Ref		
	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Sep-2017 08:15	



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Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.6(H+L)	By CC	Date 04-Aug-17	Chd
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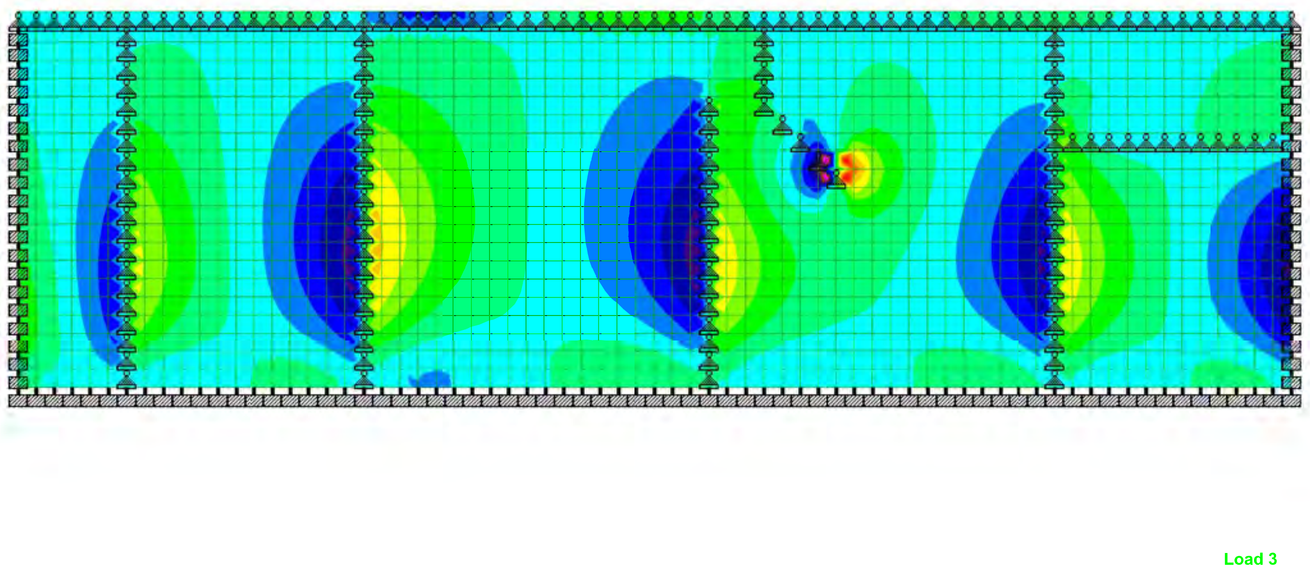
SQX (local)
psi
<= -48.5
-42.3
-36.1
-30
-23.8
-17.6
-11.4
-5.23
0.954
7.14
13.3
19.5
25.7
31.9
38.1
44.2
>= 50.4



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Job Title	Area 4 - ActiFlo	Job No 10721A.10	Sheet No 1	Rev
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	Load Case: 1.6H+1.4E	By CC	Date 04-Aug-17	Chd
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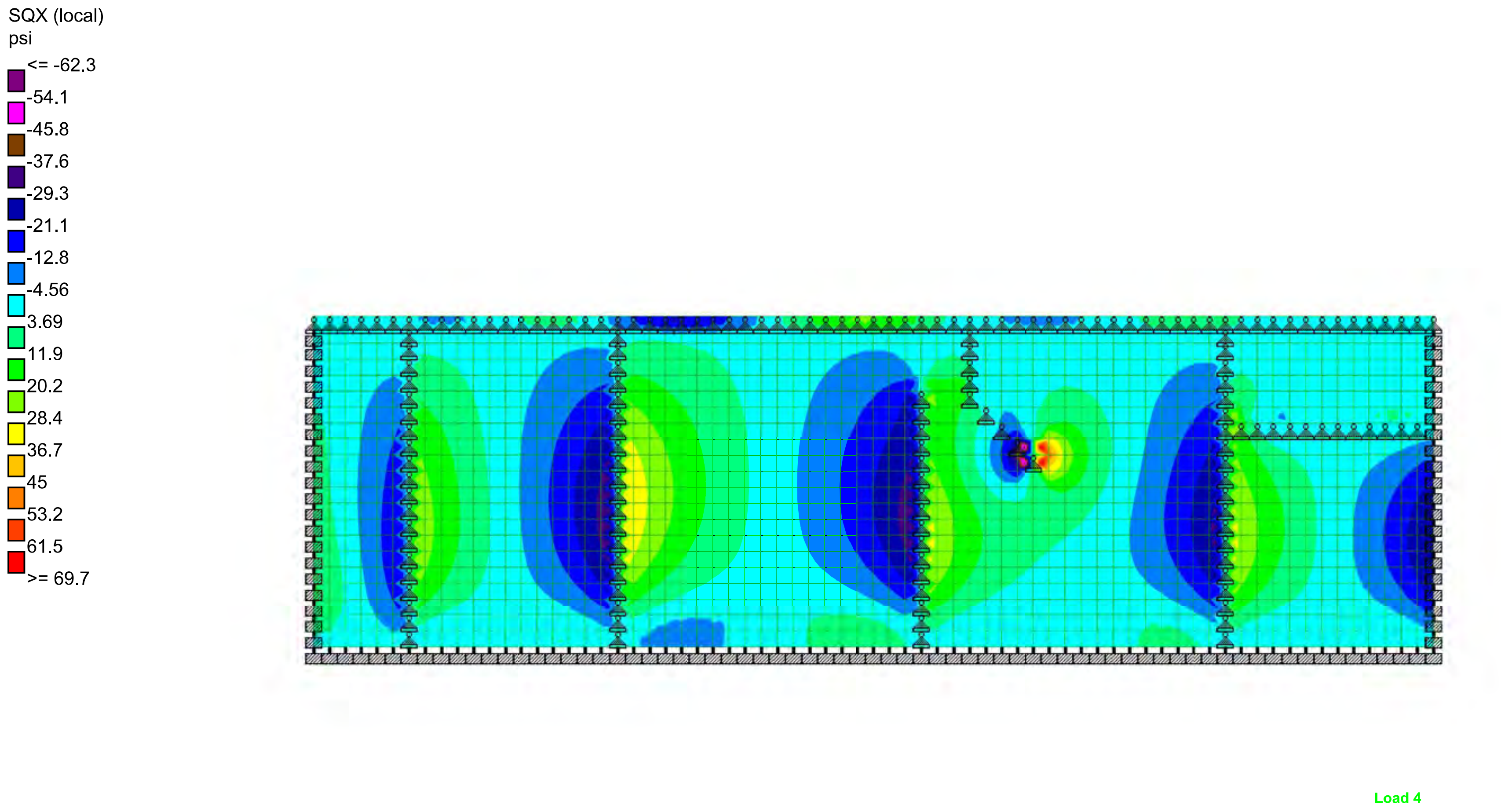

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Job Title Area 4 - ActiFlo Load Case: 1.4H	Job No **10721A.10**	Sheet No **1**	Rev
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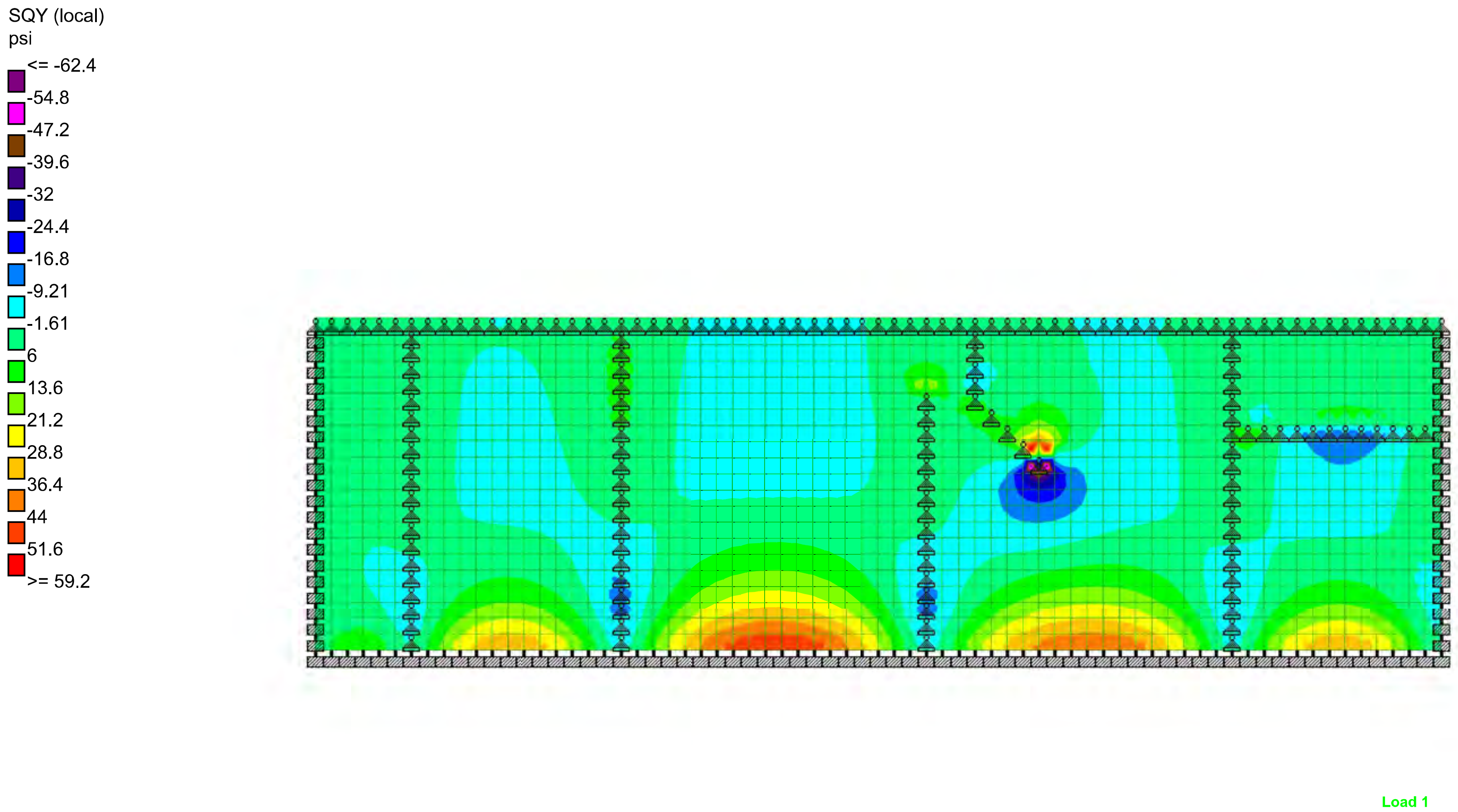

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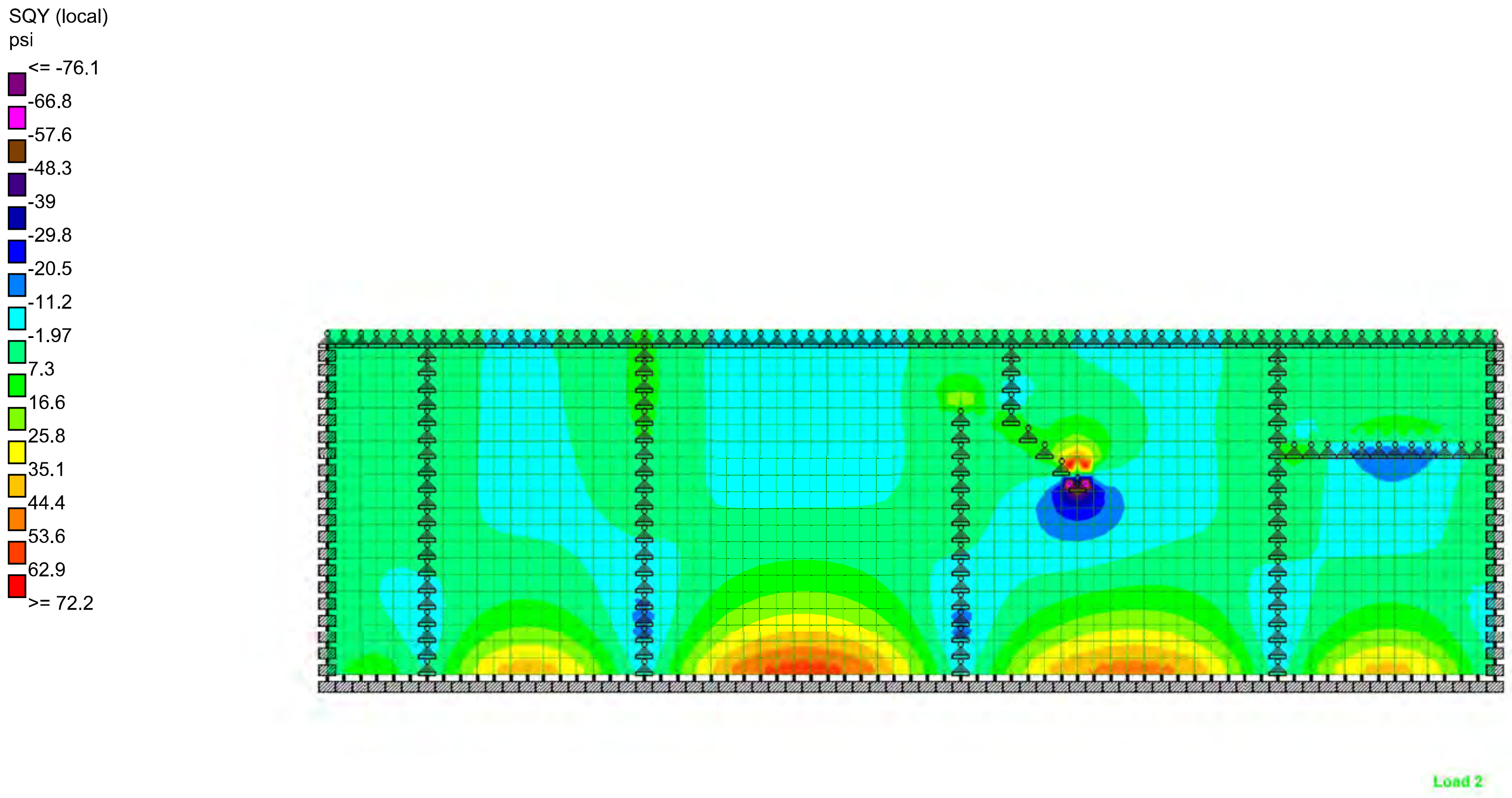
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.2F+1.4E	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Sep-2017 08:15	



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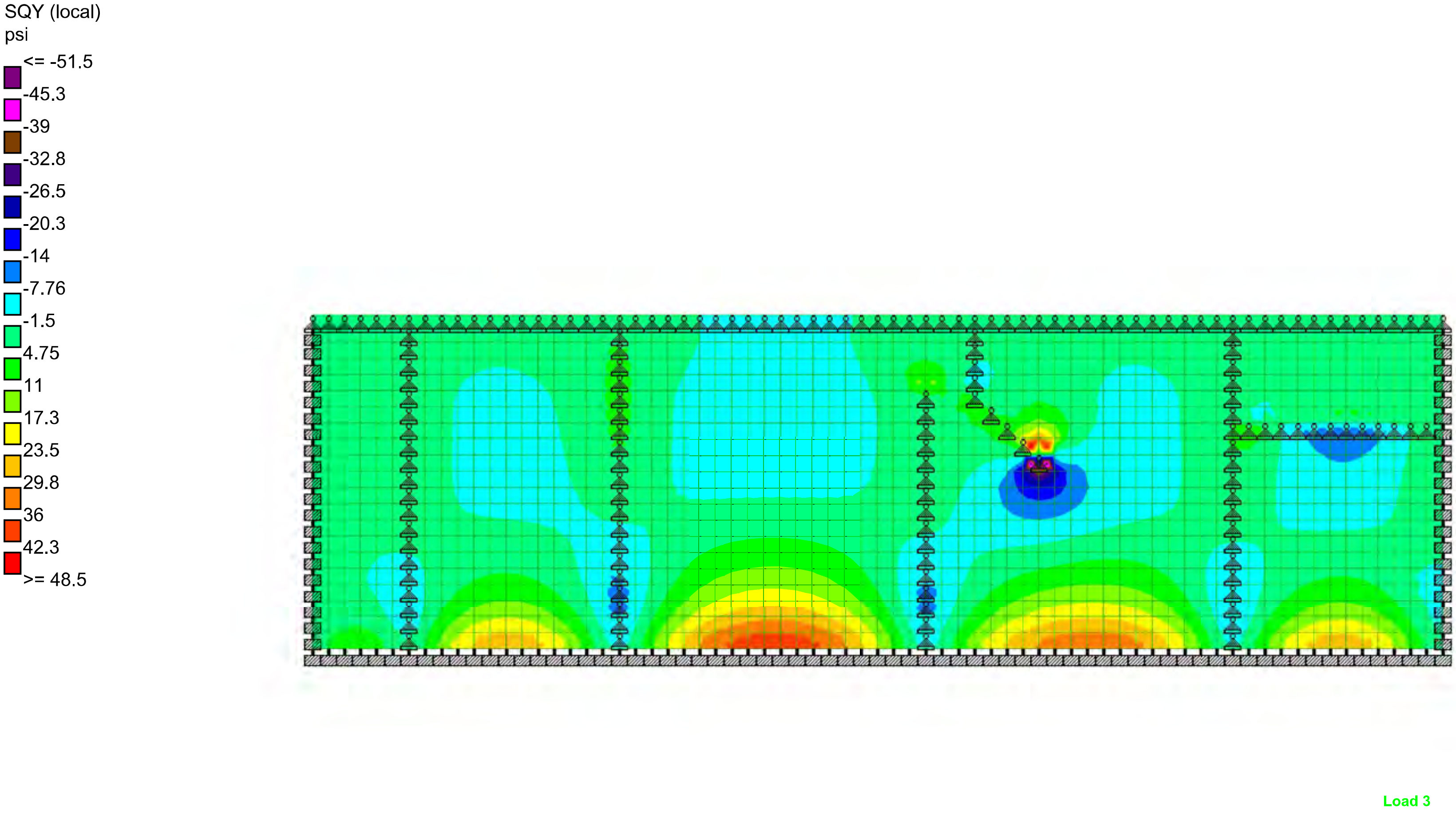
Job Title Area 4 - ActiFlo	Part Wall 1		
	Ref		
Load Case: 1.6(H+L)	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 09-Aug-2017 14:52	



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Job Title Area 4 - ActiFlo	Job No **10721A.10**	Sheet No **1**	Rev
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Load Case: 1.6H+1.4E	By CC	Date 04-Aug-17	Chd
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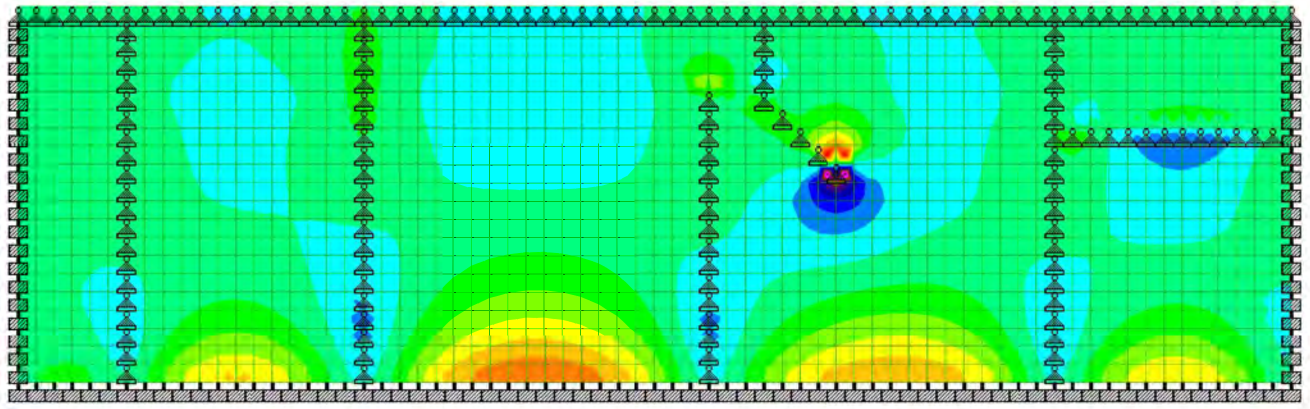
SQY (local)
psi

<= -68.5
🟪 -60.2
🟪 -51.9
🟫 -43.5
🟪 -35.2
🟦 -26.9
🟦 -18.5
🟦 -10.2
🟦 -1.88
🟩 6.45
🟩 14.8
🟩 23.1
🟨 31.4
🟨 39.8
🟧 48.1
🟥 56.4
🟥 >= 64.8



Area 4 - Actiflo™
Wall 2 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	9.44	15.19	24.50	***0.62***	5.58	14.51	***0.38***	***<- OK***
1.2F+1.4E	1.00	11.39	11.39	24.50	***0.46***	6.71	14.51	***0.46***	***<- OK***
1.4E (Water 2-Sides)	1.00	2.57	2.57	24.50	***0.10***	1.49	14.51	***0.10***	***<- OK***

Vertical Span (Mid-Height)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	2.44	3.92	24.50	***0.16***	0.00	14.51	***0.00***	***<- OK***
1.2F+1.4E	1.00	3.10	3.10	24.50	***0.13***	0.00	14.51	***0.00***	***<- OK***
1.4E (Water 2-Sides)	1.00	0.55	0.55	24.50	***0.02***	0.00	14.51	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	15.11	24.33	24.50	***0.99***	7.45	14.51	***0.51***	***<- OK***
1.2F+1.4E	1.00	10.80	10.80	24.50	***0.44***	8.47	14.51	***0.58***	***<- OK***
1.4E (Water 2-Sides)	1.00	1.90	1.90	24.50	***0.08***	1.39	14.51	***0.10***	***<- OK***

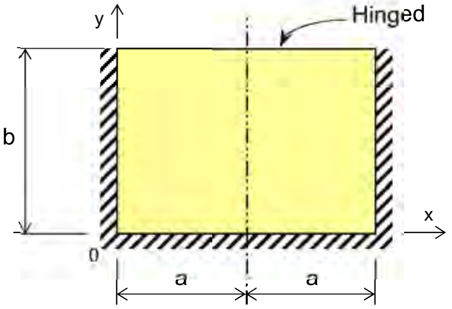
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrostatic

Rectangular Plate:

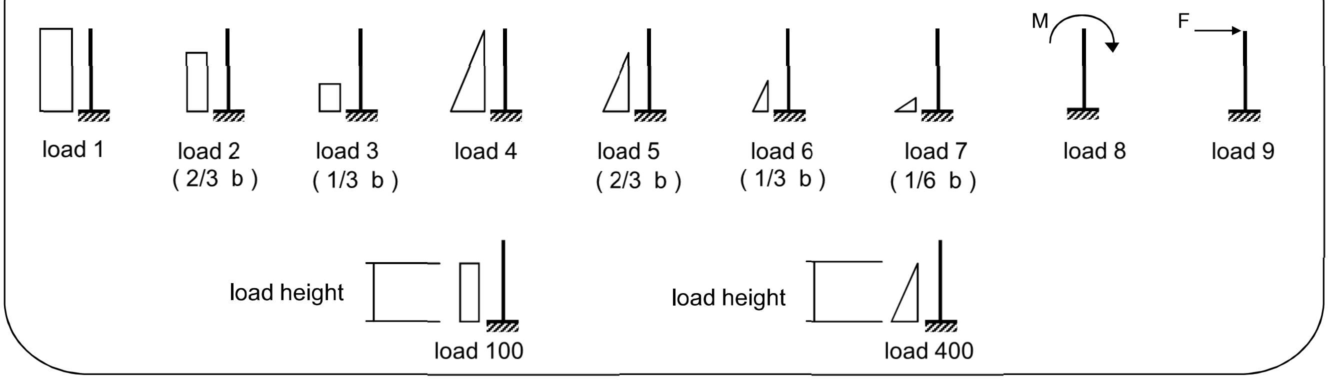
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 6 = 12 ft
plate dimension, a = **6** ft
plate dimension, b = **20.67** ft

plate sides ratio, a/b = 0.2903



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads 100 or 400	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**19.000**	**1.186**	**2.25**	**1.4**
B					
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:	Wall 2 - Hydrostatic				

M_x - Moment Summary

a = 6
b = 20.67
a / b = 0.2903

Loads: q , or M
1.186

Moment Coefficient Multipliers
506.717

Boundary Case 2

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.36
0	0.8	0.0042				2.11				2.11	4.75	0.12	0.36
0	0.6	0.0089				4.53				4.53	10.18	0.26	0.36
0	0.4	0.0133				6.74				6.74	15.16	0.39	0.36
0	0.2	0.0115				5.85				5.85	13.17	0.33	0.36
0	0	0.0000				0.00				0.00	0.00	0.00	0.36
0.2	0	0.0005				0.27				0.27	0.60	0.01	0.36
0.4	0	0.0013				0.64				0.64	1.45	0.04	0.36
0.6	0	0.0020				1.00				1.00	2.26	0.06	0.36
0.8	0	0.0025				1.27				1.27	2.86	0.07	0.36
1	0	0.0026				1.34				1.34	3.01	0.07	0.36
1	0.2	-0.0051				-2.61				-2.61	-5.87	-0.15	-0.36
1	0.4	-0.0065				-3.30				-3.30	-7.42	-0.19	-0.36
1	0.6	-0.0045				-2.29				-2.29	-5.16	-0.13	-0.36
1	0.8	-0.0021				-1.09				-1.09	-2.45	-0.06	-0.36
1	1	0.0000				0.00				0.00	0.00	0.00	0.36
0.8	1	0.0000				0.00				0.00	0.00	0.00	0.36
0.8	0.8	-0.0018				-0.93				-0.93	-2.10	-0.05	-0.36
0.8	0.6	-0.0040				-2.03				-2.03	-4.57	-0.11	-0.36
0.8	0.4	-0.0059				-2.97				-2.97	-6.68	-0.17	-0.36
0.8	0.2	-0.0048				-2.41				-2.41	-5.42	-0.14	-0.36

max negative moment, $M_{ux}(-)$ = -7.42 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.19 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 15.16 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.39 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrostatic

M_y - Moment Summary

a = 6
b = 20.67
a / b = 0.2903

Loads: q , or M: 1.186
Moment Coefficient Multipliers: 506.717

Boundary Case 2

		Moment Coefficients				M_y Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.36
0	0.8	0.0008				0.41				0.41	0.91	0.02	0.36
0	0.6	0.0018				0.89				0.89	2.00	0.05	0.36
0	0.4	0.0027				1.35				1.35	3.04	0.07	0.36
0	0.2	0.0023				1.16				1.16	2.62	0.06	0.36
0	0	0.0000				0.00				0.00	0.00	0.00	0.36
0.2	0	0.0026				1.30				1.30	2.92	0.07	0.36
0.4	0	0.0065				3.31				3.31	7.45	0.18	0.36
0.6	0	0.0101				5.10				5.10	11.48	0.27	0.37
0.8	0	0.0124				6.31				6.31	14.19	0.34	0.38
1	0	0.0133				6.71				6.71	15.11	0.36	0.38
1	0.2	-0.0039				-1.97				-1.97	-4.44	-0.10	-0.36
1	0.4	-0.0031				-1.56				-1.56	-3.51	-0.08	-0.36
1	0.6	-0.0013				-0.65				-0.65	-1.45	-0.03	-0.36
1	0.8	-0.0004				-0.18				-0.18	-0.41	-0.01	-0.36
1	1	0.0000				0.00				0.00	0.00	0.00	0.36
1	0.4	-0.0031				-1.56				-1.56	-3.51	-0.08	-0.36
0.8	0.4	-0.0028				-1.43				-1.43	-3.22	-0.08	-0.36
0.6	0.4	-0.0020				-1.04				-1.04	-2.33	-0.05	-0.36
0.4	0.4	-0.0008				-0.40				-0.40	-0.91	-0.02	-0.36
0.2	0.4	0.0008				0.42				0.42	0.96	0.02	0.36

max negative moment, $M_{uy}(-)$ = -4.44 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.10 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 15.11 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.36 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrostatic

Shear Summary

		Loads: q , or M				Boundary Case 2				SUMMARY		
a =	6	1.186								Final Shears		
b =	20.67	Shear Coefficient Multipliers										
a / b =	0.2903	24.515										
		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0075				-0.18				-0.18	-0.26	10.81
0	0.8	0.0411				1.01				1.01	1.41	10.81
0	0.6	0.0958				2.35				2.35	3.29	10.81
0	0.4	0.1626				3.99				3.99	5.58	10.81
0	0.2	0.1582				3.88				3.88	5.43	10.81
0	0.00	0.0249				0.61				0.61	0.85	10.81
0.2	0	0.0372				0.91				0.91	1.28	10.81
0.4	0	0.1199				2.94				2.94	4.12	10.81
0.6	0	0.1756				4.31				4.31	6.03	10.81
0.8	0	0.2071				5.08				5.08	7.11	10.81
1	0	0.2171				5.32				5.32	7.45	10.81
0.2	1	-0.0129				-0.32				-0.32	-0.44	10.81
0.4	1	0.0029				0.07				0.07	0.10	10.81
0.6	1	0.0143				0.35				0.35	0.49	10.81
0.8	1	0.0212				0.52				0.52	0.73	10.81
1	1	0.0235				0.58				0.58	0.81	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 7.45 k/ft **OK**
$\phi V_c = \phi*2*(f'c)^{1/2}*b*d =$ (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

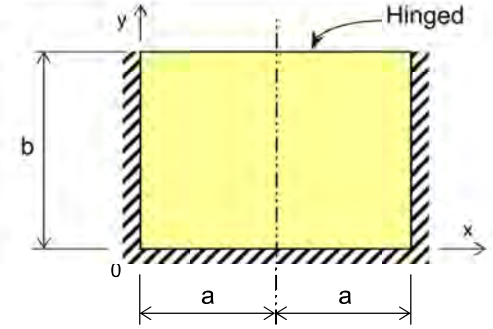
BY: C. Che **DATE:** Sep-17 **CLIENT** Willemetter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

Rectangular Plate:

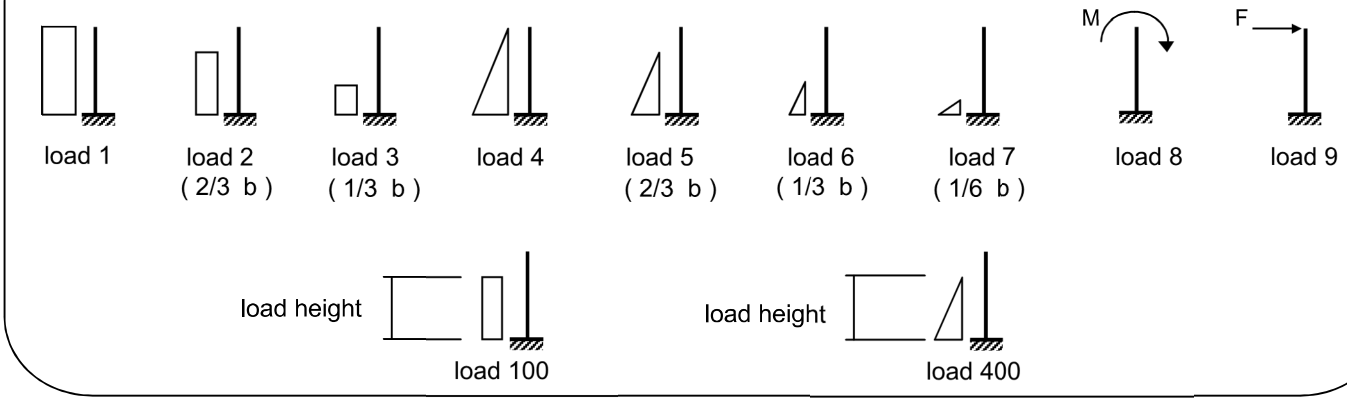
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 6 = 12 ft
plate dimension, a = **6** ft
plate dimension, b = **20.67** ft

plate sides ratio, a/b = 0.2903



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**19.000**	**1.186**	**1.2**	**1.2**
B	**100**	**19.000**	**0.121**	**1.4**	**1.4**
C	**400**	**19.000**	**0.181**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Sep-17 **CLIENT** Willemetter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

M_x - Moment Summary

	Loads: q , or M					
a = 6	1.186	0.121	0.181		Boundary Case 2	SUMMARY
b = 20.67	Moment Coefficient Multipliers					Final Moments / Reinforcing: (d = 9")
a / b = 0.2903	506.717	51.697	77.332			

		Moment Coefficients				M_x Moments, ft-k/ft				M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0	0.8	0.0042	0.0161	0.0042		2.11	0.83	0.32		3.26	4.15	0.10	0.36
0	0.6	0.0089	0.0249	0.0089		4.53	1.29	0.69		6.51	8.20	0.21	0.36
0	0.4	0.0133	0.0258	0.0133		6.74	1.33	1.03		9.10	11.39	0.29	0.36
0	0.2	0.0115	0.0166	0.0115		5.85	0.86	0.89		7.60	9.47	0.24	0.36
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.2	0	0.0005	0.0007	0.0005		0.27	0.03	0.04		0.34	0.42	0.01	0.36
0.4	0	0.0013	0.0017	0.0013		0.64	0.09	0.10		0.83	1.03	0.03	0.36
0.6	0	0.0020	0.0027	0.0020		1.00	0.14	0.15		1.30	1.61	0.04	0.36
0.8	0	0.0025	0.0034	0.0025		1.27	0.17	0.19		1.64	2.04	0.05	0.36
1	0	0.0026	0.0036	0.0026		1.34	0.19	0.20		1.73	2.15	0.05	0.36
1	0.2	-0.0051	-0.0078	-0.0051		-2.61	-0.40	-0.40		-3.41	-4.25	-0.11	-0.36
1	0.4	-0.0065	-0.0128	-0.0065		-3.30	-0.66	-0.50		-4.46	-5.59	-0.14	-0.36
1	0.6	-0.0045	-0.0124	-0.0045		-2.29	-0.64	-0.35		-3.28	-4.14	-0.10	-0.36
1	0.8	-0.0021	-0.0080	-0.0021		-1.09	-0.41	-0.17		-1.66	-2.11	-0.05	-0.36
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.8	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.8	0.8	-0.0018	-0.0072	-0.0018		-0.93	-0.37	-0.14		-1.45	-1.84	-0.05	-0.36
0.8	0.6	-0.0040	-0.0111	-0.0040		-2.03	-0.57	-0.31		-2.92	-3.68	-0.09	-0.36
0.8	0.4	-0.0059	-0.0114	-0.0059		-2.97	-0.59	-0.45		-4.01	-5.02	-0.13	-0.36
0.8	0.2	-0.0048	-0.0070	-0.0048		-2.41	-0.36	-0.37		-3.14	-3.91	-0.10	-0.36

max negative moment, $M_{ux}(-)$ = -5.59 ft-k/ft

max negative steel req'd, $A_s(-)$ = -0.14 in^2/ft

minimum steel req'd = -0.36 in^2/ft

Use

max positive moment, $M_{ux}(+)$ = 11.39 ft-k/ft

max positive steel req'd, $A_s(+)$ = 0.29 in^2/ft

minimum steel req'd = 0.36 in^2/ft

Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willemetter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

M_y - Moment Summary

a = 6
b = 20.67
a / b = 0.2903

Loads: q , or M			
1.186	0.121	0.181	
Moment Coefficient Multipliers			
506.717	51.697	77.332	

Boundary Case 2

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0	0.8	0.0008	0.0032	0.0008		0.41	0.17	0.06		0.63	0.80	0.02	0.36
0	0.6	0.0018	0.0050	0.0018		0.89	0.26	0.14		1.28	1.62	0.04	0.36
0	0.4	0.0027	0.0052	0.0027		1.35	0.27	0.21		1.82	2.28	0.05	0.36
0	0.2	0.0023	0.0033	0.0023		1.16	0.17	0.18		1.51	1.88	0.04	0.36
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.2	0	0.0026	0.0032	0.0026		1.30	0.17	0.20		1.66	2.07	0.05	0.36
0.4	0	0.0065	0.0084	0.0065		3.31	0.44	0.51		4.25	5.29	0.12	0.36
0.6	0	0.0101	0.0135	0.0101		5.10	0.70	0.78		6.58	8.19	0.19	0.36
0.8	0	0.0124	0.0169	0.0124		6.31	0.87	0.96		8.14	10.14	0.24	0.36
1	0	0.0133	0.0181	0.0133		6.71	0.94	1.02		8.67	10.80	0.26	0.36
1	0.2	-0.0039	-0.0042	-0.0039		-1.97	-0.22	-0.30		-2.49	-3.10	-0.07	-0.36
1	0.4	-0.0031	-0.0055	-0.0031		-1.56	-0.28	-0.24		-2.08	-2.60	-0.06	-0.36
1	0.6	-0.0013	-0.0049	-0.0013		-0.65	-0.25	-0.10		-1.00	-1.27	-0.03	-0.36
1	0.8	-0.0004	-0.0035	-0.0004		-0.18	-0.18	-0.03		-0.39	-0.51	-0.01	-0.36
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
1	0.4	-0.0031	-0.0055	-0.0031		-1.56	-0.28	-0.24		-2.08	-2.60	-0.06	-0.36
0.8	0.4	-0.0028	-0.0050	-0.0028		-1.43	-0.26	-0.22		-1.91	-2.38	-0.06	-0.36
0.6	0.4	-0.0020	-0.0035	-0.0020		-1.04	-0.18	-0.16		-1.38	-1.72	-0.04	-0.36
0.4	0.4	-0.0008	-0.0013	-0.0008		-0.40	-0.06	-0.06		-0.53	-0.66	-0.02	-0.36
0.2	0.4	0.0008	0.0017	0.0008		0.42	0.09	0.06		0.58	0.72	0.02	0.36

max negative moment, $M_{uy}(-)$ = -3.10 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.07 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 10.80 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.26 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willemetter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

Shear Summary

		Loads: q , or M					SUMMARY
a =	6	1.186	0.121	0.181		Boundary Case 2	
b =	20.67	Shear Coefficient Multipliers					Final Shears
a / b =	0.2903	24.515	2.501	3.741			

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0075	-0.0177	-0.0075		-0.18	-0.04	-0.03		-0.26	-0.32	10.81
0	0.8	0.0411	0.1937	0.0411		1.01	0.48	0.15		1.65	2.10	10.81
0	0.6	0.0958	0.2893	0.0958		2.35	0.72	0.36		3.43	4.33	10.81
0	0.4	0.1626	0.3071	0.1626		3.99	0.77	0.61		5.36	6.71	10.81
0	0.2	0.1582	0.2068	0.1582		3.88	0.52	0.59		4.99	6.20	10.81
0	0.00	0.0249	0.0202	0.0249		0.61	0.05	0.09		0.75	0.93	10.81
0.2	0	0.0372	0.0256	0.0372		0.91	0.06	0.14		1.11	1.38	10.81
0.4	0	0.1199	0.1314	0.1199		2.94	0.33	0.45		3.72	4.62	10.81
0.6	0	0.1756	0.2087	0.1756		4.31	0.52	0.66		5.48	6.82	10.81
0.8	0	0.2071	0.2544	0.2071		5.08	0.64	0.77		6.49	8.07	10.81
1	0	0.2171	0.2694	0.2171		5.32	0.67	0.81		6.81	8.47	10.81
0.2	1	-0.0129	0.0078	-0.0129		-0.32	0.02	-0.05		-0.34	-0.42	10.81
0.4	1	0.0029	0.0702	0.0029		0.07	0.18	0.01		0.26	0.35	10.81
0.6	1	0.0143	0.1314	0.0143		0.35	0.33	0.05		0.73	0.96	10.81
0.8	1	0.0212	0.1369	0.0212		0.52	0.34	0.08		0.94	1.21	10.81
1	1	0.0235	0.1448	0.0235		0.58	0.36	0.09		1.03	1.32	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 8.47 k/ft **OK**
$\phi V_c = \phi*2*(f\,'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

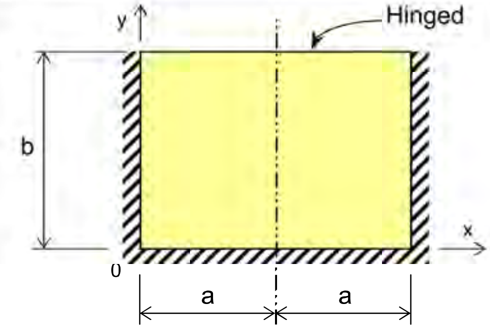
BY: C. Che **DATE:** Sep-17 **CLIENT** Willemetter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic (Water 2-Sides)

Rectangular Plate:

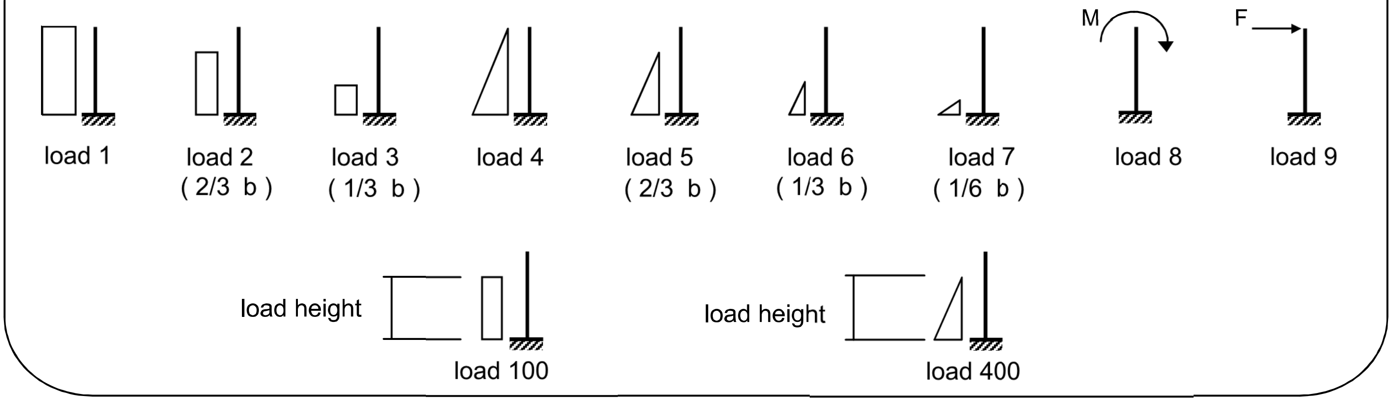
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 6 = 12 ft
plate dimension, a = **6** ft
plate dimension, b = **20.67** ft

plate sides ratio, a/b = 0.2903



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**100**	**19.000**	**0.145**	**1.4**	**1.4**
B	**400**	**19.000**	**0.042**	**1.4**	**1.4**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

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Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:**	Sep-17	**CLIENT**	Willemetter River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 2 - Hydrodynamic (Water 2-Sides)		

M_x - Moment Summary

a = 6
b = 20.67
a / b = 0.2903

Loads: q , or M			
0.145	0.042		
Moment Coefficient Multipliers			
61.951	17.944		

Boundary Case 2

SUMMARY

x / a	y / b	Moment Coefficients A	B	C	D	M_x Moments, ft-k/ft A	B	C	D	Final Moments M_x ft-k/ft	M_{ux} ft-k/ft	Reinforcing: (d = 9") $A_{s(req'd)}$ in²/ft	$A_{s(min)}$ in²/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0161	0.0042			1.00	0.07			1.07	1.50	0.04	0.36
0	0.6	0.0249	0.0089			1.54	0.16			1.70	2.39	0.06	0.36
0	0.4	0.0258	0.0133			1.60	0.24			1.84	2.57	0.06	0.36
0	0.2	0.0166	0.0115			1.03	0.21			1.24	1.73	0.04	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0007	0.0005			0.04	0.01			0.05	0.07	0.00	0.36
0.4	0	0.0017	0.0013			0.11	0.02			0.13	0.18	0.00	0.36
0.6	0	0.0027	0.0020			0.17	0.04			0.20	0.28	0.01	0.36
0.8	0	0.0034	0.0025			0.21	0.05			0.25	0.36	0.01	0.36
1	0	0.0036	0.0026			0.22	0.05			0.27	0.38	0.01	0.36
1	0.2	-0.0078	-0.0051			-0.48	-0.09			-0.57	-0.80	-0.02	-0.36
1	0.4	-0.0128	-0.0065			-0.79	-0.12			-0.91	-1.27	-0.03	-0.36
1	0.6	-0.0124	-0.0045			-0.77	-0.08			-0.85	-1.19	-0.03	-0.36
1	0.8	-0.0080	-0.0021			-0.49	-0.04			-0.53	-0.75	-0.02	-0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.8	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.8	0.8	-0.0072	-0.0018			-0.44	-0.03			-0.48	-0.67	-0.02	-0.36
0.8	0.6	-0.0111	-0.0040			-0.69	-0.07			-0.76	-1.06	-0.03	-0.36
0.8	0.4	-0.0114	-0.0059			-0.71	-0.11			-0.81	-1.14	-0.03	-0.36
0.8	0.2	-0.0070	-0.0048			-0.43	-0.09			-0.52	-0.73	-0.02	-0.36

max negative moment, $M_{ux}(-)$ = -1.27 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.03 in²/ft
minimum steel req'd = -0.36 in²/ft
Use

max positive moment, $M_{ux}(+)$ = 2.57 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.06 in²/ft
minimum steel req'd = 0.36 in²/ft
Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willemetter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic (Water 2-Sides)

M_y - Moment Summary

a = 6
b = 20.67
a / b = 0.2903

Loads: q , or M			
0.145	0.042		
Moment Coefficient Multipliers			
61.951	17.944		

Boundary Case 2

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0032	0.0008			0.20	0.01			0.21	0.30	0.01	0.36
0	0.6	0.0050	0.0018			0.31	0.03			0.34	0.47	0.01	0.36
0	0.4	0.0052	0.0027			0.32	0.05			0.37	0.51	0.01	0.36
0	0.2	0.0033	0.0023			0.21	0.04			0.25	0.35	0.01	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0032	0.0026			0.20	0.05			0.24	0.34	0.01	0.36
0.4	0	0.0084	0.0065			0.52	0.12			0.64	0.90	0.02	0.36
0.6	0	0.0135	0.0101			0.84	0.18			1.02	1.42	0.03	0.36
0.8	0	0.0169	0.0124			1.05	0.22			1.27	1.78	0.04	0.36
1	0	0.0181	0.0133			1.12	0.24			1.36	1.90	0.04	0.36
1	0.2	-0.0042	-0.0039			-0.26	-0.07			-0.33	-0.46	-0.01	-0.36
1	0.4	-0.0055	-0.0031			-0.34	-0.06			-0.39	-0.55	-0.01	-0.36
1	0.6	-0.0049	-0.0013			-0.30	-0.02			-0.33	-0.46	-0.01	-0.36
1	0.8	-0.0035	-0.0004			-0.22	-0.01			-0.22	-0.31	-0.01	-0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
1	0.4	-0.0055	-0.0031			-0.34	-0.06			-0.39	-0.55	-0.01	-0.36
0.8	0.4	-0.0050	-0.0028			-0.31	-0.05			-0.36	-0.51	-0.01	-0.36
0.6	0.4	-0.0035	-0.0020			-0.22	-0.04			-0.26	-0.36	-0.01	-0.36
0.4	0.4	-0.0013	-0.0008			-0.08	-0.01			-0.09	-0.13	0.00	-0.36
0.2	0.4	0.0017	0.0008			0.10	0.02			0.12	0.17	0.00	0.36

max negative moment, $M_{uy}(-)$ = -0.55 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.01 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 1.90 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.04 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willemetter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic (Water 2-Sides)

Shear Summary

a = 6 b = 20.67 a / b = 0.2903		Loads: q , or M				Boundary Case 2				SUMMARY		
		0.145	0.042									
		Shear Coefficient Multipliers								Final Shears		
		2.997	0.868									
		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0177	-0.0075			-0.05	-0.01			-0.06	-0.08	10.81
0	0.8	0.1937	0.0411			0.58	0.04			0.62	0.86	10.81
0	0.6	0.2893	0.0958			0.87	0.08			0.95	1.33	10.81
0	0.4	0.3071	0.1626			0.92	0.14			1.06	1.49	10.81
0	0.2	0.2068	0.1582			0.62	0.14			0.76	1.06	10.81
0	0.00	0.0202	0.0249			0.06	0.02			0.08	0.11	10.81
0.2	0	0.0256	0.0372			0.08	0.03			0.11	0.15	10.81
0.4	0	0.1314	0.1199			0.39	0.10			0.50	0.70	10.81
0.6	0	0.2087	0.1756			0.63	0.15			0.78	1.09	10.81
0.8	0	0.2544	0.2071			0.76	0.18			0.94	1.32	10.81
1	0	0.2694	0.2171			0.81	0.19			1.00	1.39	10.81
0.2	1	0.0078	-0.0129			0.02	-0.01			0.01	0.02	10.81
0.4	1	0.0702	0.0029			0.21	0.00			0.21	0.30	10.81
0.6	1	0.1314	0.0143			0.39	0.01			0.41	0.57	10.81
0.8	1	0.1369	0.0212			0.41	0.02			0.43	0.60	10.81
1	1	0.1448	0.0235			0.43	0.02			0.45	0.64	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 1.49 k/ft **OK**
$\phi V_c = \phi*2*(f'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Area 4 - Actiflo™
Wall 3 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	19.10	30.75	47.00	***0.65***	96	126	***0.76***	***<- OK***
1.2F+1.4E	1.00	23.90	23.90	47.00	***0.51***	137	126	***1.08***	***<- NG***
1.4E (Water 2-Sides)	1.00	15.10	15.10	47.00	***0.32***	109	126	***0.86***	***<- OK***

Vertical Span (Mid-Height)

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	13.60	21.90	20.50	***1.07***	0	126	***0.00***	***<- NG***
1.2F+1.4E	1.00	16.80	16.80	20.50	***0.82***	0	126	***0.00***	***<- OK***
1.4E (Water 2-Sides)	1.00	10.70	10.70	20.50	***0.52***	0	126	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	31.40	50.55	51.00	***0.99***	64	126	***0.50***	***<- OK***
1.2F+1.4E	1.00	38.20	38.20	51.00	***0.75***	86	126	***0.68***	***<- OK***
1.4E (Water 2-Sides)	1.00	22.50	22.50	51.00	***0.44***	68	126	***0.53***	***<- OK***

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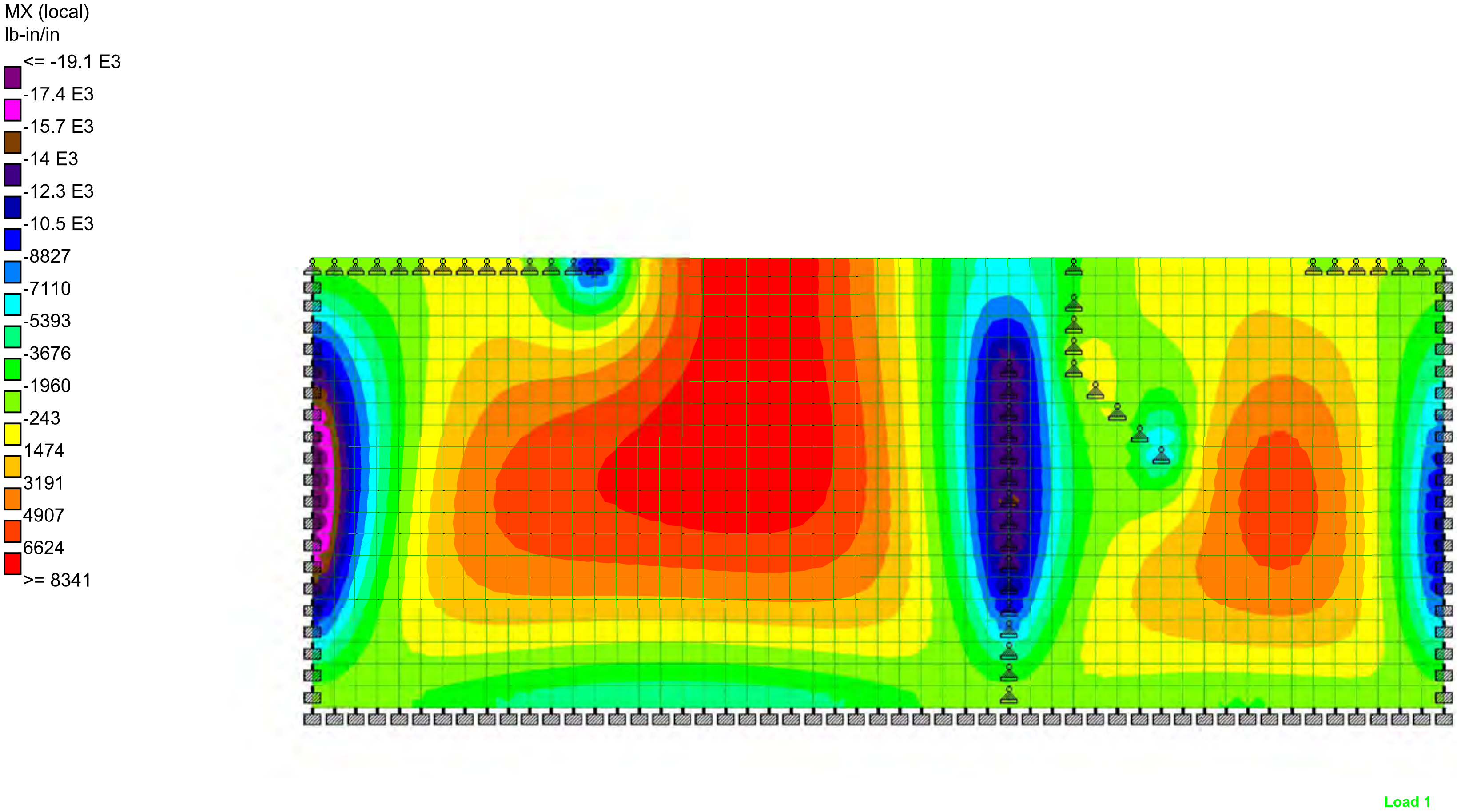
	Part Wall 3		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Aug-2017 15:20	



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Job Title Area 4 - ActiFlo Load Case: 1.2F+1.4E	Job No **10721A.10**	Sheet No **1**		Rev
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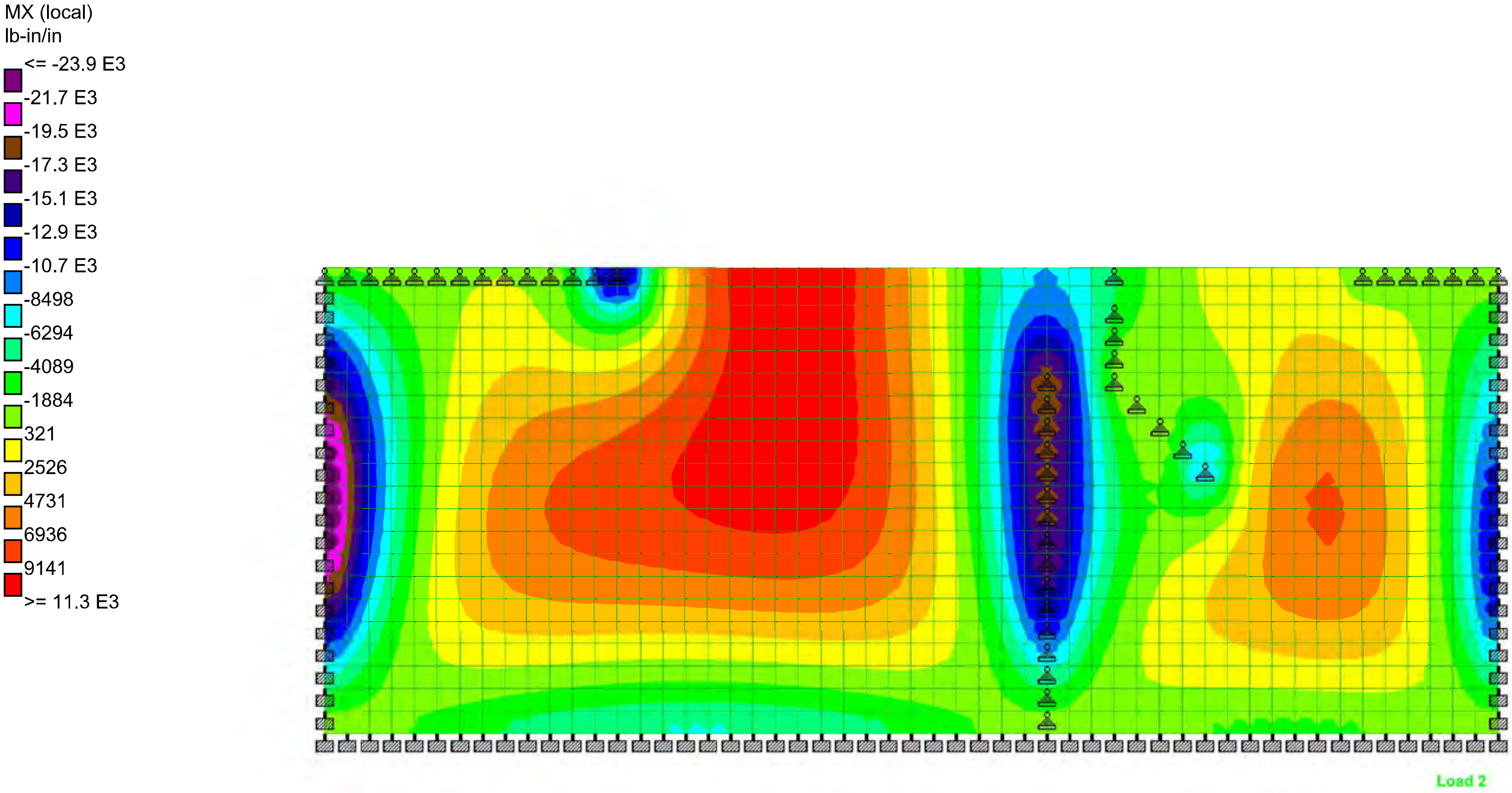
	Ref			
	By	Date 04-Aug-17	Chd	
Client Willamette River WTP	File Wall 3.std		Date/Time 09-Sep-2017 10:11	



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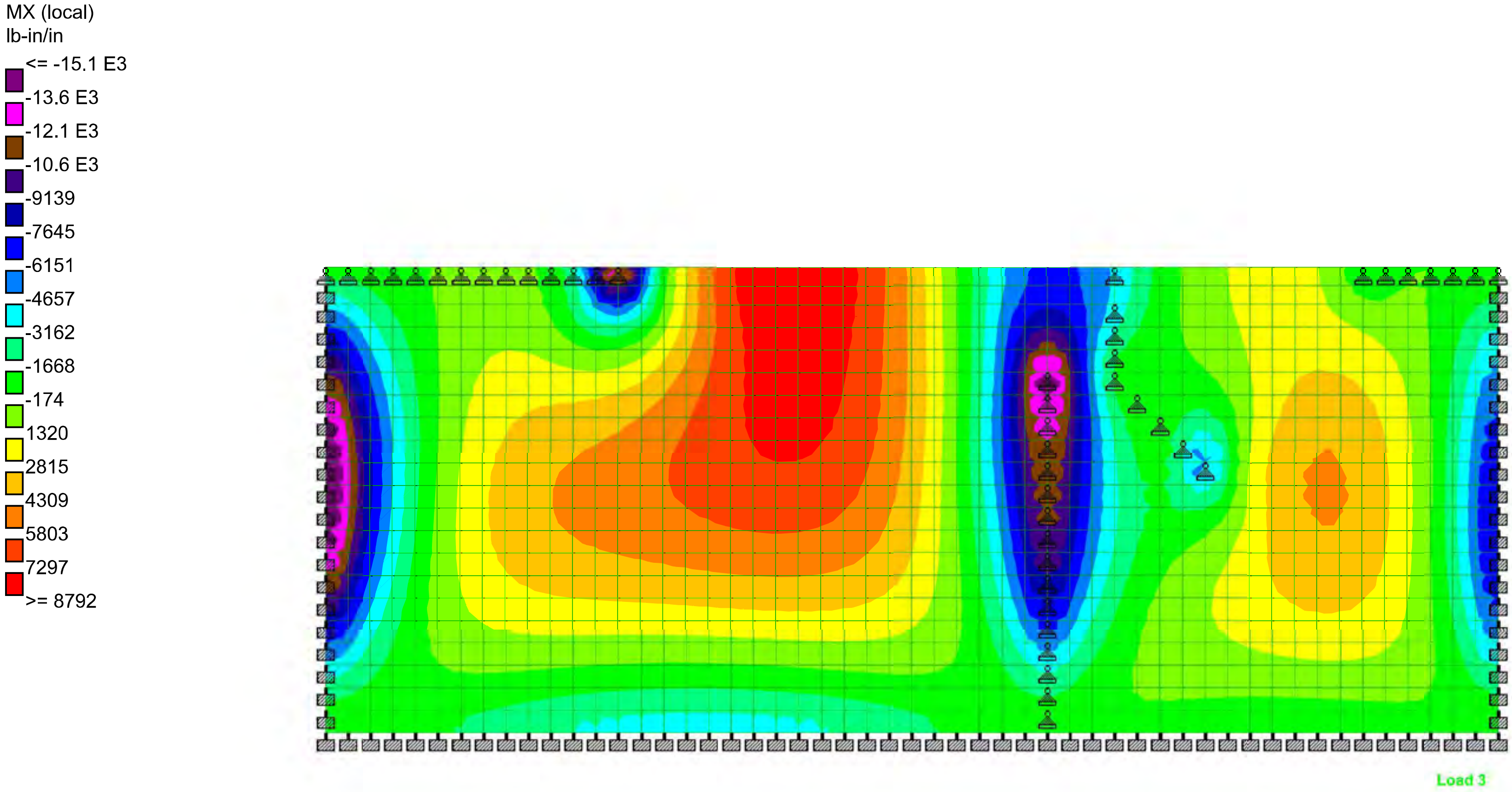
Job No 10721A.10	Sheet No 1		Rev
Part Wall 3			
Ref			
By	Date 04-Aug-17	Chd	
File Wall 3.std		Date/Time 09-Sep-2017 10:11	

Job Title Area 4 - ActiFlo

Load Case: 1.4E (Water 2-Sides)

Client Willamette River WTP



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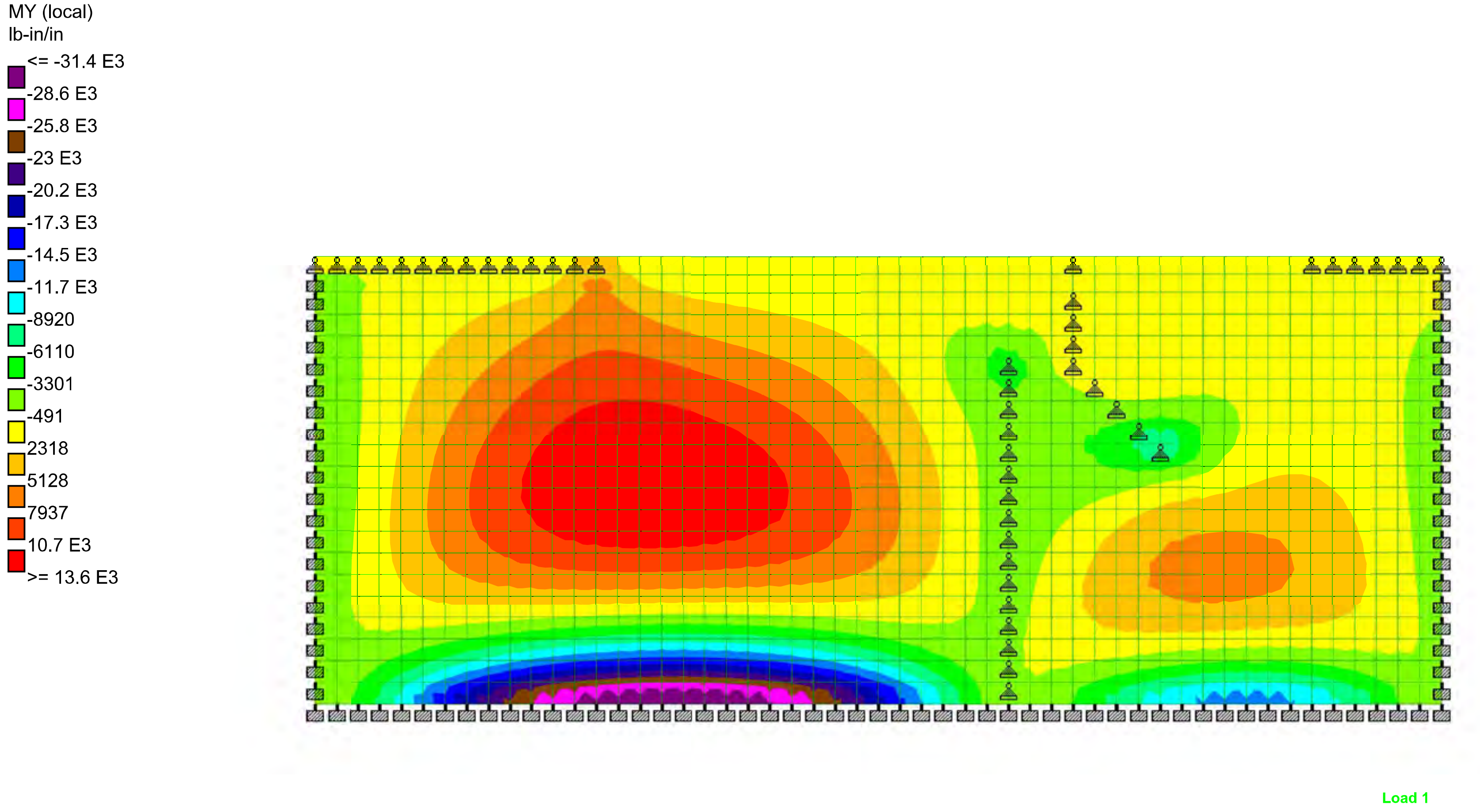
	Part Wall 3		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Aug-2017 15:20	



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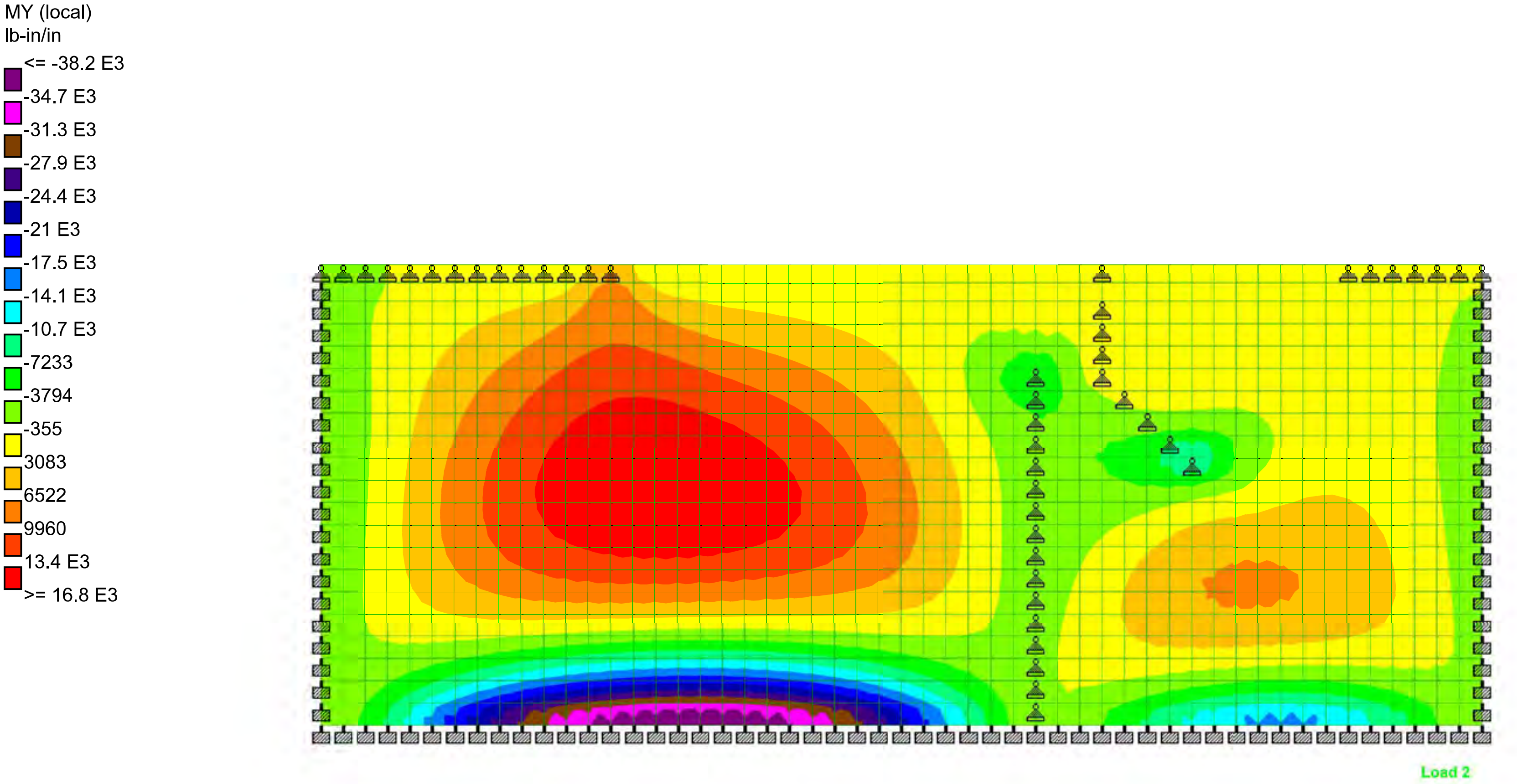
	Part Wall 3		
Job Title Area 4 - ActiFlo Load Case: 1.2F+1.4E	Ref		
	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Sep-2017 10:11	



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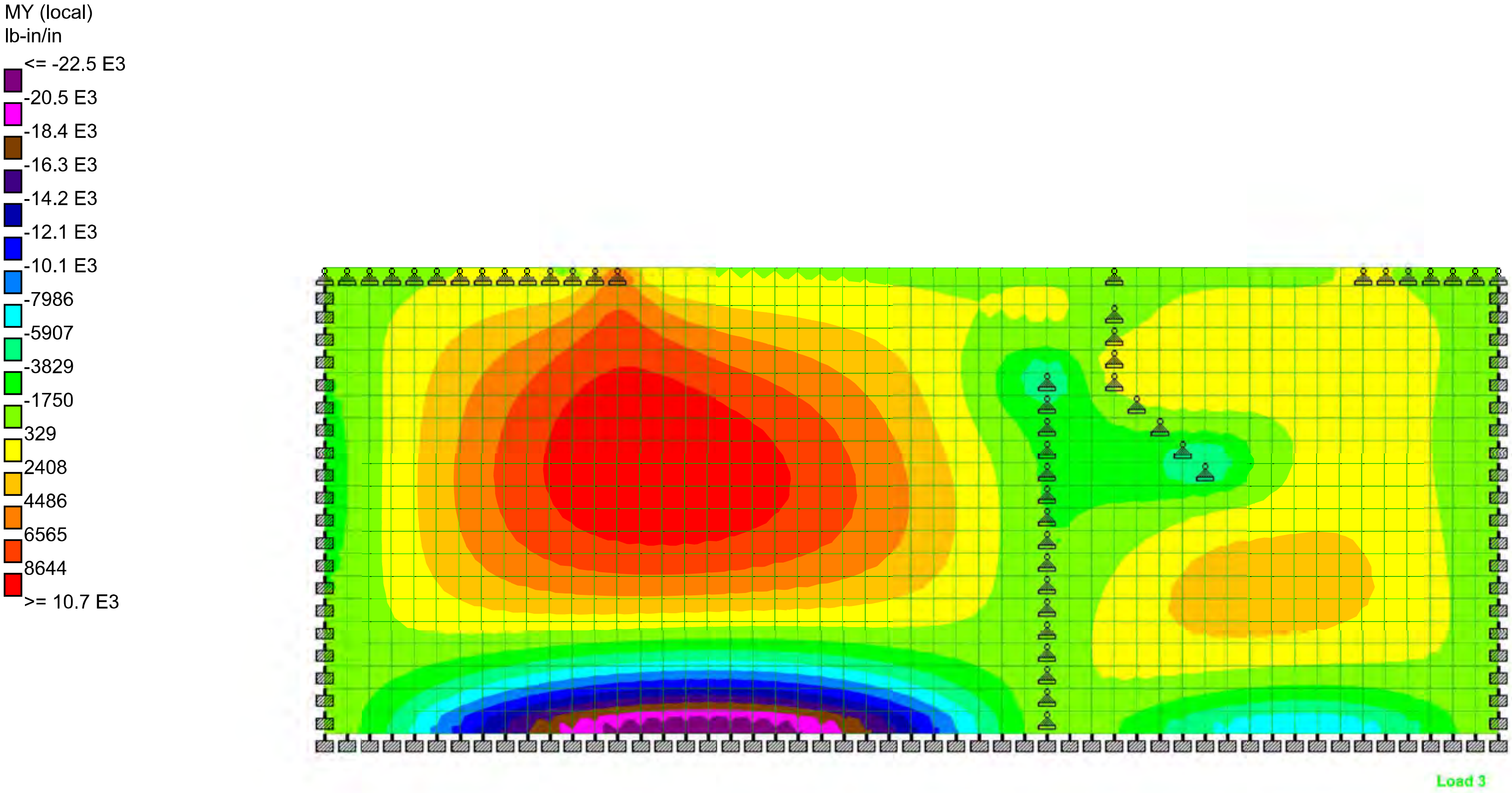
Job No 10721A.10	Sheet No 1	Rev	
Part Wall 3			
Ref			
By	Date 04-Aug-17	Chd	
File Wall 3.std	Date/Time 09-Sep-2017 10:11		

Job Title Area 4 - ActiFlo

Load Case: 1.4E (Water 2-Sides)

Client Willamette River WTP



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	Part Wall 3		
Job Title Area 4 - ActiFlo	Ref		
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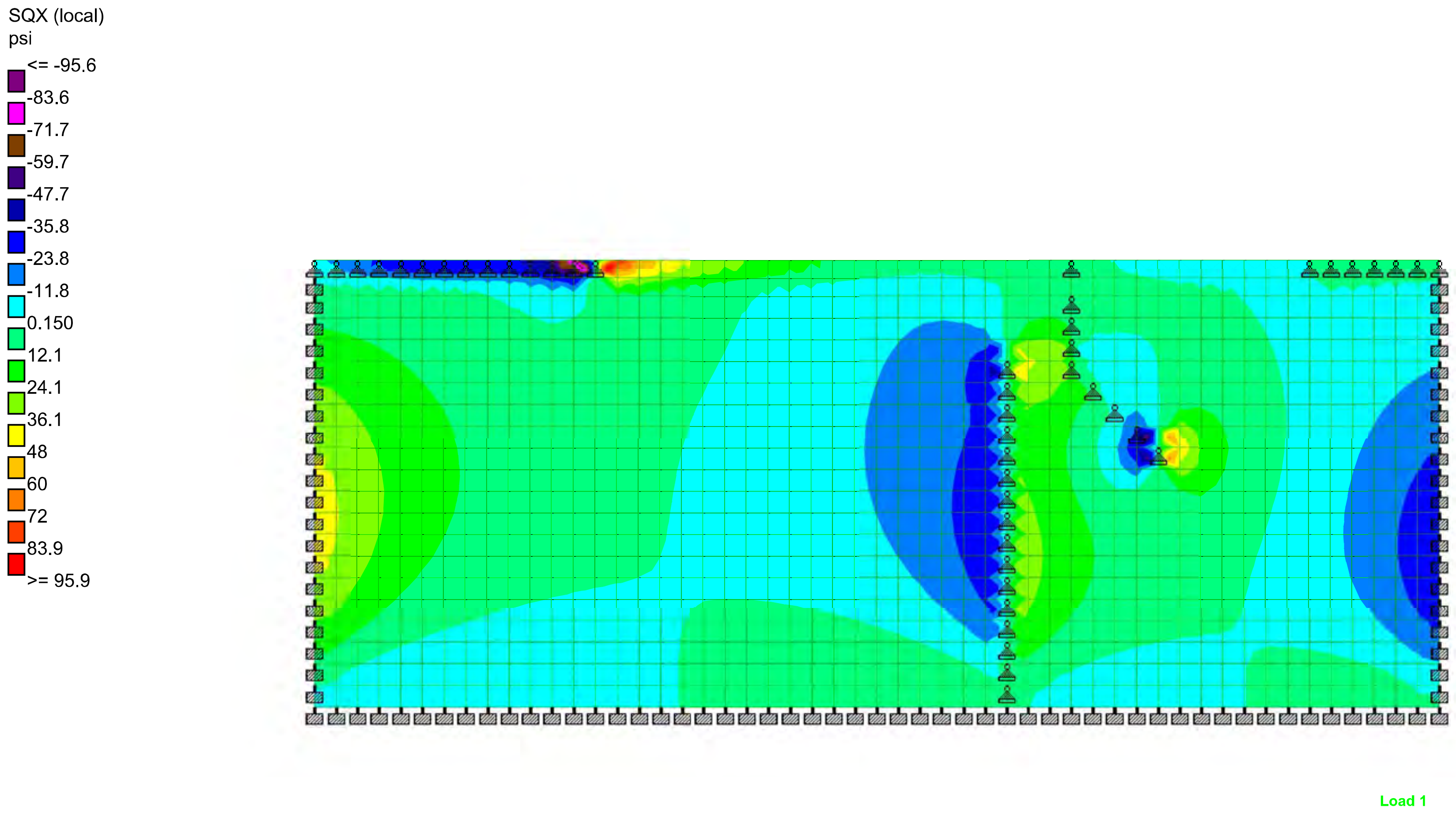
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Aug-2017 15:20	



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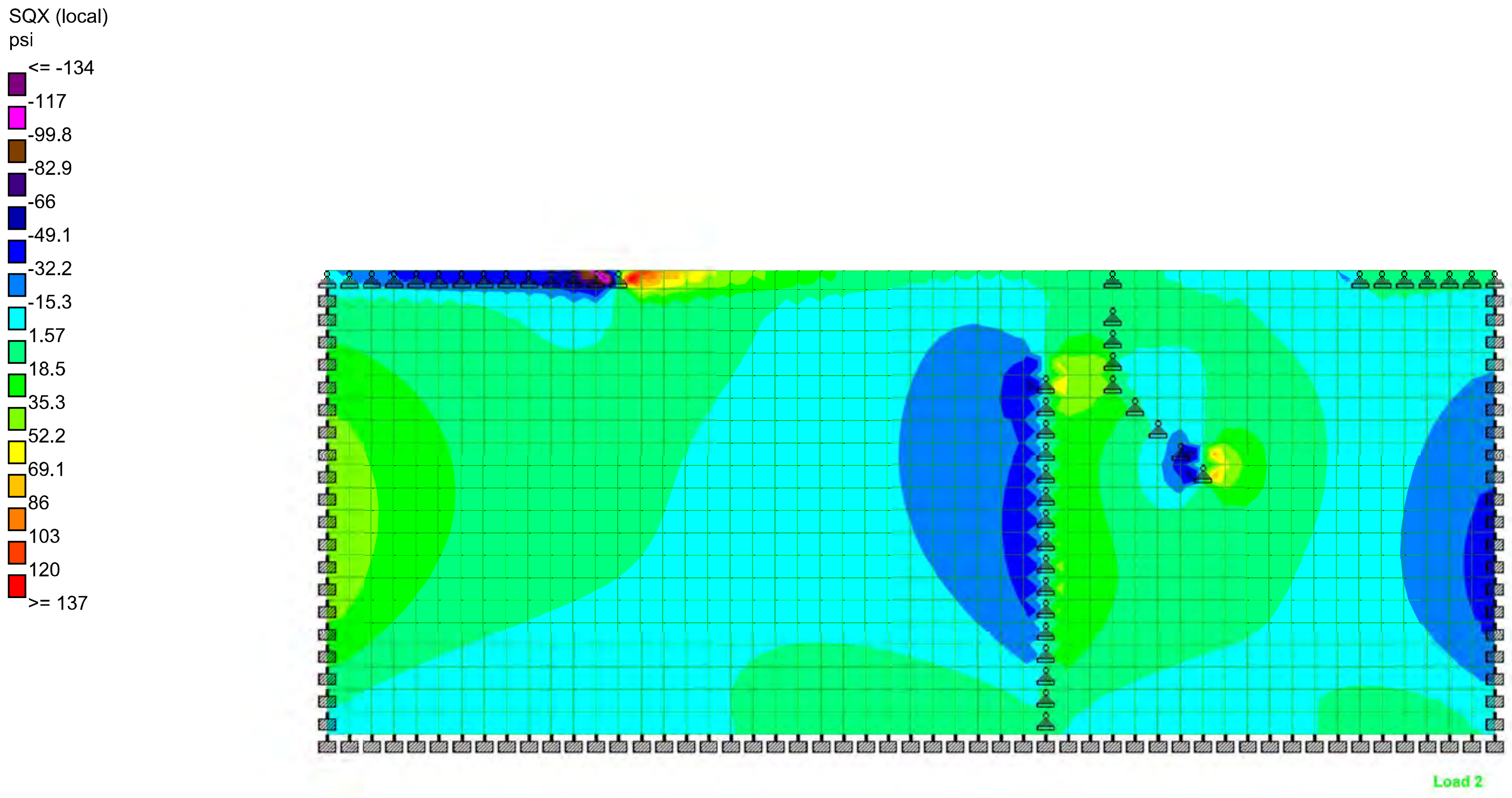
	Part Wall 3		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.2F+1.4E	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Sep-2017 10:11	



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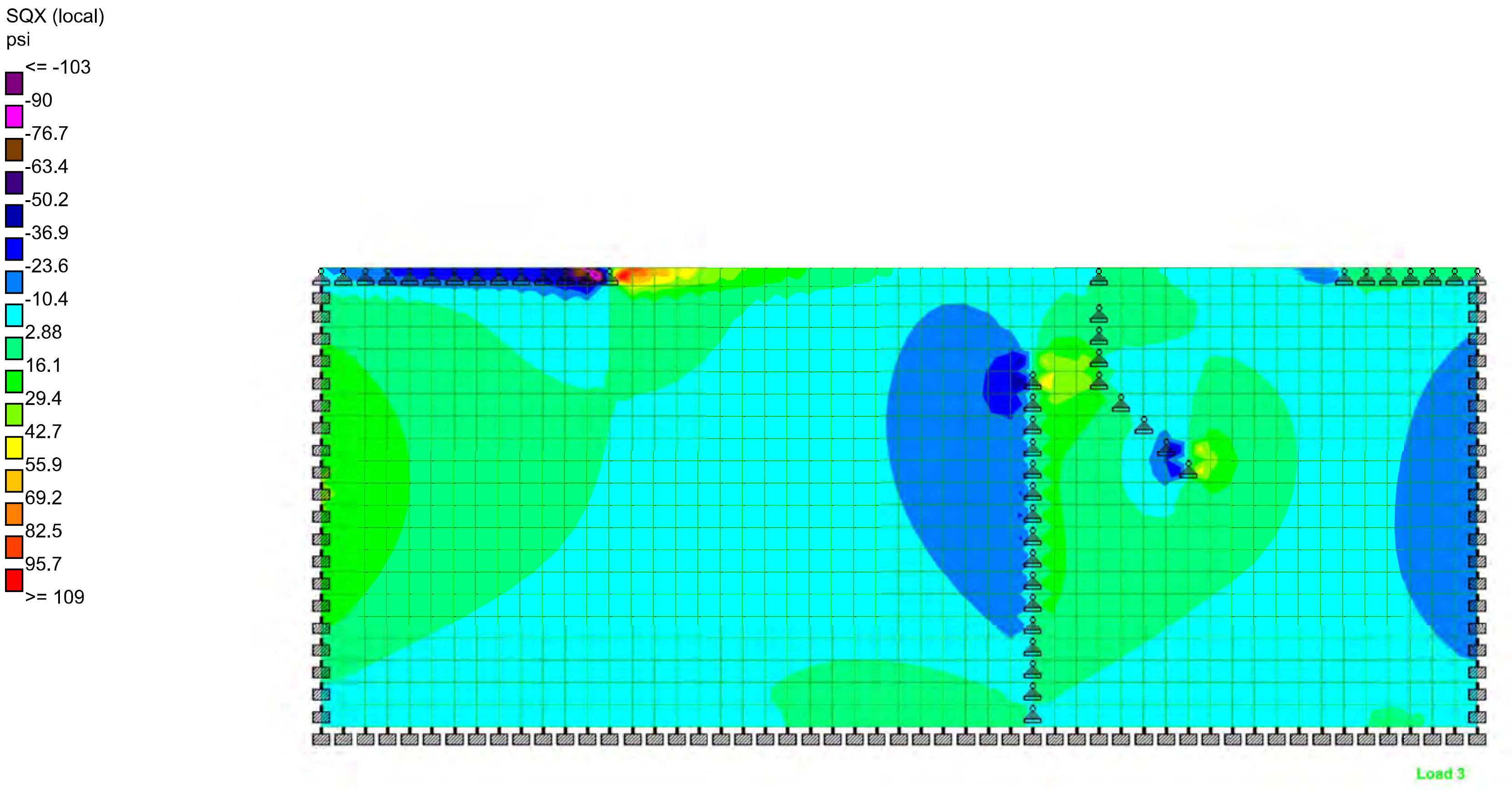
Part Wall 3			
Ref			
By	Date 04-Aug-17	Chd	
File Wall 3.std		Date/Time 09-Sep-2017 10:11	

Job Title Area 4 - ActiFlo

Load Case: 1.4E (Water 2-Sides)

Client Willamette River WTP



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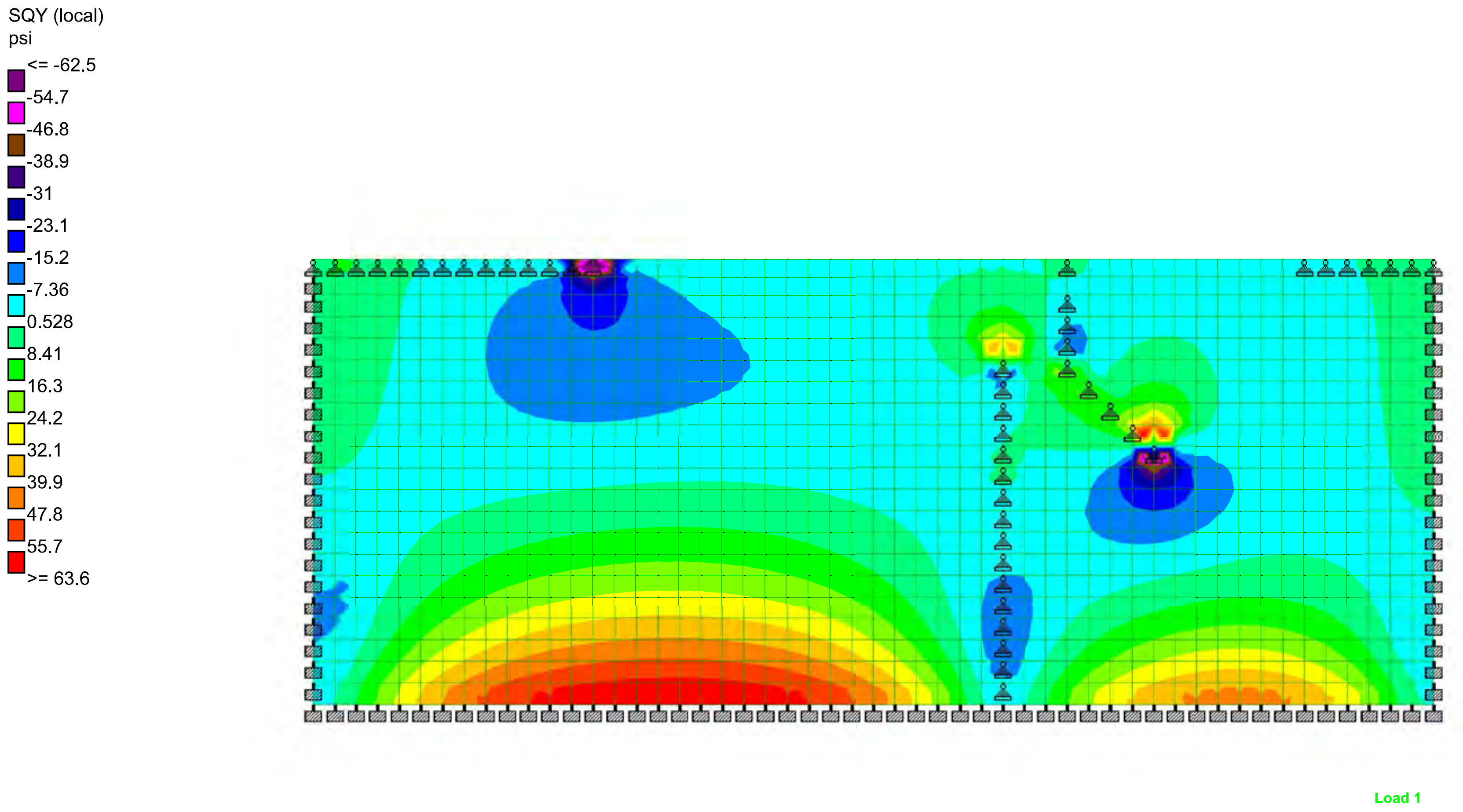
	Part Wall 3		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Aug-2017 15:20	



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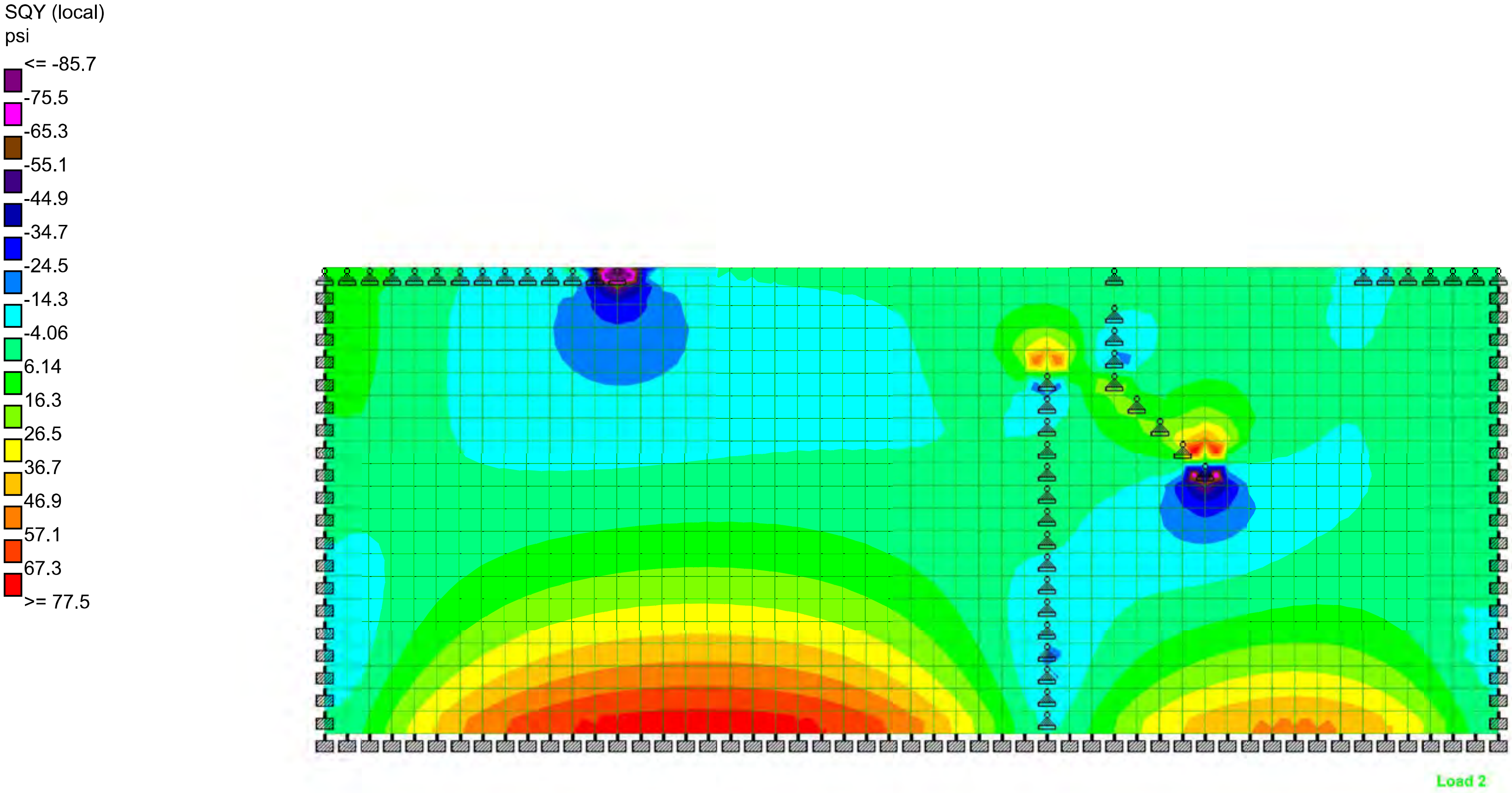
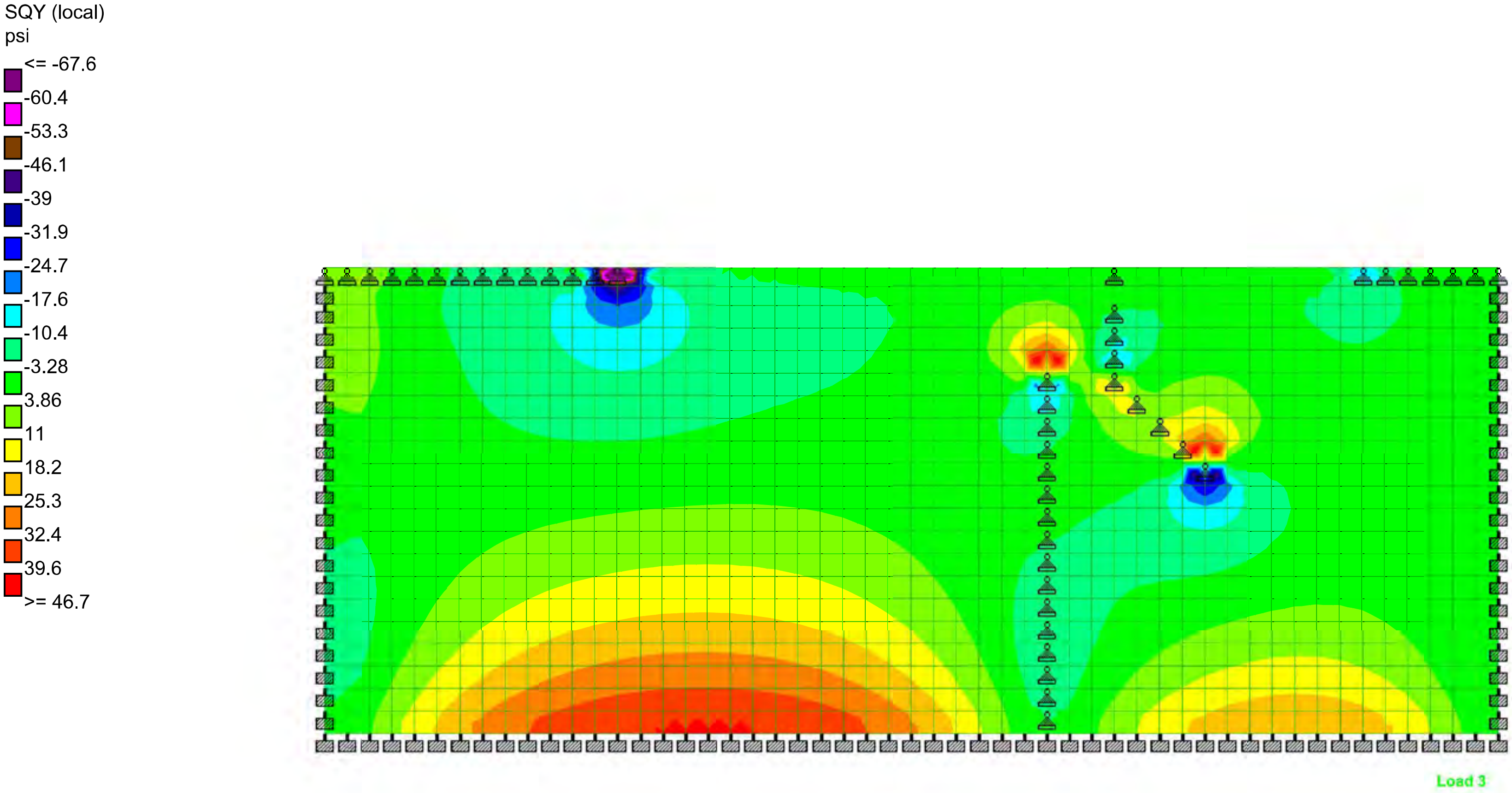
	Part Wall 3		
Job Title Area 4 - ActiFlo Load Case: 1.2F+1.4E	Ref		
	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Sep-2017 10:11	



Software licensed to Carollo Engineers CONNECTED User: Caleb Che	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 3		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4E (Water 2-Sides)	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 09-Sep-2017 10:11	



Area 4 - Actiflo™
Wall 4 - Moment & Shear

Horizontal Span - Ouside Face

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.0F-0.6H	1.00	3.10	3.10	18.50	***0.17***	0.00	14.51	***0.00***	***<- OK***
1.0F+1.4E-0.6H	1.00	4.23	4.23	18.50	***0.23***	0.00	14.51	***0.00***	***<- OK***
1.6(H+L)	1.41	14.75	20.80	18.50	***1.12***	6.88	14.51	***0.47***	***<- NG***
1.6H+1.4E	1.00	11.79	11.79	18.50	***0.64***	5.57	14.51	***0.38***	***<- OK***

Vertical Span (Mid-Height) - Outside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.0F-0.6H	1.00	7.63	7.63	27.50	***0.28***	0.00	14.51	***0.00***	***<- OK***
1.0F+1.4E-0.6H	1.00	10.39	10.39	27.50	***0.38***	0.00	14.51	***0.00***	***<- OK***

Vertical Span (Bottom) - Outside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.6(H+L)	1.41	31.34	44.20	51.50	***0.86***	11.13	14.51	***0.77***	***<- OK***
1.6H+1.4E	1.00	25.87	25.87	51.50	***0.50***	9.59	14.51	***0.66***	***<- OK***

Horizontal Span - Inside Face

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.0F-0.6H	1.00	8.95	8.95	13.00	***0.69***	3.85	14.51	***0.27***	***<- OK***
1.0F+1.4E-0.6H	1.00	12.25	12.25	13.00	***0.94***	5.37	14.51	***0.37***	***<- OK***
1.6(H+L)	1.41	4.67	6.59	13.00	***0.51***	0.00	14.51	***0.00***	***<- OK***
1.6H+1.4E	1.00	3.68	3.68	13.00	***0.28***	0.00	14.51	***0.00***	***<- OK***

Vertical Span (Mid-Height) - Inside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.6(H+L)	1.41	12.45	17.55	35.00	***0.50***	0.00	14.51	***0.00***	***<- OK***
1.6H+1.4E	1.00	10.06	10.06	35.00	***0.29***	0.00	14.51	***0.00***	***<- OK***

Vertical Span (Bottom) - Inside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.0F-0.6H	1.00	17.63	17.63	66.00	***0.27***	5.77	14.51	***0.40***	***<- OK***
1.0F+1.4E-0.6H	1.00	24.61	24.61	66.00	***0.37***	8.16	14.51	***0.56***	***<- OK***

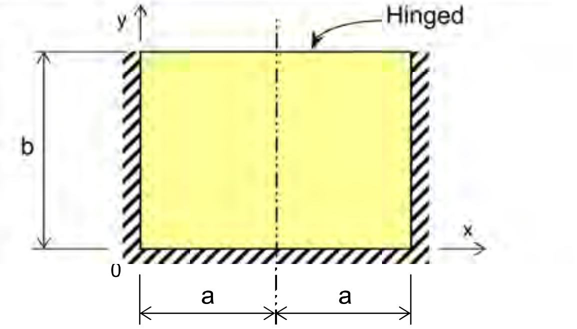
BY: C. Che **DATE:** Aug-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 4: Hydrostatic - Soil Static

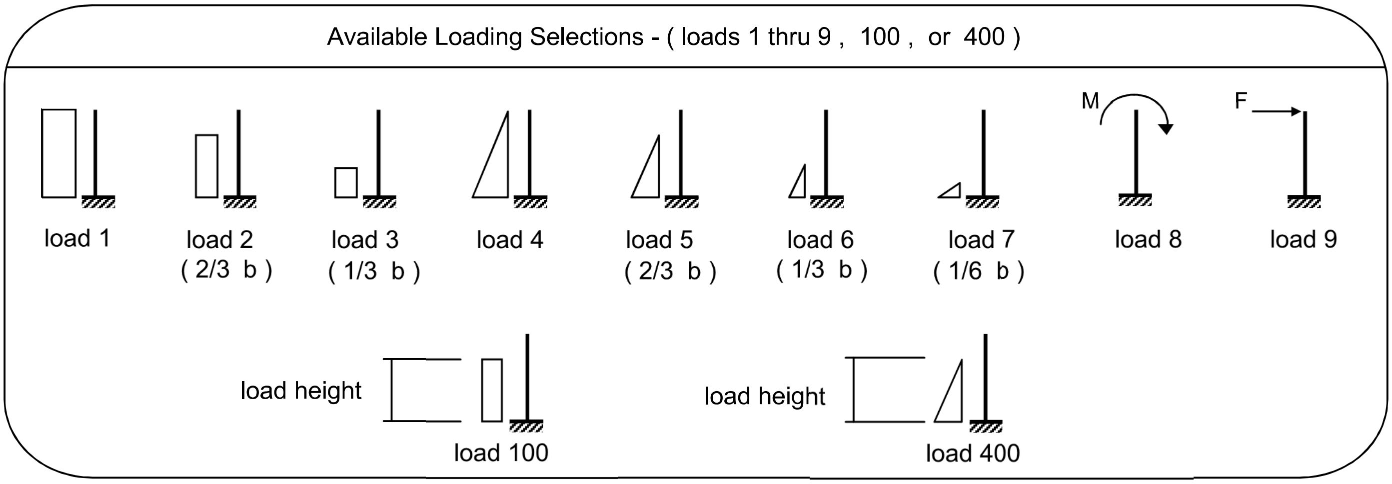
Rectangular Plate:

plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 19.67 = 39.34 ft
plate dimension, a = **19.67** ft
plate dimension, b = **20.67** ft

plate sides ratio, a/b = 0.9516





Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads 100 or 400	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**19.000**	**1.186**	**1**	**1**
B	**400**	**15.500**	**-0.853**	**0.6**	**0.6**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willametter River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 4 - Actiflo™	**JOB NO:**	10723A.10
DESIGN TASK:	Wall 4: Hydrostatic - Soil Static				

M_x - Moment Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
1.186	-0.853		
Moment Coefficient Multipliers			
506.717	-364.443		

Boundary Case 2

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0149	0.0095			7.54	-3.47			4.07	5.46	0.14	0.36
0	0.6	0.0252	0.0174			12.75	-6.34			6.41	8.95	0.23	0.36
0	0.4	0.0256	0.0195			12.98	-7.10			5.88	8.72	0.22	0.36
0	0.2	0.0131	0.0109			6.65	-3.96			2.69	4.27	0.11	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0037	0.0032			1.90	-1.18			0.72	1.19	0.03	0.36
0.4	0	0.0072	0.0060			3.65	-2.18			1.48	2.35	0.06	0.36
0.6	0	0.0093	0.0075			4.71	-2.75			1.96	3.06	0.08	0.36
0.8	0	0.0103	0.0083			5.23	-3.03			2.20	3.41	0.08	0.36
1	0	0.0107	0.0086			5.41	-3.12			2.29	3.54	0.09	0.36
1	0.2	-0.0016	-0.0016			-0.80	0.57			-0.23	-0.46	-0.01	-0.36
1	0.4	-0.0079	-0.0060			-4.02	2.19			-1.83	-2.70	-0.07	-0.36
1	0.6	-0.0086	-0.0059			-4.35	2.15			-2.20	-3.06	-0.08	-0.36
1	0.8	-0.0053	-0.0034			-2.68	1.23			-1.44	-1.94	-0.05	-0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.8	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.8	0.8	-0.0053	-0.0034			-2.69	1.23			-1.46	-1.95	-0.05	-0.36
0.8	0.6	-0.0086	-0.0059			-4.38	2.14			-2.24	-3.10	-0.08	-0.36
0.8	0.4	-0.0080	-0.0061			-4.08	2.22			-1.86	-2.75	-0.07	-0.36
0.8	0.2	-0.0018	-0.0017			-0.91	0.61			-0.30	-0.54	-0.01	-0.36

max negative moment, $M_{ux}(-)$ = -3.10 ft-k/ft

max negative steel req'd, $A_s(-)$ = -0.08 in^2/ft

minimum steel req'd = -0.36 in^2/ft

Use

max positive moment, $M_{ux}(+)$ = 8.95 ft-k/ft

max positive steel req'd, $A_s(+)$ = 0.23 in^2/ft

minimum steel req'd = 0.36 in^2/ft

Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 4: Hydrostatic - Soil Static

M_y - Moment Summary

	Loads: q , or M					SUMMARY	
a = 19.67	1.186	-0.853			Boundary Case 2		
b = 20.67	Moment Coefficient Multipliers					Final Moments	Reinforcing: (d = 9.5")
a / b = 0.9516	506.717	-364.443					

		Moment Coefficients				M_y Moments, ft-k/ft				M_y	M_{uy}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0030	0.0019			1.50	-0.70			0.80	1.08	0.03	0.36
0	0.6	0.0051	0.0035			2.56	-1.28			1.28	1.79	0.04	0.36
0	0.4	0.0051	0.0039			2.59	-1.41			1.18	1.74	0.04	0.36
0	0.2	0.0026	0.0022			1.33	-0.80			0.52	0.84	0.02	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0187	0.0161			9.50	-5.88			3.62	5.97	0.14	0.36
0.4	0	0.0359	0.0298			18.21	-10.87			7.34	11.69	0.28	0.37
0.6	0	0.0465	0.0378			23.54	-13.78			9.76	15.28	0.37	0.38
0.8	0	0.0517	0.0416			26.19	-15.17			11.02	17.09	0.41	0.38
1	0	0.0533	0.0428			26.99	-15.59			11.40	17.63	0.43	0.38
1	0.2	-0.0009	-0.0026			-0.45	0.95			0.50	0.12	0.00	0.36
1	0.4	-0.0211	-0.0166			-10.68	6.06			-4.61	-7.04	-0.17	-0.36
1	0.6	-0.0211	-0.0139			-10.67	5.06			-5.61	-7.63	-0.18	-0.36
1	0.8	-0.0120	-0.0068			-6.09	2.47			-3.62	-4.61	-0.11	-0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
1	0.4	-0.0211	-0.0166			-10.68	6.06			-4.61	-7.04	-0.17	-0.36
0.8	0.4	-0.0204	-0.0161			-10.33	5.88			-4.46	-6.81	-0.16	-0.36
0.6	0.4	-0.0181	-0.0144			-9.15	5.24			-3.91	-6.01	-0.14	-0.36
0.4	0.4	-0.0134	-0.0108			-6.78	3.92			-2.86	-4.43	-0.10	-0.36
0.2	0.4	-0.0055	-0.0046			-2.78	1.68			-1.11	-1.78	-0.04	-0.36

max negative moment, $M_{uy}(-)$ = -7.63 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.18 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 17.63 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.43 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 4: Hydrostatic - Soil Static

Shear Summary

		Loads: q , or M				Boundary Case 2	SUMMARY
a =	19.67	1.186	-0.853				Final Shears
b =	20.67	Shear Coefficient Multipliers					
a / b =	0.9516	24.515	-17.632				

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0632	-0.0414			-1.55	0.73			-0.82	-1.11	10.81
0	0.8	0.1004	0.0516			2.46	-0.91			1.55	1.92	10.81
0	0.6	0.1909	0.1217			4.68	-2.15			2.53	3.39	10.81
0	0.4	0.2393	0.1906			5.87	-3.36			2.51	3.85	10.81
0	0.2	0.1431	0.1364			3.51	-2.40			1.10	2.06	10.81
0	0.00	-0.0111	-0.0017			-0.27	0.03			-0.24	-0.25	10.81
0.2	0	0.1892	0.1809			4.64	-3.19			1.45	2.72	10.81
0.4	0	0.3061	0.2753			7.50	-4.85			2.65	4.59	10.81
0.6	0	0.3543	0.3116			8.69	-5.49			3.19	5.39	10.81
0.8	0	0.3724	0.3246			9.13	-5.72			3.40	5.69	10.81
1	0	0.3768	0.3277			9.24	-5.78			3.46	5.77	10.81
0.2	1	-0.0071	-0.0119			-0.17	0.21			0.04	-0.05	10.81
0.4	1	0.0520	0.0266			1.27	-0.47			0.81	0.99	10.81
0.6	1	0.0771	0.0437			1.89	-0.77			1.12	1.43	10.81
0.8	1	0.0863	0.0501			2.11	-0.88			1.23	1.58	10.81
1	1	0.0885	0.0516			2.17	-0.91			1.26	1.62	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in

maximum shear, V_u = 5.77 k/ft **OK**

$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

carollo
Engineers...Working Wonders With Water™

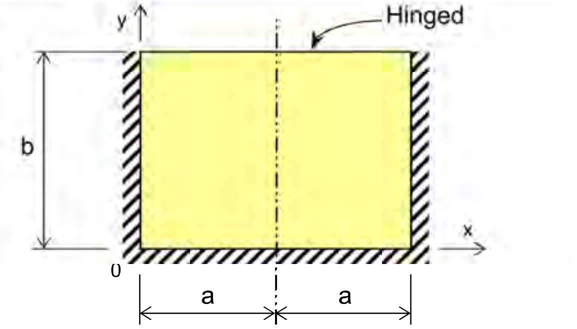
BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 4: Hydrodynami - Soil Static

Rectangular Plate:

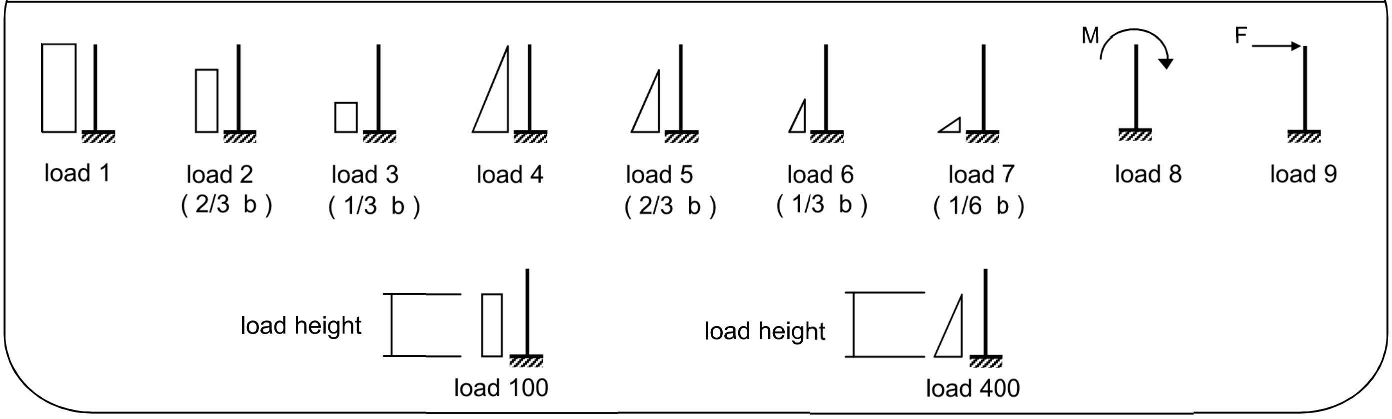
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 19.67 = 39.34 ft
plate dimension, a = **19.67** ft
plate dimension, b = **20.67** ft

plate sides ratio, a/b = 0.9516



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	for shear
A	**400**	**19.000**	**1.186**	**1**	**1**
B	**400**	**15.500**	**-0.853**	**0.6**	**0.6**
C	**400**	**19.000**	**0.066**	**1.4**	**1.4**
D	**400**	**19.000**	**0.153**	**1.4**	**1.4**

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 4: Hydrodynami - Soil Static

M_x - Moment Summary

a = 19.67
b = 20.67
a / b = 0.9516

	A	B	C	D
Loads: q , or M	1.186	-0.853	0.066	0.153
Moment Coefficient Multipliers	506.717	-364.443	28.198	65.369

Boundary Case 2

		Moment Coefficients				M_x Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0	0.8	0.0149	0.0095	0.0149	0.0149	7.54	-3.47	0.42	0.97	5.46	7.41	0.19	0.36
0	0.6	0.0252	0.0174	0.0252	0.0252	12.75	-6.34	0.71	1.64	8.77	12.25	0.31	0.36
0	0.4	0.0256	0.0195	0.0256	0.0256	12.98	-7.10	0.72	1.67	8.27	12.07	0.31	0.36
0	0.2	0.0131	0.0109	0.0131	0.0131	6.65	-3.96	0.37	0.86	3.92	5.99	0.15	0.36
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0.2	0	0.0037	0.0032	0.0037	0.0037	1.90	-1.18	0.11	0.24	1.07	1.68	0.04	0.36
0.4	0	0.0072	0.0060	0.0072	0.0072	3.65	-2.18	0.20	0.47	2.15	3.29	0.08	0.36
0.6	0	0.0093	0.0075	0.0093	0.0093	4.71	-2.75	0.26	0.61	2.83	4.28	0.11	0.36
0.8	0	0.0103	0.0083	0.0103	0.0103	5.23	-3.03	0.29	0.67	3.17	4.77	0.12	0.36
1	0	0.0107	0.0086	0.0107	0.0107	5.41	-3.12	0.30	0.70	3.29	4.94	0.12	0.36
1	0.2	-0.0016	-0.0016	-0.0016	-0.0016	-0.80	0.57	-0.04	-0.10	-0.38	-0.67	-0.02	-0.36
1	0.4	-0.0079	-0.0060	-0.0079	-0.0079	-4.02	2.19	-0.22	-0.52	-2.57	-3.74	-0.09	-0.36
1	0.6	-0.0086	-0.0059	-0.0086	-0.0086	-4.35	2.15	-0.24	-0.56	-3.01	-4.19	-0.10	-0.36
1	0.8	-0.0053	-0.0034	-0.0053	-0.0053	-2.68	1.23	-0.15	-0.35	-1.94	-2.63	-0.07	-0.36
1	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0.8	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0.8	0.8	-0.0053	-0.0034	-0.0053	-0.0053	-2.69	1.23	-0.15	-0.35	-1.95	-2.64	-0.07	-0.36
0.8	0.6	-0.0086	-0.0059	-0.0086	-0.0086	-4.38	2.14	-0.24	-0.57	-3.05	-4.23	-0.11	-0.36
0.8	0.4	-0.0080	-0.0061	-0.0080	-0.0080	-4.08	2.22	-0.23	-0.53	-2.61	-3.80	-0.09	-0.36
0.8	0.2	-0.0018	-0.0017	-0.0018	-0.0018	-0.91	0.61	-0.05	-0.12	-0.46	-0.78	-0.02	-0.36

max negative moment, $M_{ux}(-)$ = -4.23 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.11 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 12.25 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.31 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY:	C. Che	**DATE:**	Sep-17	**CLIENT**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™	**JOB NO:**	10723A.10
DESIGN TASK:					Wall 4: Hydrodynami - Soil Static		

M_y - Moment Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
1.186	-0.853	0.066	0.153
Moment Coefficient Multipliers			
506.717	-364.443	28.198	65.369

Boundary Case 2

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0	0.8	0.0030	0.0019	0.0030	0.0030	1.50	-0.70	0.08	0.19	1.08	1.47	0.03	0.36
0	0.6	0.0051	0.0035	0.0051	0.0051	2.56	-1.28	0.14	0.33	1.76	2.46	0.06	0.36
0	0.4	0.0051	0.0039	0.0051	0.0051	2.59	-1.41	0.14	0.33	1.65	2.41	0.06	0.36
0	0.2	0.0026	0.0022	0.0026	0.0026	1.33	-0.80	0.07	0.17	0.77	1.19	0.03	0.36
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0.2	0	0.0187	0.0161	0.0187	0.0187	9.50	-5.88	0.53	1.23	5.37	8.42	0.20	0.36
0.4	0	0.0359	0.0298	0.0359	0.0359	18.21	-10.87	1.01	2.35	10.70	16.40	0.40	0.38
0.6	0	0.0465	0.0378	0.0465	0.0465	23.54	-13.78	1.31	3.04	14.11	21.36	0.52	0.38
0.8	0	0.0517	0.0416	0.0517	0.0517	26.19	-15.17	1.46	3.38	15.85	23.86	0.58	0.38
1	0	0.0533	0.0428	0.0533	0.0533	26.99	-15.59	1.50	3.48	16.38	24.61	0.60	0.38
1	0.2	-0.0009	-0.0026	-0.0009	-0.0009	-0.45	0.95	-0.03	-0.06	0.42	0.00	0.00	0.36
1	0.4	-0.0211	-0.0166	-0.0211	-0.0211	-10.68	6.06	-0.59	-1.38	-6.58	-9.80	-0.23	-0.36
1	0.6	-0.0211	-0.0139	-0.0211	-0.0211	-10.67	5.06	-0.59	-1.38	-7.58	-10.39	-0.25	-0.36
1	0.8	-0.0120	-0.0068	-0.0120	-0.0120	-6.09	2.47	-0.34	-0.79	-4.75	-6.19	-0.15	-0.36
1	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
1	0.4	-0.0211	-0.0166	-0.0211	-0.0211	-10.68	6.06	-0.59	-1.38	-6.58	-9.80	-0.23	-0.36
0.8	0.4	-0.0204	-0.0161	-0.0204	-0.0204	-10.33	5.88	-0.58	-1.33	-6.37	-9.48	-0.23	-0.36
0.6	0.4	-0.0181	-0.0144	-0.0181	-0.0181	-9.15	5.24	-0.51	-1.18	-5.60	-8.38	-0.20	-0.36
0.4	0.4	-0.0134	-0.0108	-0.0134	-0.0134	-6.78	3.92	-0.38	-0.87	-4.11	-6.18	-0.15	-0.36
0.2	0.4	-0.0055	-0.0046	-0.0055	-0.0055	-2.78	1.68	-0.15	-0.36	-1.62	-2.50	-0.06	-0.36

max negative moment, $M_{uy}(-)$ = -10.39 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.25 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 24.61 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.60 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 4: Hydrodynami - Soil Static

Shear Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
1.186	-0.853	0.066	0.153
Shear Coefficient Multipliers			
24.515	-17.632	1.364	3.163

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0632	-0.0414	-0.0632	-0.0632	-1.55	0.73	-0.09	-0.20	-1.11	-1.51	10.81
0	0.8	0.1004	0.0516	0.1004	0.1004	2.46	-0.91	0.14	0.32	2.01	2.55	10.81
0	0.6	0.1909	0.1217	0.1909	0.1909	4.68	-2.15	0.26	0.60	3.40	4.60	10.81
0	0.4	0.2393	0.1906	0.2393	0.2393	5.87	-3.36	0.33	0.76	3.59	5.37	10.81
0	0.2	0.1431	0.1364	0.1431	0.1431	3.51	-2.40	0.20	0.45	1.75	2.97	10.81
0	0.00	-0.0111	-0.0017	-0.0111	-0.0111	-0.27	0.03	-0.02	-0.04	-0.29	-0.33	10.81
0.2	0	0.1892	0.1809	0.1892	0.1892	4.64	-3.19	0.26	0.60	2.30	3.92	10.81
0.4	0	0.3061	0.2753	0.3061	0.3061	7.50	-4.85	0.42	0.97	4.03	6.53	10.81
0.6	0	0.3543	0.3116	0.3543	0.3543	8.69	-5.49	0.48	1.12	4.80	7.63	10.81
0.8	0	0.3724	0.3246	0.3724	0.3724	9.13	-5.72	0.51	1.18	5.09	8.05	10.81
1	0	0.3768	0.3277	0.3768	0.3768	9.24	-5.78	0.51	1.19	5.16	8.16	10.81
0.2	1	-0.0071	-0.0119	-0.0071	-0.0071	-0.17	0.21	-0.01	-0.02	0.00	-0.09	10.81
0.4	1	0.0520	0.0266	0.0520	0.0520	1.27	-0.47	0.07	0.16	1.04	1.32	10.81
0.6	1	0.0771	0.0437	0.0771	0.0771	1.89	-0.77	0.11	0.24	1.47	1.92	10.81
0.8	1	0.0863	0.0501	0.0863	0.0863	2.11	-0.88	0.12	0.27	1.62	2.13	10.81
1	1	0.0885	0.0516	0.0885	0.0885	2.17	-0.91	0.12	0.28	1.66	2.18	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 8.16 k/ft **OK**
$\phi V_c = \phi*2*(f\,'c)^{1/2}*b*d =$ (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water™

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP
CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™
DESIGN TASK:					Wall 4 - Soil Static

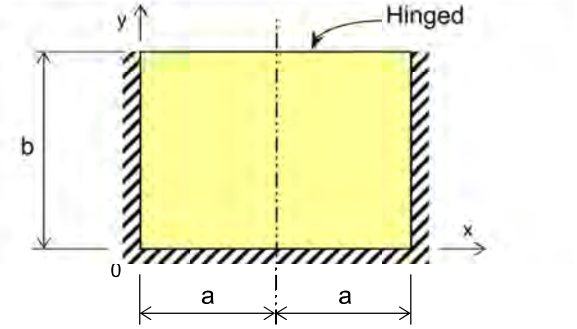
SHEET:
JOB NO: 10721A.10

Rectangular Plate:

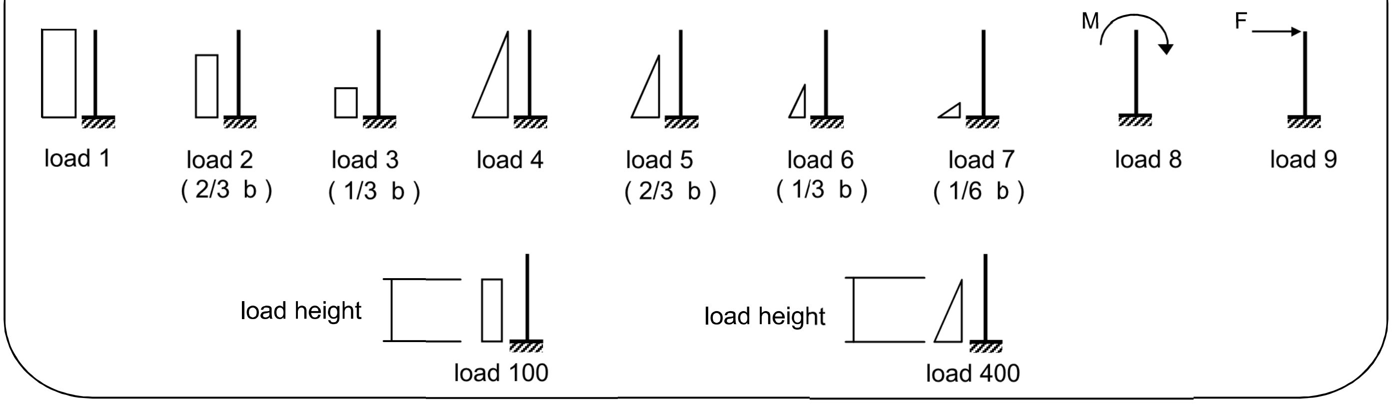
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 19.67 = 39.34 ft
plate dimension, a = **19.67** ft
plate dimension, b = **20.67** ft

plate sides ratio, a/b = 0.9516



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	for shear
A	**400**	**15.500**	**0.853**	**2.25**	**1.6**
B	**100**	**15.500**	**0.100**	**2.25**	**1.6**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY:	C. Che	**DATE:** Aug-17	**CLIENT** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:			Wall 4 - Soil Static		

M_x - Moment Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
0.853	0.100		
Moment Coefficient Multipliers			
364.443	42.725		

Boundary Case 2

SUMMARY

x / a	y / b	Moment Coefficients A	B	C	D	M_x Moments, ft-k/ft A	B	C	D	Final Moments M_x ft-k/ft	M_{ux} ft-k/ft	Reinforcing: (d = 9") $A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0095	0.0309			3.47	1.32			4.79	10.78	0.27	0.36
0	0.6	0.0174	0.0524			6.34	2.24			8.58	19.30	0.50	0.36
0	0.4	0.0195	0.0495			7.10	2.11			9.22	20.74	0.54	0.36
0	0.2	0.0109	0.0221			3.96	0.95			4.91	11.04	0.28	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0032	0.0058			1.18	0.25			1.42	3.20	0.08	0.36
0.4	0	0.0060	0.0120			2.18	0.51			2.69	6.05	0.15	0.36
0.6	0	0.0075	0.0160			2.75	0.68			3.43	7.73	0.19	0.36
0.8	0	0.0083	0.0181			3.03	0.77			3.80	8.55	0.22	0.36
1	0	0.0086	0.0187			3.12	0.80			3.92	8.82	0.22	0.36
1	0.2	-0.0016	-0.0018			-0.57	-0.08			-0.64	-1.45	-0.04	-0.36
1	0.4	-0.0060	-0.0154			-2.19	-0.66			-2.85	-6.41	-0.16	-0.36
1	0.6	-0.0059	-0.0182			-2.15	-0.78			-2.92	-6.58	-0.16	-0.36
1	0.8	-0.0034	-0.0109			-1.23	-0.46			-1.70	-3.82	-0.10	-0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.8	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.8	0.8	-0.0034	-0.0108			-1.23	-0.46			-1.69	-3.80	-0.09	-0.36
0.8	0.6	-0.0059	-0.0183			-2.14	-0.78			-2.92	-6.58	-0.16	-0.36
0.8	0.4	-0.0061	-0.0157			-2.22	-0.67			-2.89	-6.50	-0.16	-0.36
0.8	0.2	-0.0017	-0.0022			-0.61	-0.10			-0.71	-1.59	-0.04	-0.36

max negative moment, $M_{ux}(-)$ = -6.58 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.16 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 20.74 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.54 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 4 - Soil Static

M_y - Moment Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
0.853	0.100		
Moment Coefficient Multipliers			
364.443	42.725		

Boundary Case 2

SUMMARY

Final Moments — Reinforcing: (d = 9.5")

		Moment Coefficients				M_y Moments, ft-k/ft				M_y	M_{uy}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0019	0.0062			0.70	0.26			0.97	2.18	0.05	0.36
0	0.6	0.0035	0.0105			1.28	0.45			1.73	3.88	0.09	0.36
0	0.4	0.0039	0.0099			1.41	0.42			1.84	4.13	0.10	0.36
0	0.2	0.0022	0.0044			0.80	0.19			0.99	2.23	0.05	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0161	0.0295			5.88	1.26			7.14	16.07	0.39	0.38
0.4	0	0.0298	0.0601			10.87	2.57			13.44	30.23	0.75	0.38
0.6	0	0.0378	0.0801			13.78	3.42			17.20	38.71	0.98	0.38
0.8	0	0.0416	0.0904			15.17	3.86			19.03	42.82	1.09	0.38
1	0	0.0428	0.0935			15.59	3.99			19.59	44.07	1.13	0.38
1	0.2	-0.0026	0.0044			-0.95	0.19			-0.76	-1.72	-0.04	-0.36
1	0.4	-0.0166	-0.0401			-6.06	-1.71			-7.78	-17.50	-0.42	-0.38
1	0.6	-0.0139	-0.0466			-5.06	-1.99			-7.05	-15.87	-0.38	-0.38
1	0.8	-0.0068	-0.0249			-2.47	-1.06			-3.53	-7.95	-0.19	-0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
1	0.4	-0.0166	-0.0401			-6.06	-1.71			-7.78	-17.50	-0.42	-0.38
0.8	0.4	-0.0161	-0.0387			-5.88	-1.65			-7.53	-16.94	-0.41	-0.38
0.6	0.4	-0.0144	-0.0342			-5.24	-1.46			-6.70	-15.07	-0.36	-0.38
0.4	0.4	-0.0108	-0.0251			-3.92	-1.07			-4.99	-11.23	-0.27	-0.36
0.2	0.4	-0.0046	-0.0101			-1.68	-0.43			-2.11	-4.74	-0.11	-0.36

max negative moment, $M_{uy}(-)$ = -17.50 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.42 in^2/ft
minimum steel req'd = -0.38 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 44.07 ft-k/ft
max positive steel req'd, $A_s(+)$ = 1.13 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use

Engineers...Working Wonders With Water™

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP
CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™
DESIGN TASK:					Wall 4 - Soil Static

SHEET:
JOB NO: 10721A.10

Shear Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
0.853	0.100		
Shear Coefficient Multipliers			
17.632	2.067		

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c	
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft	
0	1	-0.0414	-0.1279			-0.73	-0.26			-0.99	-1.59	10.81	
0	0.8	0.0516	0.2002			0.91	0.41			1.32	2.12	10.81	
0	0.6	0.1217	0.4431			2.15	0.92			3.06	4.90	10.81	
0	0.4	0.1906	0.4539			3.36	0.94			4.30	6.88	10.81	
0	0.2	0.1364	0.1762			2.40	0.36			2.77	4.43	10.81	
0	0.00	-0.0017	-0.0486			-0.03	-0.10			-0.13	-0.21	10.81	
0.2	0	0.1809	0.2280			3.19	0.47			3.66	5.86	10.81	
0.4	0	0.2753	0.4329			4.85	0.89			5.75	9.20	10.81	
0.6	0	0.3116	0.5256			5.49	1.09			6.58	10.53	10.81	
0.8	0	0.3246	0.5619			5.72	1.16			6.89	11.02	10.81	NG
1	0	0.3277	0.5711			5.78	1.18			6.96	11.13	10.81	NG
0.2	1	-0.0119	-0.0080			-0.21	-0.02			-0.23	-0.36	10.81	
0.4	1	0.0266	0.1144			0.47	0.24			0.70	1.13	10.81	
0.6	1	0.0437	0.1659			0.77	0.34			1.11	1.78	10.81	
0.8	1	0.0501	0.1848			0.88	0.38			1.27	2.02	10.81	
1	1	0.0516	0.1893			0.91	0.39			1.30	2.08	10.81	

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 11.13 k/ft
$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d =$ (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

SHEAR NOT SATISFIED ! , CHANGE PLATE THICKNESS, or CHECK SHEAR AT DISTANCE "d".

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water™

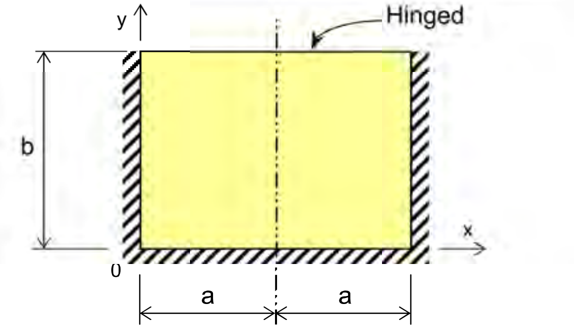
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 4 - Soil EQ

Rectangular Plate:

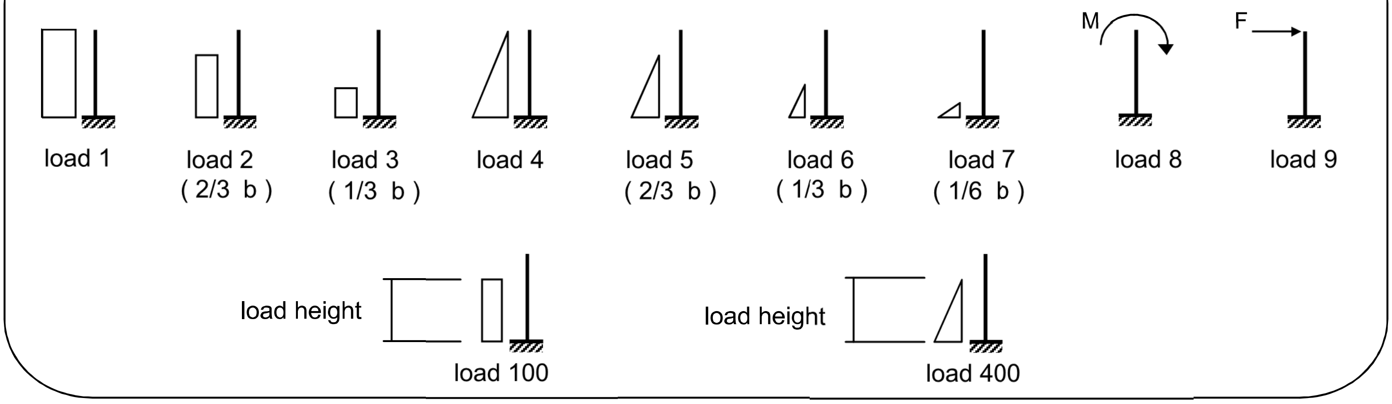
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 19.67 = 39.34 ft
plate dimension, a = **19.67** ft
plate dimension, b = **20.67** ft

plate sides ratio, a/b = 0.9516



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads 100 or 400	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors	
				for moment	for shear
A	**400**	**15.500**	**0.853**	**1.6**	**1.6**
B	**400**	**15.500**	**0.412**	**1.4**	**1.4**
C	**400**	**15.500**	**-0.376**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 4 - Soil EQ

M_x - Moment Summary

		Loads: q , or M				Boundary Case 2				SUMMARY			
a = 19.67		0.853	0.412	-0.376						Final Moments		Reinforcing: (d = 9")	
b = 20.67		Moment Coefficient Multipliers											
a / b = 0.9516		364.443	176.027	-160.646									
		Moment Coefficients				M_x Moments, ft-k/ft				M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0	0.8	0.0095	0.0095	0.0095		3.47	1.68	-1.53		3.62	5.76	0.14	0.36
0	0.6	0.0174	0.0174	0.0174		6.34	3.06	-2.79		6.60	10.51	0.27	0.36
0	0.4	0.0195	0.0195	0.0195		7.10	3.43	-3.13		7.40	11.79	0.30	0.36
0	0.2	0.0109	0.0109	0.0109		3.96	1.91	-1.75		4.13	6.57	0.16	0.36
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.2	0	0.0032	0.0032	0.0032		1.18	0.57	-0.52		1.22	1.95	0.05	0.36
0.4	0	0.0060	0.0060	0.0060		2.18	1.05	-0.96		2.27	3.61	0.09	0.36
0.6	0	0.0075	0.0075	0.0075		2.75	1.33	-1.21		2.87	4.56	0.11	0.36
0.8	0	0.0083	0.0083	0.0083		3.03	1.46	-1.34		3.16	5.03	0.13	0.36
1	0	0.0086	0.0086	0.0086		3.12	1.51	-1.38		3.25	5.18	0.13	0.36
1	0.2	-0.0016	-0.0016	-0.0016		-0.57	-0.27	0.25		-0.59	-0.94	-0.02	-0.36
1	0.4	-0.0060	-0.0060	-0.0060		-2.19	-1.06	0.97		-2.28	-3.63	-0.09	-0.36
1	0.6	-0.0059	-0.0059	-0.0059		-2.15	-1.04	0.95		-2.24	-3.56	-0.09	-0.36
1	0.8	-0.0034	-0.0034	-0.0034		-1.23	-0.60	0.54		-1.28	-2.04	-0.05	-0.36
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.8	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.8	0.8	-0.0034	-0.0034	-0.0034		-1.23	-0.59	0.54		-1.28	-2.04	-0.05	-0.36
0.8	0.6	-0.0059	-0.0059	-0.0059		-2.14	-1.03	0.94		-2.23	-3.55	-0.09	-0.36
0.8	0.4	-0.0061	-0.0061	-0.0061		-2.22	-1.07	0.98		-2.31	-3.68	-0.09	-0.36
0.8	0.2	-0.0017	-0.0017	-0.0017		-0.61	-0.30	0.27		-0.64	-1.02	-0.03	-0.36

max negative moment, $M_{ux}(-)$ = -3.68 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.09 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 11.79 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.30 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP
CHKD:		**DESCRIPTION:**			Area 4 - Actiflo™
DESIGN TASK:					Wall 4 - Soil EQ

SHEET:

JOB NO: 10721A.10

M_y - Moment Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
0.853	0.412	-0.376	
Moment Coefficient Multipliers			
364.443	176.027	-160.646	

Boundary Case 2

SUMMARY

x / a	y / b	Moment Coefficients A	B	C	D	M_y Moments, ft-k/ft A	B	C	D	Final Moments M_y ft-k/ft	M_{uy} ft-k/ft	Reinforcing: (d = 9.5") $A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0	0.8	0.0019	0.0019	0.0019		0.70	0.34	-0.31		0.73	1.17	0.03	0.36
0	0.6	0.0035	0.0035	0.0035		1.28	0.62	-0.56		1.33	2.12	0.05	0.36
0	0.4	0.0039	0.0039	0.0039		1.41	0.68	-0.62		1.47	2.34	0.06	0.36
0	0.2	0.0022	0.0022	0.0022		0.80	0.39	-0.35		0.84	1.33	0.03	0.36
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.2	0	0.0161	0.0161	0.0161		5.88	2.84	-2.59		6.13	9.76	0.23	0.36
0.4	0	0.0298	0.0298	0.0298		10.87	5.25	-4.79		11.33	18.03	0.44	0.38
0.6	0	0.0378	0.0378	0.0378		13.78	6.66	-6.07		14.36	22.86	0.56	0.38
0.8	0	0.0416	0.0416	0.0416		15.17	7.33	-6.69		15.81	25.17	0.62	0.38
1	0	0.0428	0.0428	0.0428		15.59	7.53	-6.87		16.25	25.87	0.64	0.38
1	0.2	-0.0026	-0.0026	-0.0026		-0.95	-0.46	0.42		-0.99	-1.58	-0.04	-0.36
1	0.4	-0.0166	-0.0166	-0.0166		-6.06	-2.93	2.67		-6.32	-10.06	-0.24	-0.36
1	0.6	-0.0139	-0.0139	-0.0139		-5.06	-2.44	2.23		-5.27	-8.40	-0.20	-0.36
1	0.8	-0.0068	-0.0068	-0.0068		-2.47	-1.19	1.09		-2.57	-4.10	-0.10	-0.36
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
1	0.4	-0.0166	-0.0166	-0.0166		-6.06	-2.93	2.67		-6.32	-10.06	-0.24	-0.36
0.8	0.4	-0.0161	-0.0161	-0.0161		-5.88	-2.84	2.59		-6.12	-9.75	-0.23	-0.36
0.6	0.4	-0.0144	-0.0144	-0.0144		-5.24	-2.53	2.31		-5.46	-8.69	-0.21	-0.36
0.4	0.4	-0.0108	-0.0108	-0.0108		-3.92	-1.89	1.73		-4.09	-6.50	-0.15	-0.36
0.2	0.4	-0.0046	-0.0046	-0.0046		-1.68	-0.81	0.74		-1.75	-2.78	-0.07	-0.36

max negative moment, $M_{uy}(-)$ = -10.06 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.24 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 25.87 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.64 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use

Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 4 - Soil EQ

Shear Summary

a = 19.67
b = 20.67
a / b = 0.9516

Loads: q , or M			
0.853	0.412	-0.376	
Shear Coefficient Multipliers			
17.632	8.516	-7.772	

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0414	-0.0414	-0.0414		-0.73	-0.35	0.32		-0.76	-1.21	10.81
0	0.8	0.0516	0.0516	0.0516		0.91	0.44	-0.40		0.95	1.51	10.81
0	0.6	0.1217	0.1217	0.1217		2.15	1.04	-0.95		2.24	3.56	10.81
0	0.4	0.1906	0.1906	0.1906		3.36	1.62	-1.48		3.50	5.57	10.81
0	0.2	0.1364	0.1364	0.1364		2.40	1.16	-1.06		2.51	3.99	10.81
0	0.00	-0.0017	-0.0017	-0.0017		-0.03	-0.01	0.01		-0.03	-0.05	10.81
0.2	0	0.1809	0.1809	0.1809		3.19	1.54	-1.41		3.32	5.29	10.81
0.4	0	0.2753	0.2753	0.2753		4.85	2.34	-2.14		5.06	8.05	10.81
0.6	0	0.3116	0.3116	0.3116		5.49	2.65	-2.42		5.73	9.12	10.81
0.8	0	0.3246	0.3246	0.3246		5.72	2.76	-2.52		5.97	9.50	10.81
1	0	0.3277	0.3277	0.3277		5.78	2.79	-2.55		6.02	9.59	10.81
0.2	1	-0.0119	-0.0119	-0.0119		-0.21	-0.10	0.09		-0.22	-0.35	10.81
0.4	1	0.0266	0.0266	0.0266		0.47	0.23	-0.21		0.49	0.78	10.81
0.6	1	0.0437	0.0437	0.0437		0.77	0.37	-0.34		0.80	1.28	10.81
0.8	1	0.0501	0.0501	0.0501		0.88	0.43	-0.39		0.92	1.47	10.81
1	1	0.0516	0.0516	0.0516		0.91	0.44	-0.40		0.95	1.51	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 9.59 k/ft **OK**
$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Area 4 - Actiflo™
Wall 5 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	5.55	8.94	13.00	***0.69***	34	126	***0.27***	***<- OK***
1.2F+1.4E	1.00	6.92	6.92	13.00	***0.53***	42	126	***0.33***	***<- OK***
1.4E (Water 2-Sides)	1.00	4.48	4.48	13.00	***0.34***	25	126	***0.20***	***<- OK***

Vertical Span (Mid-Height)

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	2.00	3.22	14.50	***0.22***	0	126	***0.00***	***<- OK***
1.2F+1.4E	1.00	2.34	2.34	14.50	***0.16***	0	126	***0.00***	***<- OK***
1.4E (Water 2-Sides)	1.00	1.25	1.25	14.50	***0.09***	0	126	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	4.60	7.41	14.50	***0.51***	35	126	***0.28***	***<- OK***
1.2F+1.4E	1.00	5.55	5.55	14.50	***0.38***	42	126	***0.33***	***<- OK***
1.4E (Water 2-Sides)	1.00	3.18	3.18	14.50	***0.22***	23	126	***0.18***	***<- OK***

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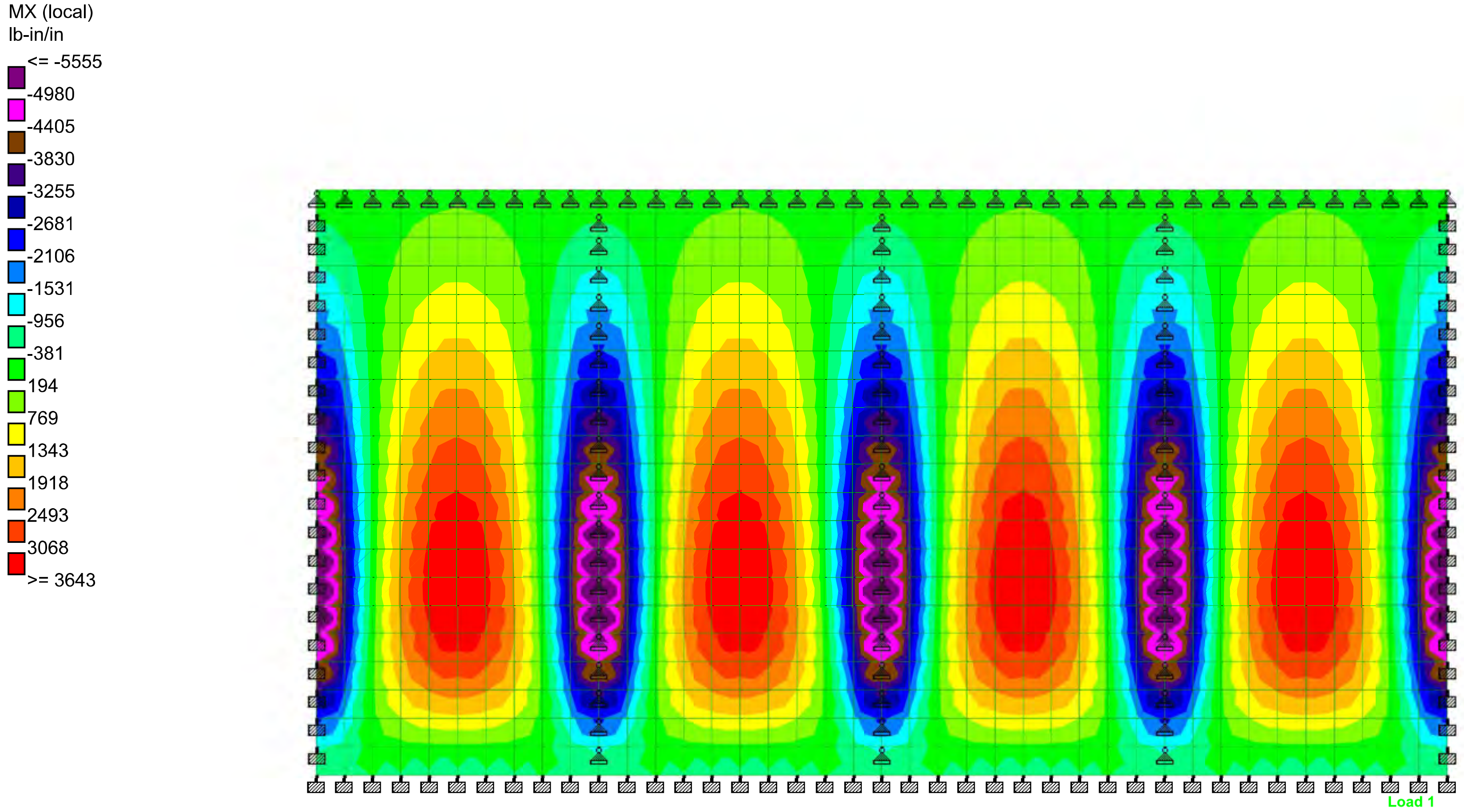
Job Title	Area 4 - ActiFlo Load Case: 1.4F	Job No 10721A.10	Sheet No 1	Rev
		Part Wall 5		
		Ref		
		By	Date 04-Aug-17	Chd
Client	Willamette River WTP	File Wall 5.std	Date/Time 09-Aug-2017 15:39	



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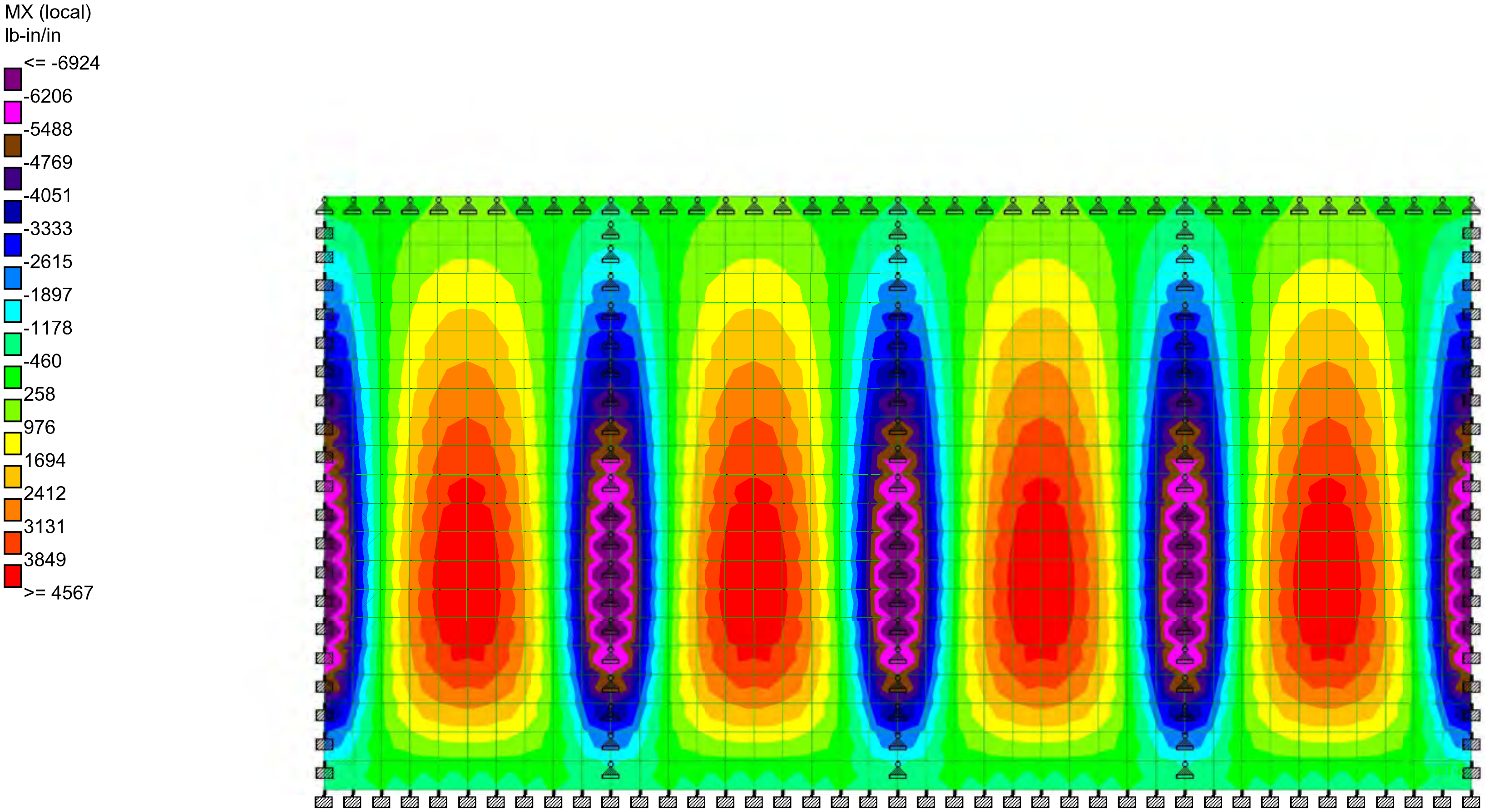
Job Title Area 4 - ActiFlo Load Case: 1.2F+1.4E	Job No 10721A.10		Sheet No 1		Rev
	Part Wall 5				
	Ref				
	By		Date 04-Aug-17		Chd
Client Willametter River WTP	File Wall 5.std		Date/Time 09-Sep-2017 21:45		



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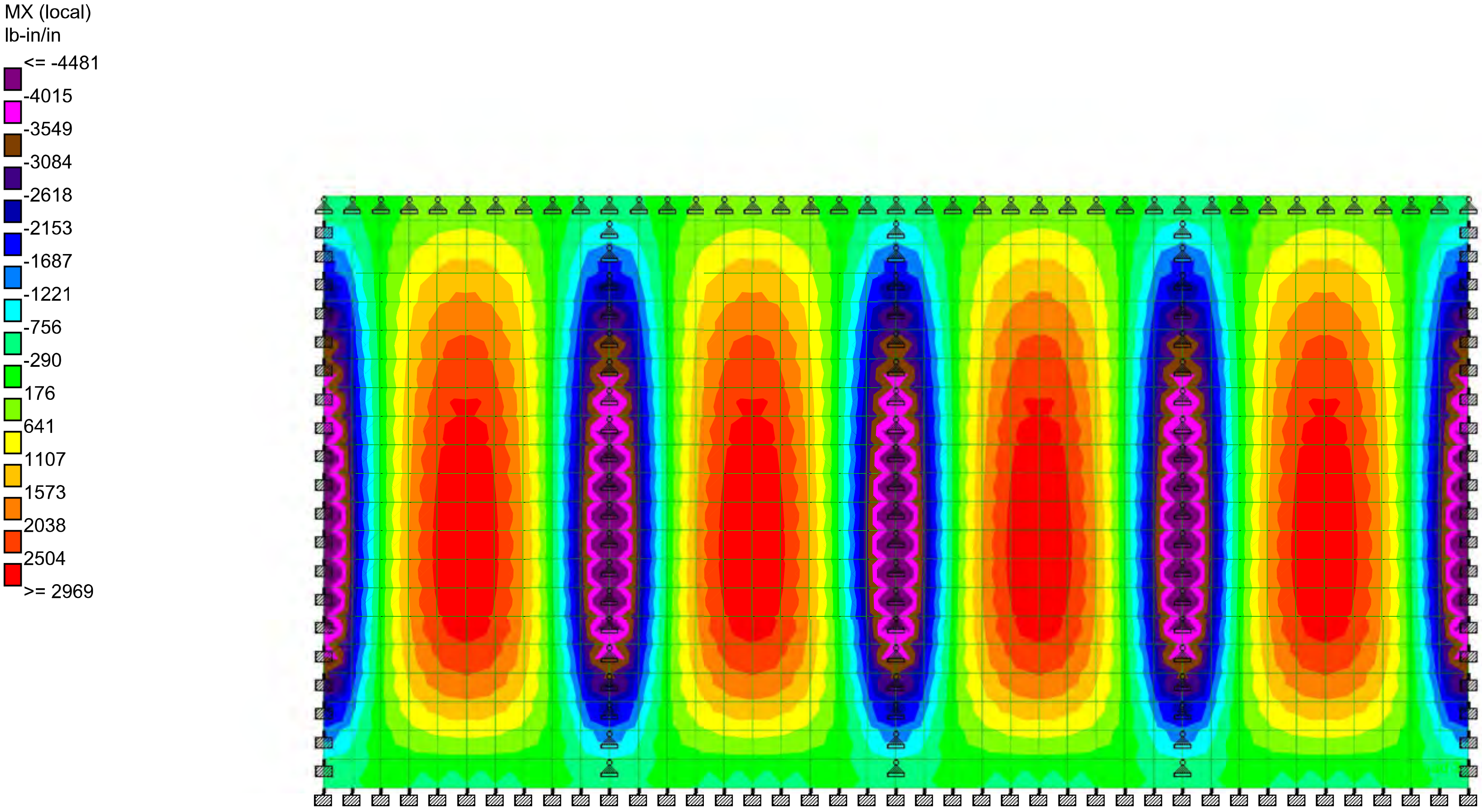
Job No **10721A.10**	Sheet No **1**		Rev
Part Wall 5			
Ref			
By	Date 04-Aug-17		Chd
File Wall 5.std		Date/Time 09-Sep-2017 21:45	

Job Title Area 4 - ActiFlo

Load Case: 1.4E (Water 2-Sides)

Client Willametter River WTP



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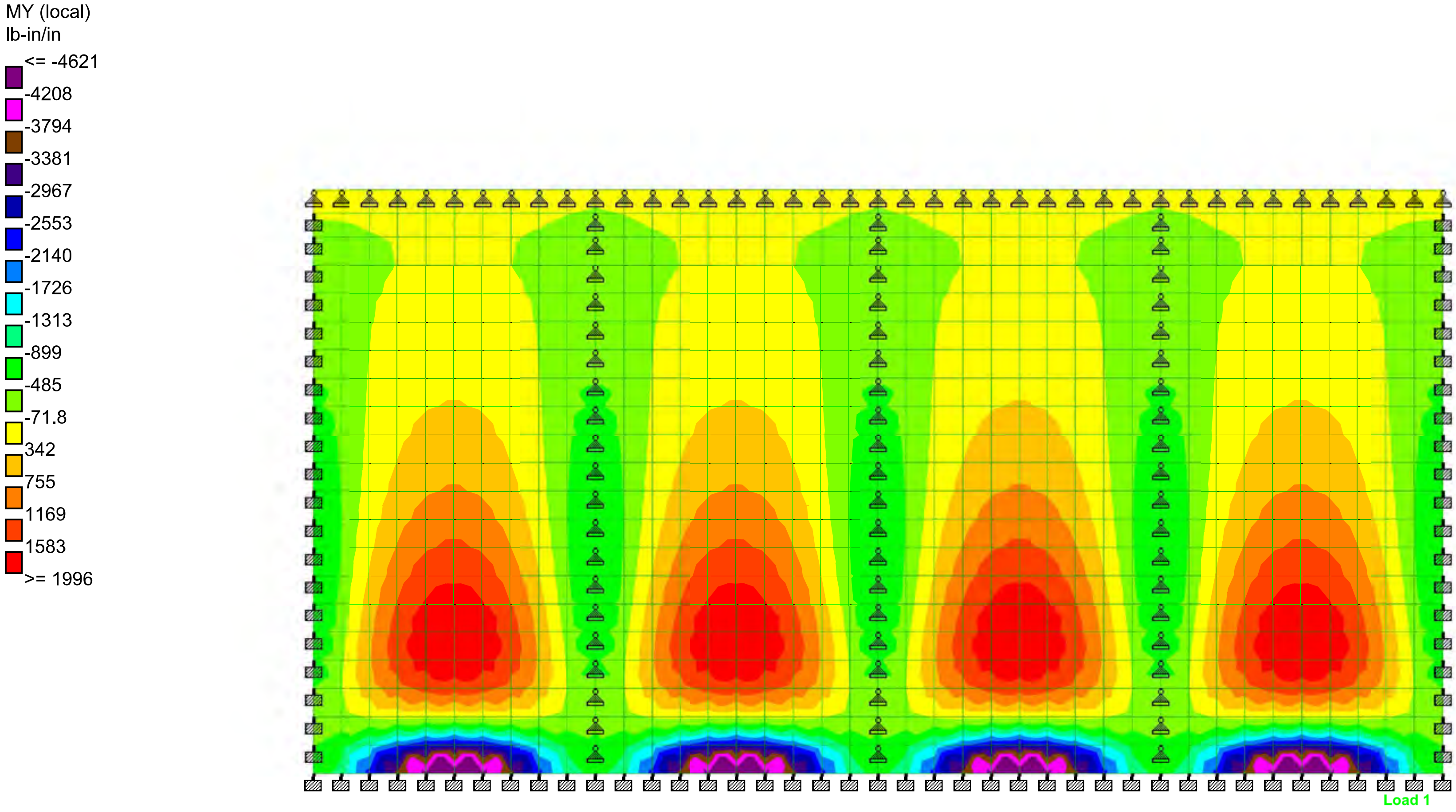
	Part Wall 5		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 5.std	Date/Time 09-Aug-2017 15:39	



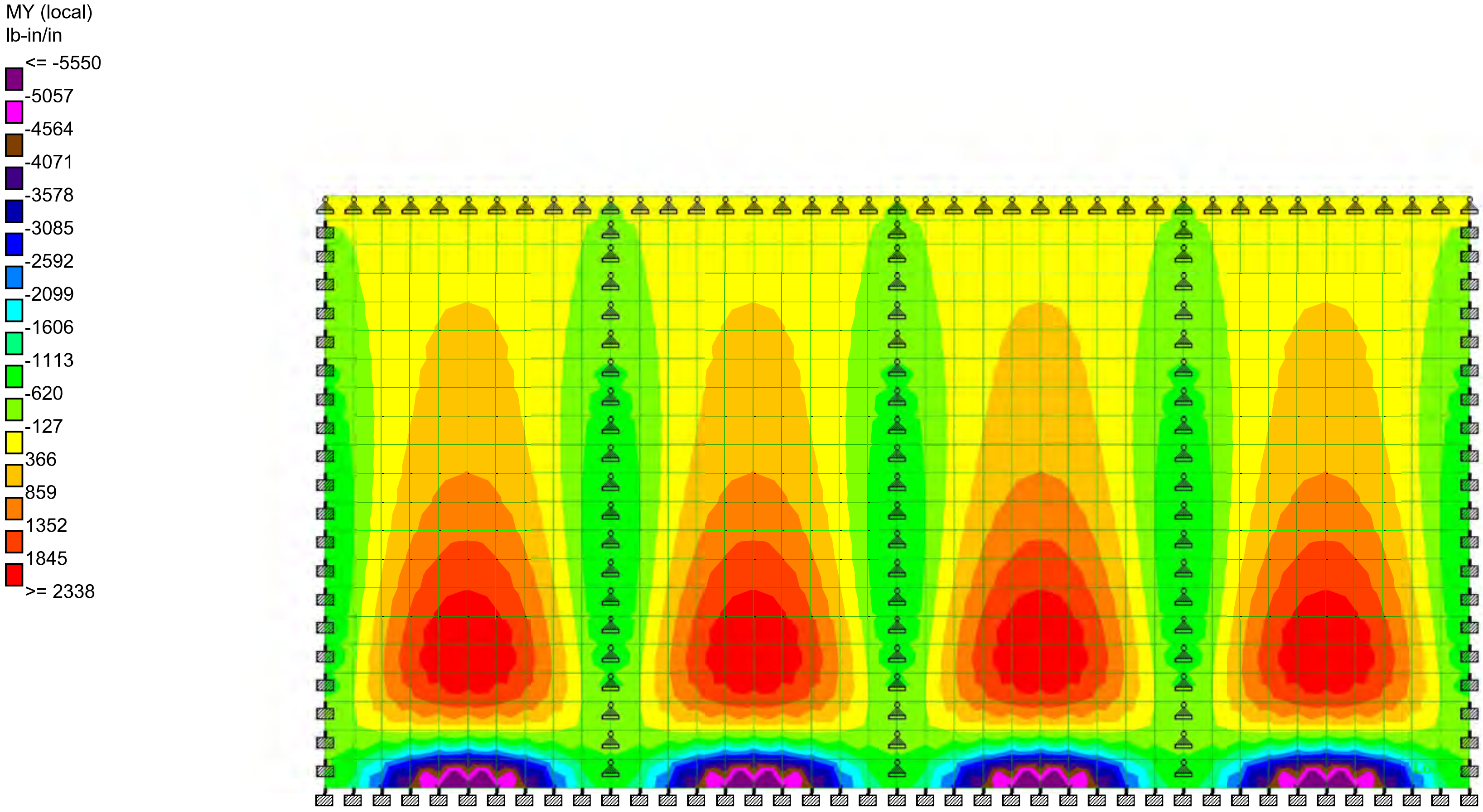
Software licensed to Carollo Engineers
CONNECTED User: Caleb Che

Job No 10721A.10	Sheet No 1	Rev	
Part Wall 5			
Ref			
By	Date 04-Aug-17	Chd	
File Wall 5.std	Date/Time 09-Sep-2017 21:45		

Job Title Area 4 - ActiFlo

Load Case: 1.2F+1.4E

Client Willamettер River WTP



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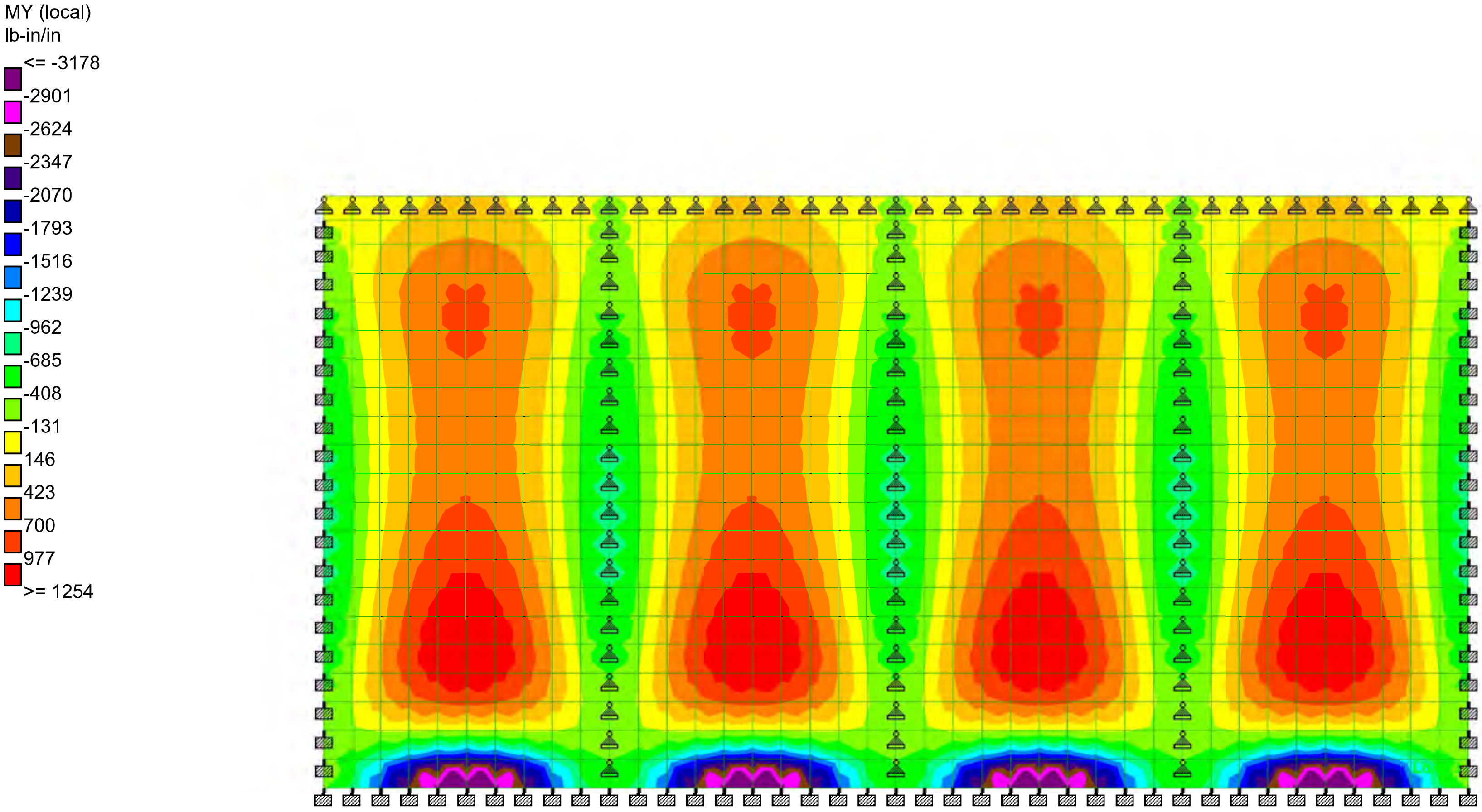
	Part Wall 5		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4E (Water 2-Sides)	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 5.std	Date/Time 09-Sep-2017 21:45	



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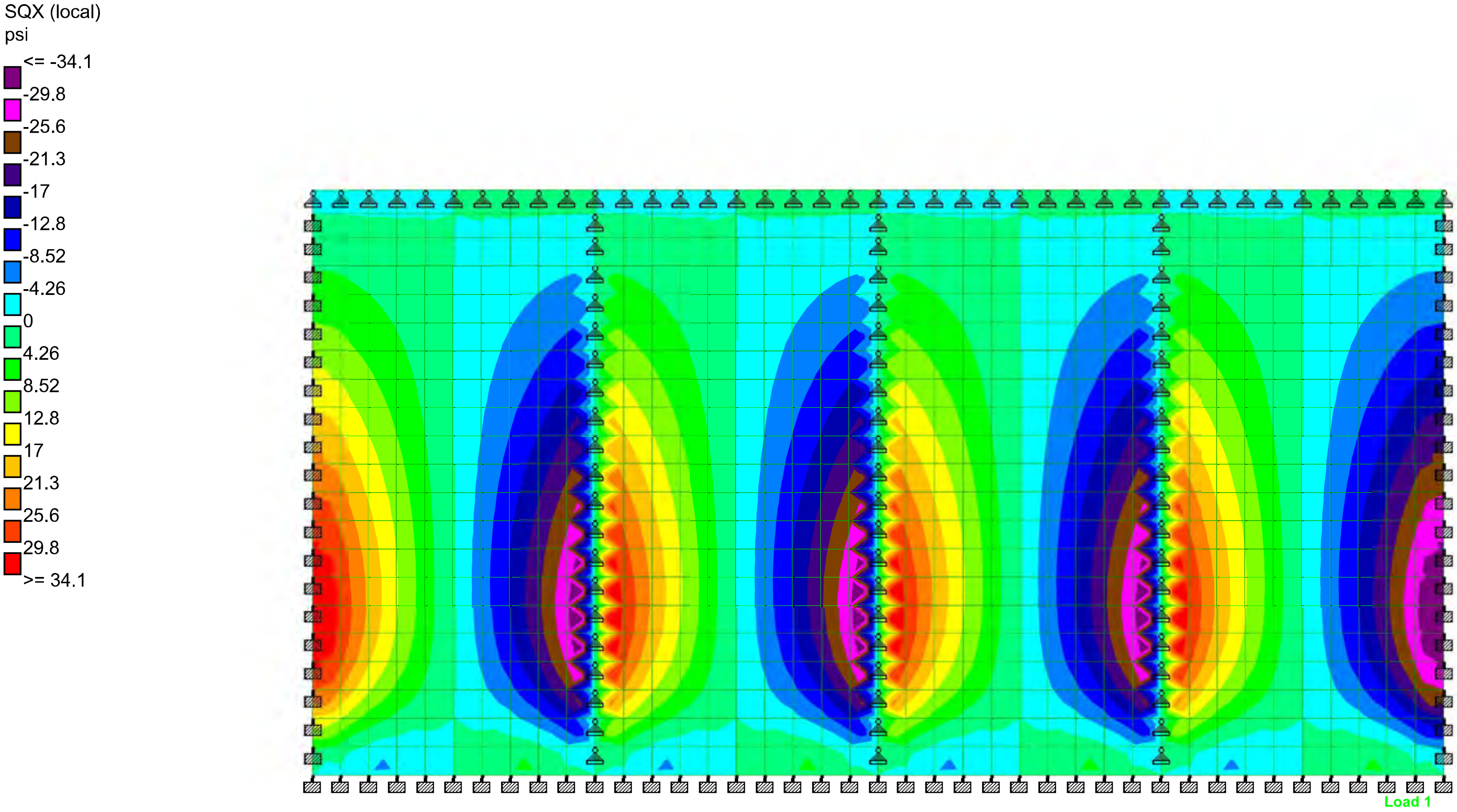
	Part Wall 5		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 5.std	Date/Time 09-Aug-2017 15:39	



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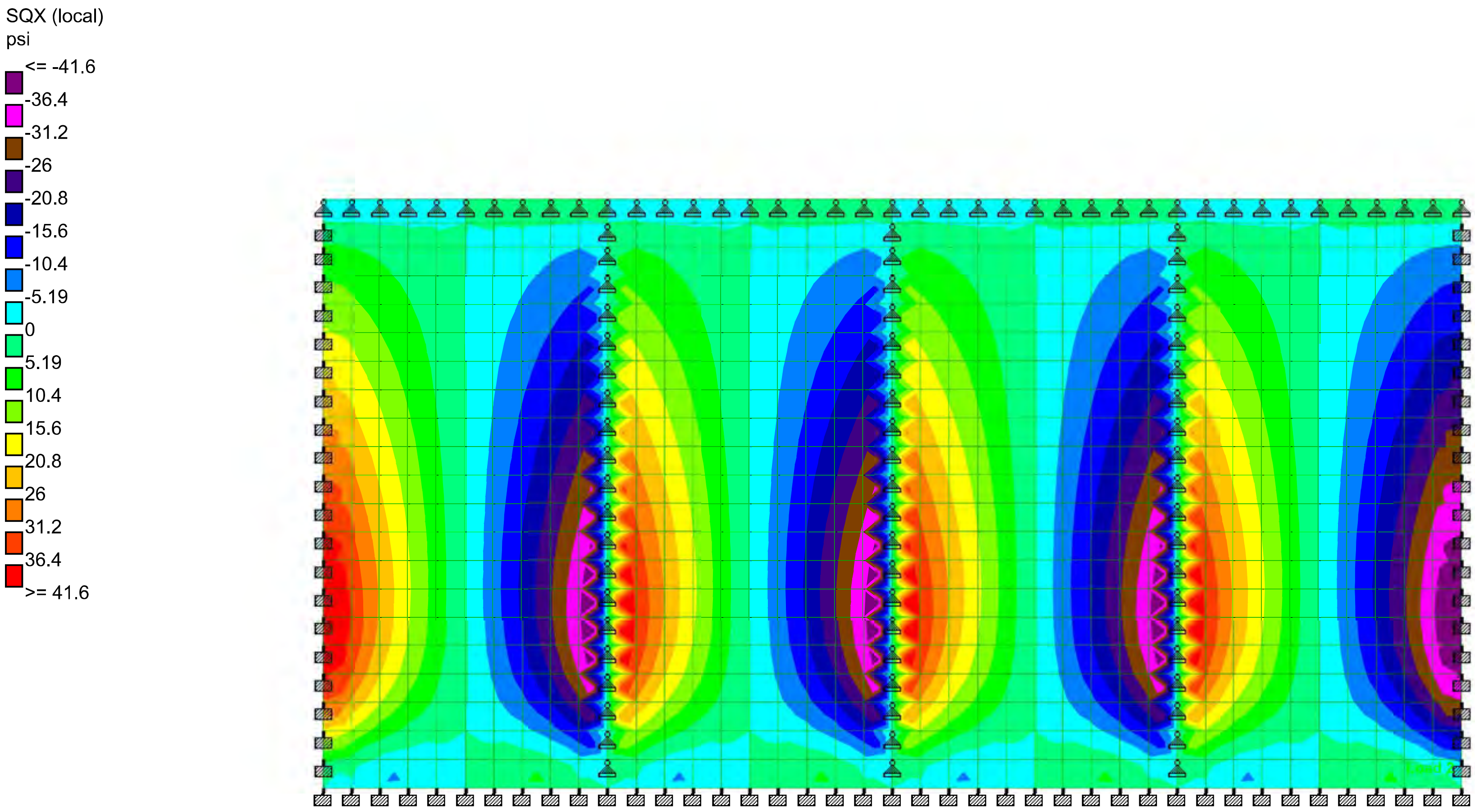
CONNECTED User: Caleb Che

Job No **10721A.10**	Sheet No **1**	Rev	
Part Wall 5			
Ref			
By	Date 04-Aug-17	Chd	
File Wall 5.std	Date/Time 09-Sep-2017 21:45		

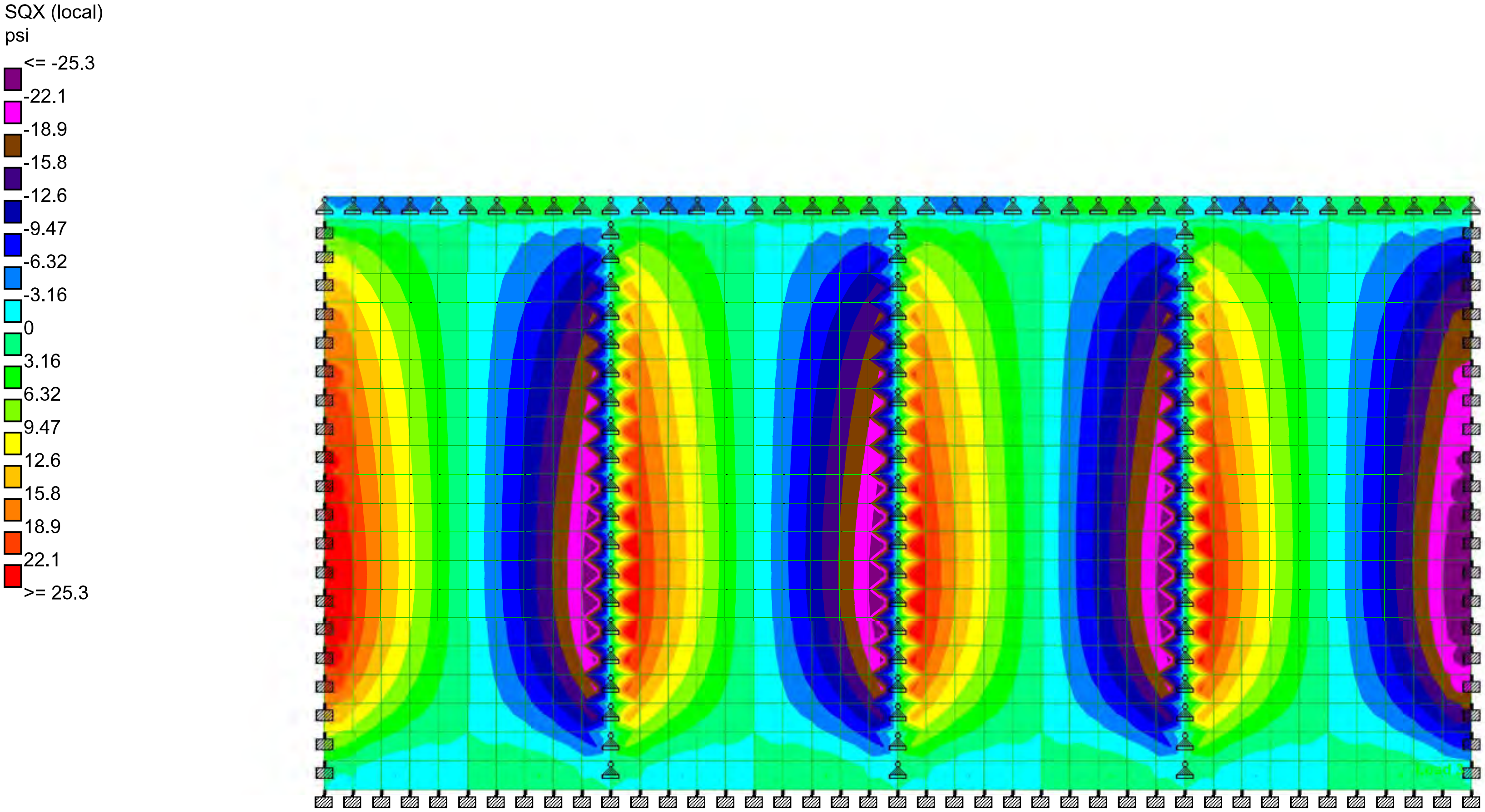
Job Title Area 4 - ActiFlo

Load Case: 1.2F+1.4E

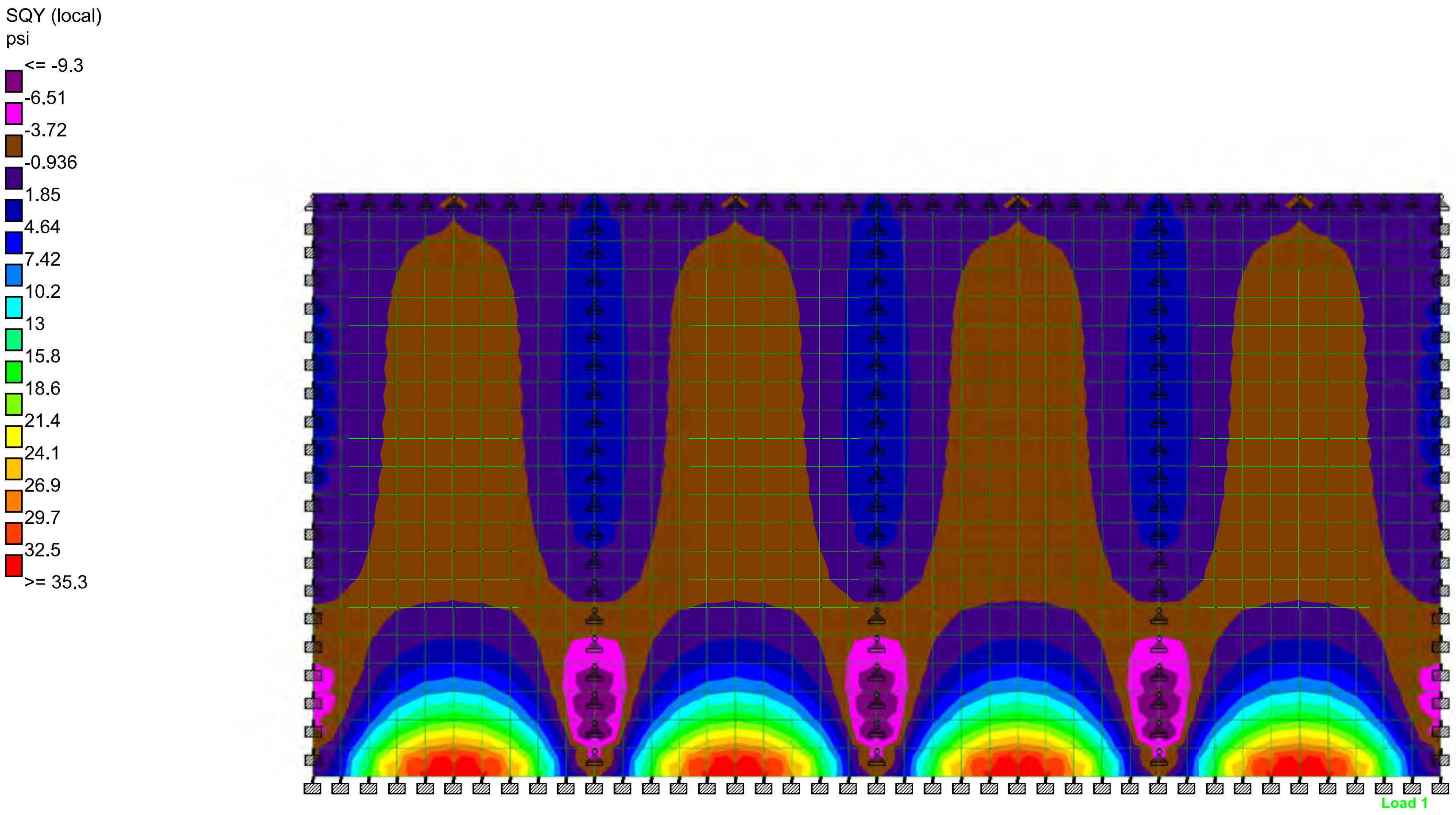
Client Willametter River WTP



Software licensed to Carollo Engineers CONNECTED User: Caleb Che	Job No **10721A.10**	Sheet No **1**		Rev
	Part Wall 5			
Job Title Area 4 - ActiFlo	Ref			
Load Case: 1.4E (Water 2-Sides)	By	Date 04-Aug-17	Chd	
Client Willametter River WTP	File Wall 5.std	Date/Time 09-Sep-2017 21:45		

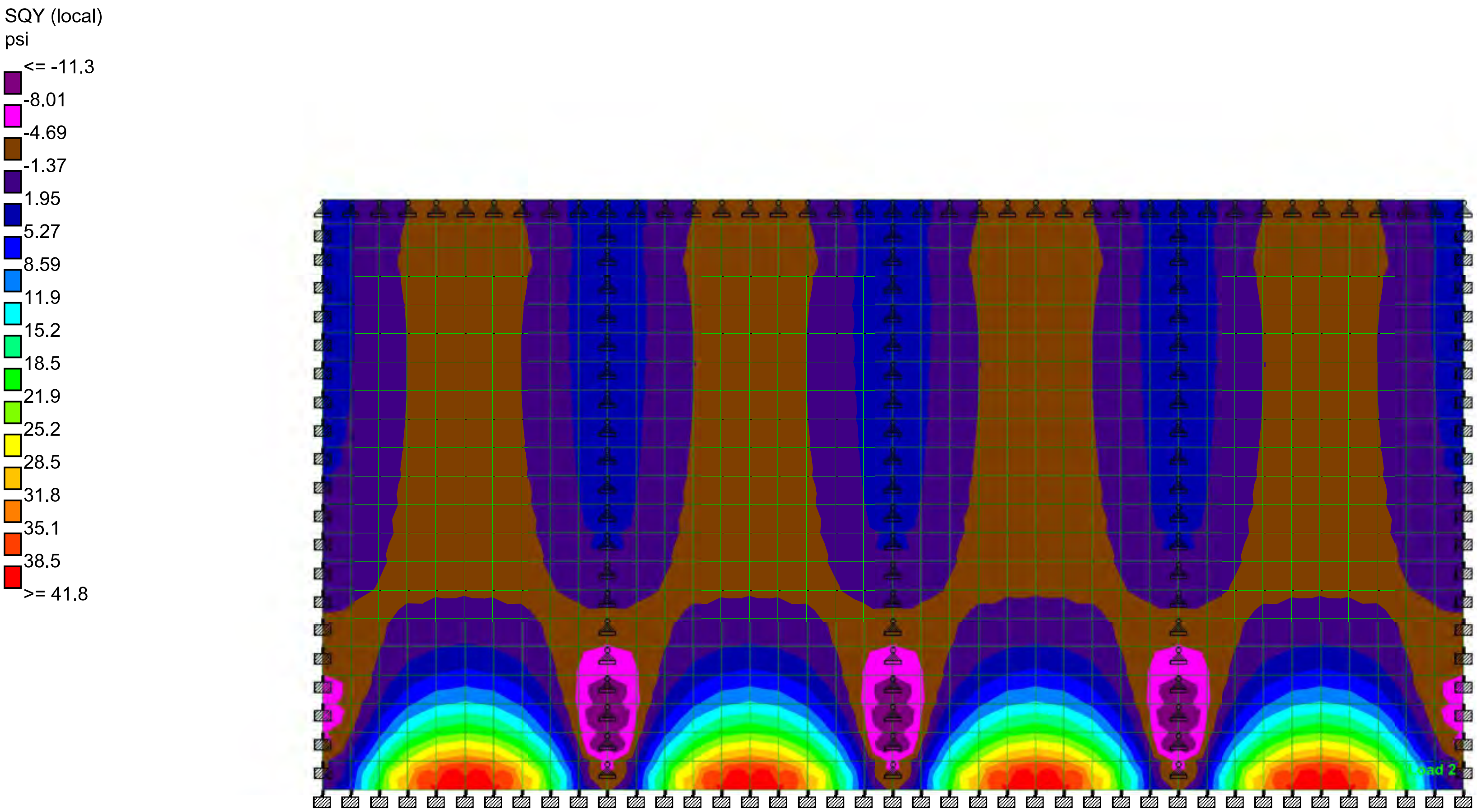


Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 5		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 5.std	Date/Time 09-Aug-2017 15:39	

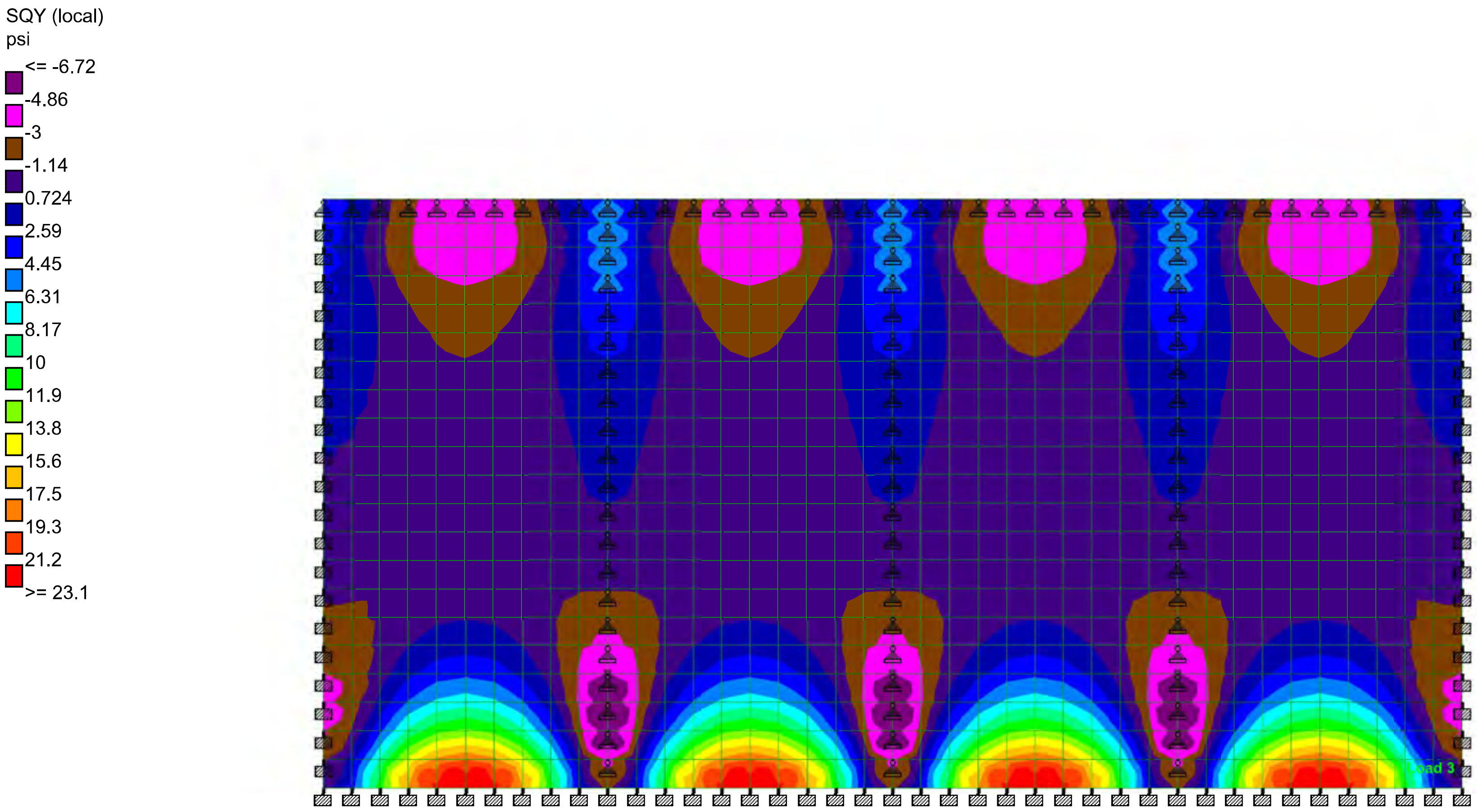


Software licensed to Carollo Engineers
CONNECTED User: Caleb Che

Job Title	Area 4 - ActiFlo Load Case: 1.2F+1.4E	Job No	10721A.10	Sheet No	1
		Part	Wall 5	Rev	
		Ref			
		By		Date	04-Aug-17
		Chd			
Client	Willametter River WTP	File	Wall 5.std	Date/Time	09-Sep-2017 21:45



Software licensed to Carollo Engineers CONNECTED User: Caleb Che	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 5		
Job Title Area 4 - ActiFlo	Ref		
Load Case: 1.4E (Water 2-Sides)	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 5.std	Date/Time 09-Sep-2017 21:45	



Area 4 - Actiflo™
Wall 6A - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	14.32	23.06	30.50	***0.76***	6.76	17.55	***0.39***	***<- OK***
1.2F+1.4E	1.00	19.84	19.84	30.50	***0.65***	8.45	17.55	***0.48***	***<- OK***
1.4E (Water 2-Sides)	1.00	15.35	15.35	30.50	***0.50***	5.33	17.55	***0.30***	***<- OK***

Vertical Span (Mid-Height)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	5.21	8.38	17.50	***0.48***	0.00	14.51	***0.00***	***<- OK***
1.2F+1.4E	1.00	6.30	6.30	17.50	***0.36***	0.00	14.51	***0.00***	***<- OK***
1.4E (Water 2-Sides)	1.00	2.75	2.75	17.50	***0.16***	0.00	14.51	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	17.88	28.78	43.00	***0.67***	9.56	17.55	***0.54***	***<- OK***
1.2F+1.4E	1.00	22.55	22.55	43.00	***0.52***	11.65	17.55	***0.66***	***<- OK***
1.4E (Water 2-Sides)	1.00	11.81	11.81	43.00	***0.27***	5.52	17.55	***0.31***	***<- OK***

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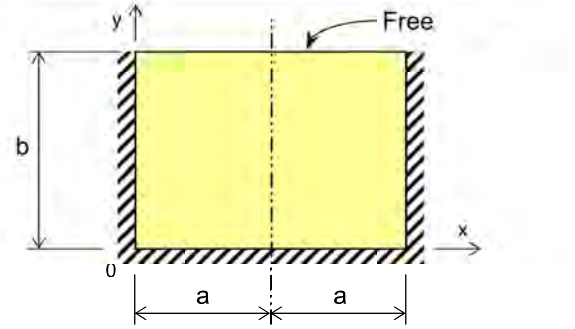
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 6A - Hydrostatic

Rectangular Plate:

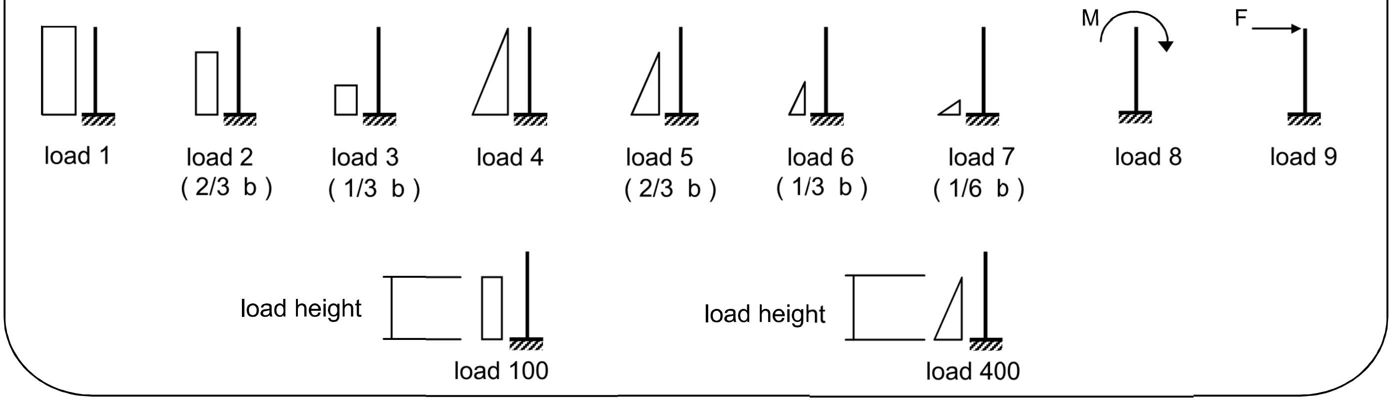
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 9.5 = 19 ft
plate dimension, a = **9.5** ft
plate dimension, b = **16** ft

plate sides ratio, a/b = 0.5938



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors	
				for moment	for shear
A	**4**		**1.186**	**2.25**	**1.4**
B					
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **14** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	11"	3"
My bending	11.5"	2.5"

Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 6A - Hydrostatic

M_x - Moment Summary

a = 9.5
b = 16
a / b = 0.5938

Loads: q , M , or F			
1.186			
Moment Coefficient Multipliers			
303.616			

Boundary Case 1

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 11")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0233				7.08				7.08	15.94	0.33	0.44
0	0.8	0.0294				8.94				8.94	20.11	0.42	0.44
0	0.6	0.0337				10.23				10.23	23.01	0.48	0.44
0	0.4	0.0314				9.54				9.54	21.47	0.45	0.44
0	0.2	0.0165				5.02				5.02	11.30	0.23	0.42
0	0	0.0000				0.00				0.00	0.00	0.00	0.42
0.2	0	0.0019				0.57				0.57	1.29	0.03	0.42
0.4	0	0.0044				1.33				1.33	3.00	0.06	0.42
0.6	0	0.0066				1.99				1.99	4.49	0.09	0.42
0.8	0	0.0079				2.40				2.40	5.41	0.11	0.42
1	0	0.0084				2.56				2.56	5.75	0.12	0.42
1	0.2	-0.0052				-1.57				-1.57	-3.52	-0.07	-0.42
1	0.4	-0.0136				-4.13				-4.13	-9.29	-0.19	-0.42
1	0.6	-0.0158				-4.80				-4.80	-10.81	-0.22	-0.42
1	0.8	-0.0148				-4.49				-4.49	-10.11	-0.21	-0.42
1	1	-0.0139				-4.22				-4.22	-9.48	-0.19	-0.42
0.8	1	-0.0121				-3.68				-3.68	-8.28	-0.17	-0.42
0.8	0.8	-0.0132				-4.00				-4.00	-8.99	-0.18	-0.42
0.8	0.6	-0.0144				-4.36				-4.36	-9.81	-0.20	-0.42
0.8	0.4	-0.0126				-3.83				-3.83	-8.61	-0.18	-0.42
0.8	0.2	-0.0050				-1.50				-1.50	-3.39	-0.07	-0.42

max negative moment, $M_{ux}(-)$ = -10.81 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.22 in^2/ft
minimum steel req'd = -0.42 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 23.01 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.48 in^2/ft
minimum steel req'd = 0.44 in^2/ft
Use

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Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10721A.10
DESIGN TASK: Wall 6A - Hydrostatic

M_y - Moment Summary

a = 9.5
b = 16
a / b = 0.5938

Loads: q , M , or F
1.186

Moment Coefficient Multipliers
303.616

Boundary Case 1

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 11.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.42
0	0.8	0.0059				1.79				1.79	4.02	0.08	0.42
0	0.6	0.0068				2.06				2.06	4.63	0.09	0.42
0	0.4	0.0062				1.89				1.89	4.26	0.08	0.42
0	0.2	0.0033				1.01				1.01	2.27	0.04	0.42
0	0	0.0000				0.00				0.00	0.00	0.00	0.42
0.2	0	0.0093				2.81				2.81	6.33	0.12	0.42
0.4	0	0.0222				6.73				6.73	15.15	0.30	0.42
0.6	0	0.0330				10.01				10.01	22.53	0.45	0.46
0.8	0	0.0398				12.09				12.09	27.20	0.54	0.46
1	0	0.0421				12.77				12.77	28.74	0.58	0.46
1	0.2	-0.0027				-0.81				-0.81	-1.83	-0.04	-0.42
1	0.4	-0.0126				-3.82				-3.82	-8.61	-0.17	-0.42
1	0.6	-0.0097				-2.94				-2.94	-6.62	-0.13	-0.42
1	0.8	-0.0037				-1.11				-1.11	-2.50	-0.05	-0.42
1	1	0.0000				0.00				0.00	0.00	0.00	0.42
1	0.4	-0.0126				-3.82				-3.82	-8.61	-0.17	-0.42
0.8	0.4	-0.0119				-3.60				-3.60	-8.10	-0.16	-0.42
0.6	0.4	-0.0095				-2.89				-2.89	-6.50	-0.13	-0.42
0.4	0.4	-0.0056				-1.71				-1.71	-3.85	-0.07	-0.42
0.2	0.4	-0.0001				-0.03				-0.03	-0.06	0.00	-0.42

max negative moment, $M_{uy}(-)$ = -8.61 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.17 in^2/ft
minimum steel req'd = -0.42 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 28.74 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.58 in^2/ft
minimum steel req'd = 0.46 in^2/ft
Use

BY:	C. Che	**DATE:** Aug-17	**CLIENT** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 4 - Actiflo™	**JOB NO:**	10721A.10
DESIGN TASK:			Wall 6A - Hydrostatic		

Shear Summary

a = 9.5
b = 16
a / b = 0.5938

Loads: q , M , or F: 1.186

Shear Coefficient Multipliers: 18.976

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.0530				1.00				1.00	1.41	13.09
0	0.8	0.1616				3.07				3.07	4.29	13.09
0	0.6	0.2202				4.18				4.18	5.85	13.09
0	0.4	0.2546				4.83				4.83	6.76	13.09
0	0.2	0.1522				2.89				2.89	4.04	13.09
0	0.00	-0.0124				-0.24				-0.24	-0.33	13.09
0.2	0	0.0940				1.78				1.78	2.50	13.09
0.4	0	0.2242				4.25				4.25	5.96	13.09
0.6	0	0.3044				5.78				5.78	8.09	13.09
0.8	0	0.3468				6.58				6.58	9.21	13.09
1	0	0.3600				6.83				6.83	9.56	13.09

Concrete strength reduction factor for shear, ϕ = 0.75

d = 11.5 in

maximum shear, V_u = 9.56 k/ft **OK**

$\phi V_c = \phi*2*(f'c)^{1/2}*b*d =$ (0.75*2*(4000)ˆ½ *12*11.5)/1000 = 13.09 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water™

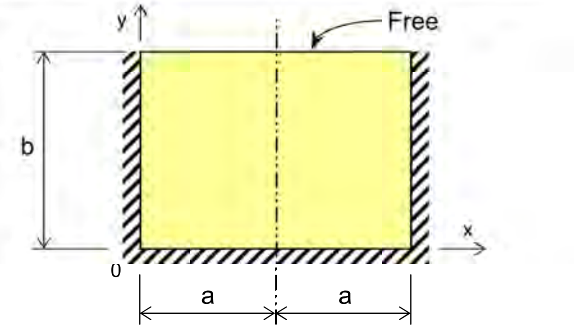
BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 6A - Hydrodynamic

Rectangular Plate:

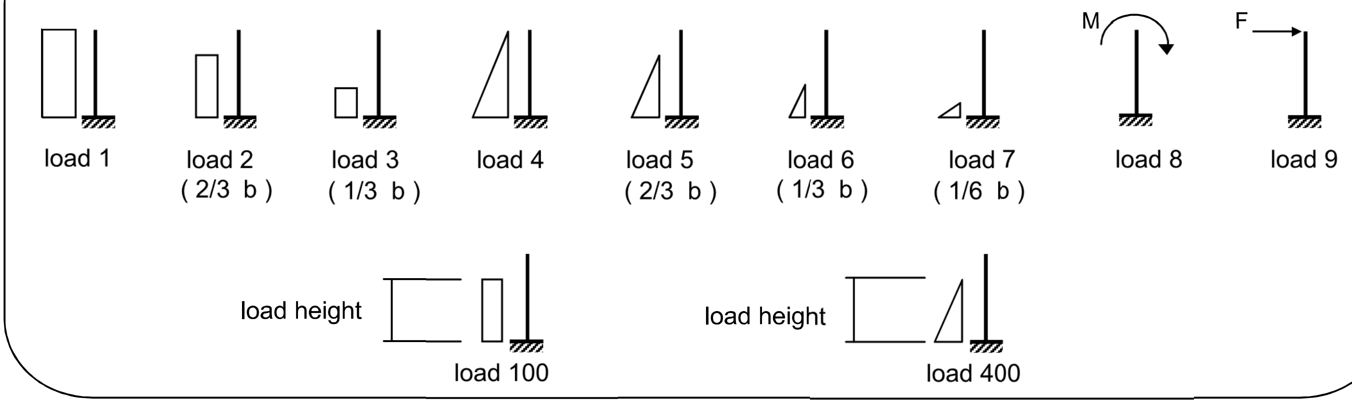
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 9.5 = 19 ft
plate dimension, a = **9.5** ft
plate dimension, b = **16** ft

plate sides ratio, a/b = 0.5938



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	 for shear
A	**4**		**1.186**	**1.2**	**1.2**
B	**1**		**0.168**	**1.4**	**1.4**
C	**4**		**0.176**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **14** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	11"	3"
My bending	11.5"	2.5"

Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 6A - Hydrodynamic

M_x - Moment Summary

a = 9.5
b = 16
a / b = 0.5938

Loads: q , M , or F	1.186	0.168	0.176	
Moment Coefficient Multipliers	303.616	43.008	45.056	

Boundary Case 1

SUMMARY

Final Moments

Reinforcing: (d = 11")

		Moment Coefficients				M_x Moments, ft-k/ft				M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0233	0.1174	0.0233		7.08	5.05	1.05		13.19	17.04	0.35	0.44
0	0.8	0.0294	0.1077	0.0294		8.94	4.63	1.33		14.90	19.07	0.40	0.44
0	0.6	0.0337	0.0905	0.0337		10.23	3.89	1.52		15.63	19.84	0.41	0.44
0	0.4	0.0314	0.0650	0.0314		9.54	2.79	1.42		13.75	17.35	0.36	0.44
0	0.2	0.0165	0.0271	0.0165		5.02	1.17	0.74		6.93	8.70	0.18	0.42
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.42
0.2	0	0.0019	0.0027	0.0019		0.57	0.12	0.09		0.78	0.97	0.02	0.42
0.4	0	0.0044	0.0071	0.0044		1.33	0.31	0.20		1.84	2.30	0.05	0.42
0.6	0	0.0066	0.0114	0.0066		1.99	0.49	0.30		2.78	3.49	0.07	0.42
0.8	0	0.0079	0.0142	0.0079		2.40	0.61	0.36		3.37	4.24	0.09	0.42
1	0	0.0084	0.0152	0.0084		2.56	0.65	0.38		3.59	4.51	0.09	0.42
1	0.2	-0.0052	-0.0088	-0.0052		-1.57	-0.38	-0.23		-2.18	-2.73	-0.06	-0.42
1	0.4	-0.0136	-0.0297	-0.0136		-4.13	-1.28	-0.61		-6.02	-7.60	-0.16	-0.42
1	0.6	-0.0158	-0.0433	-0.0158		-4.80	-1.86	-0.71		-7.38	-9.37	-0.19	-0.42
1	0.8	-0.0148	-0.0513	-0.0148		-4.49	-2.21	-0.67		-7.37	-9.42	-0.19	-0.42
1	1	-0.0139	-0.0572	-0.0139		-4.22	-2.46	-0.63		-7.30	-9.38	-0.19	-0.42
0.8	1	-0.0121	-0.0510	-0.0121		-3.68	-2.19	-0.55		-6.42	-8.25	-0.17	-0.42
0.8	0.8	-0.0132	-0.0459	-0.0132		-4.00	-1.97	-0.59		-6.56	-8.39	-0.17	-0.42
0.8	0.6	-0.0144	-0.0389	-0.0144		-4.36	-1.67	-0.65		-6.68	-8.48	-0.17	-0.42
0.8	0.4	-0.0126	-0.0270	-0.0126		-3.83	-1.16	-0.57		-5.56	-7.01	-0.14	-0.42
0.8	0.2	-0.0050	-0.0082	-0.0050		-1.50	-0.35	-0.22		-2.08	-2.61	-0.05	-0.42

max negative moment, $M_{ux}(-)$ = -9.42 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.19 in^2/ft
minimum steel req'd = -0.42 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 19.84 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.41 in^2/ft
minimum steel req'd = 0.44 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 6A - Hydrodynamic

M_y - Moment Summary

a = 9.5
b = 16
a / b = 0.5938

	Loads: q , M , or F			
	1.186	0.168	0.176	
Moment Coefficient Multipliers	303.616	43.008	45.056	

Boundary Case 1

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 11.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.42
0	0.8	0.0059	0.0215	0.0059		1.79	0.92	0.27		2.98	3.81	0.07	0.42
0	0.6	0.0068	0.0181	0.0068		2.06	0.78	0.31		3.14	3.99	0.08	0.42
0	0.4	0.0062	0.0130	0.0062		1.89	0.56	0.28		2.73	3.45	0.07	0.42
0	0.2	0.0033	0.0054	0.0033		1.01	0.23	0.15		1.39	1.74	0.03	0.42
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.42
0.2	0	0.0093	0.0134	0.0093		2.81	0.57	0.42		3.80	4.76	0.09	0.42
0.4	0	0.0222	0.0359	0.0222		6.73	1.55	1.00		9.28	11.64	0.23	0.42
0.6	0	0.0330	0.0569	0.0330		10.01	2.45	1.49		13.95	17.52	0.35	0.46
0.8	0	0.0398	0.0710	0.0398		12.09	3.05	1.79		16.94	21.30	0.42	0.46
1	0	0.0421	0.0759	0.0421		12.77	3.27	1.90		17.93	22.55	0.45	0.46
1	0.2	-0.0027	0.0064	-0.0027		-0.81	0.28	-0.12		-0.65	-0.75	-0.01	-0.42
1	0.4	-0.0126	-0.0152	-0.0126		-3.82	-0.65	-0.57		-5.04	-6.30	-0.12	-0.42
1	0.6	-0.0097	-0.0178	-0.0097		-2.94	-0.76	-0.44		-4.15	-5.21	-0.10	-0.42
1	0.8	-0.0037	-0.0122	-0.0037		-1.11	-0.53	-0.16		-1.80	-2.30	-0.04	-0.42
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.42
1	0.4	-0.0126	-0.0152	-0.0126		-3.82	-0.65	-0.57		-5.04	-6.30	-0.12	-0.42
0.8	0.4	-0.0119	-0.0141	-0.0119		-3.60	-0.61	-0.53		-4.74	-5.92	-0.12	-0.42
0.6	0.4	-0.0095	-0.0108	-0.0095		-2.89	-0.46	-0.43		-3.78	-4.72	-0.09	-0.42
0.4	0.4	-0.0056	-0.0051	-0.0056		-1.71	-0.22	-0.25		-2.19	-2.72	-0.05	-0.42
0.2	0.4	-0.0001	0.0029	-0.0001		-0.03	0.12	0.00		0.09	0.14	0.00	0.42

max negative moment, $M_{uy}(-)$ = -6.30 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.12 in^2/ft
minimum steel req'd = -0.42 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 22.55 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.45 in^2/ft
minimum steel req'd = 0.46 in^2/ft
Use

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Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 6A - Hydrodynamic

Shear Summary

a = 9.5
b = 16
a / b = 0.5938

Boundary Case 1

	q	M	or F	
Loads	1.186	0.168	0.176	
Shear Coefficient Multipliers	18.976	2.688	2.816	

		Shear Coefficients				Shears, k/ft				SUMMARY Final Shears		
x / a	y / b	A	B	C	D	A	B	C	D	V k/ft	V_u k/ft	ϕV_c k/ft
0	1	0.0530	0.6299	0.0530		1.00	1.69	0.15		2.85	3.79	13.09
0	0.8	0.1616	0.6334	0.1616		3.07	1.70	0.46		5.22	6.70	13.09
0	0.6	0.2202	0.5392	0.2202		4.18	1.45	0.62		6.25	7.91	13.09
0	0.4	0.2546	0.4388	0.2546		4.83	1.18	0.72		6.73	8.45	13.09
0	0.2	0.1522	0.1701	0.1522		2.89	0.46	0.43		3.77	4.71	13.09
0	0.00	-0.0124	-0.0469	-0.0124		-0.24	-0.13	-0.03		-0.40	-0.51	13.09
0.2	0	0.0940	0.0609	0.0940		1.78	0.16	0.26		2.21	2.74	13.09
0.4	0	0.2242	0.2695	0.2242		4.25	0.72	0.63		5.61	7.00	13.09
0.6	0	0.3044	0.4219	0.3044		5.78	1.13	0.86		7.77	9.72	13.09
0.8	0	0.3468	0.5114	0.3468		6.58	1.37	0.98		8.93	11.19	13.09
1	0	0.3600	0.5406	0.3600		6.83	1.45	1.01		9.30	11.65	13.09

Concrete strength reduction factor for shear, ϕ = 0.75

d = 11.5 in
maximum shear, V_u = 11.65 k/ft **OK**
$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d$ = (0.75*2*(4000)^½ *12*11.5)/1000 = 13.09 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

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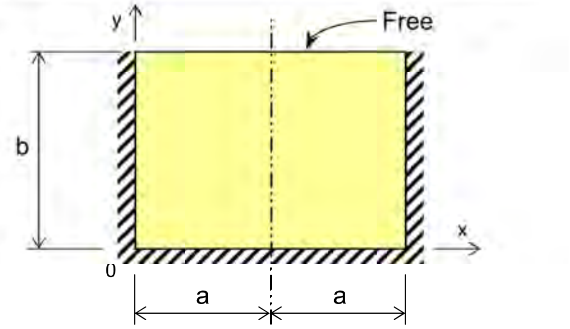
Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 6A - Hydrodynamic (Water 2-Sides)

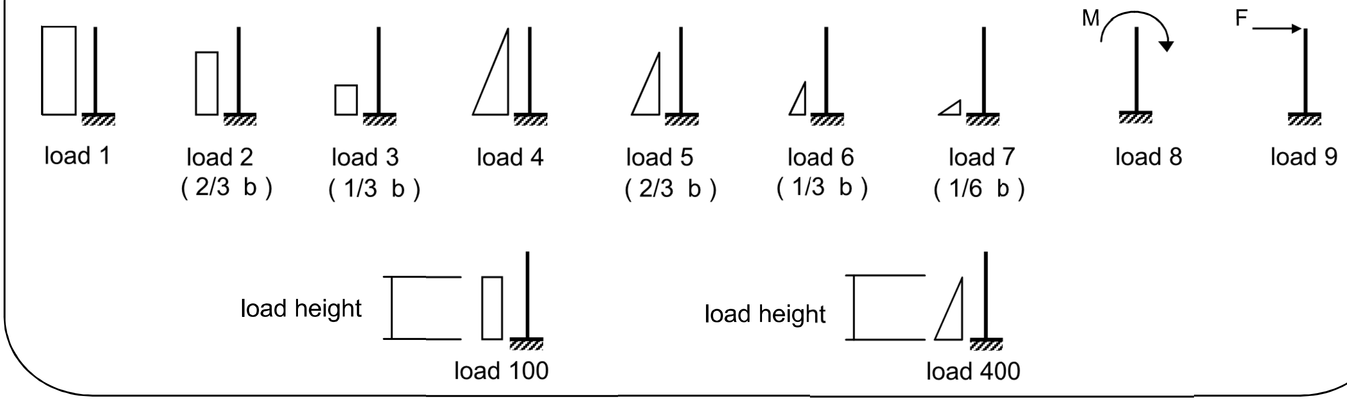
Rectangular Plate:
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 9.5 = 19 ft
plate dimension, a = **9.5** ft
plate dimension, b = **16** ft

plate sides ratio, a/b = 0.5938



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	concrete load factors for shear
A	**1**		**0.326**	**1.4**	**1.4**
B	**4**		**0.195**	**1.4**	**1.4**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **14** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	11"	3"
My bending	11.5"	2.5"

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**

CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10

DESIGN TASK: Wall 6A - Hydrodynamic (Water 2-Sides)

M_x - Moment Summary

a = 9.5
b = 16
a / b = 0.5938

Loads: q , M , or F			
0.326	0.195		
Moment Coefficient Multipliers			
83.456	49.920		

Boundary Case 1

		Moment Coefficients				M_x Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 11")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.1174	0.0233			9.80	1.16			10.96	15.35	0.32	0.42
0	0.8	0.1077	0.0294			8.98	1.47			10.45	14.64	0.30	0.42
0	0.6	0.0905	0.0337			7.55	1.68			9.23	12.92	0.27	0.42
0	0.4	0.0650	0.0314			5.42	1.57			6.99	9.79	0.20	0.42
0	0.2	0.0271	0.0165			2.26	0.83			3.09	4.32	0.09	0.42
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.42
0.2	0	0.0027	0.0019			0.22	0.09			0.32	0.45	0.01	0.42
0.4	0	0.0071	0.0044			0.60	0.22			0.81	1.14	0.02	0.42
0.6	0	0.0114	0.0066			0.95	0.33			1.28	1.79	0.04	0.42
0.8	0	0.0142	0.0079			1.19	0.39			1.58	2.21	0.04	0.42
1	0	0.0152	0.0084			1.27	0.42			1.69	2.36	0.05	0.42
1	0.2	-0.0088	-0.0052			-0.73	-0.26			-0.99	-1.38	-0.03	-0.42
1	0.4	-0.0297	-0.0136			-2.48	-0.68			-3.16	-4.42	-0.09	-0.42
1	0.6	-0.0433	-0.0158			-3.62	-0.79			-4.41	-6.17	-0.13	-0.42
1	0.8	-0.0513	-0.0148			-4.29	-0.74			-5.02	-7.03	-0.14	-0.42
1	1	-0.0572	-0.0139			-4.77	-0.69			-5.47	-7.65	-0.16	-0.42
0.8	1	-0.0510	-0.0121			-4.25	-0.61			-4.86	-6.80	-0.14	-0.42
0.8	0.8	-0.0459	-0.0132			-3.83	-0.66			-4.49	-6.28	-0.13	-0.42
0.8	0.6	-0.0389	-0.0144			-3.25	-0.72			-3.97	-5.55	-0.11	-0.42
0.8	0.4	-0.0270	-0.0126			-2.25	-0.63			-2.88	-4.03	-0.08	-0.42
0.8	0.2	-0.0082	-0.0050			-0.68	-0.25			-0.93	-1.30	-0.03	-0.42

max negative moment, $M_{ux}(-)$ = -7.65 ft-k/ft

max negative steel req'd, $A_s(-)$ = -0.16 in^2/ft

minimum steel req'd = -0.42 in^2/ft

Use

max positive moment, $M_{ux}(+)$ = 15.35 ft-k/ft

max positive steel req'd, $A_s(+)$ = 0.32 in^2/ft

minimum steel req'd = 0.42 in^2/ft

Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 6A - Hydrodynamic (Water 2-Sides)

M_y - Moment Summary

a = 9.5
b = 16
a / b = 0.5938

Loads: q , M , or F			
0.326	0.195		
Moment Coefficient Multipliers			
83.456	49.920		

Boundary Case 1

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 11.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.42
0	0.8	0.0215	0.0059			1.79	0.29			2.09	2.92	0.06	0.42
0	0.6	0.0181	0.0068			1.51	0.34			1.85	2.58	0.05	0.42
0	0.4	0.0130	0.0062			1.08	0.31			1.39	1.95	0.04	0.42
0	0.2	0.0054	0.0033			0.45	0.17			0.62	0.87	0.02	0.42
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.42
0.2	0	0.0134	0.0093			1.11	0.46			1.58	2.21	0.04	0.42
0.4	0	0.0359	0.0222			3.00	1.11			4.11	5.75	0.11	0.42
0.6	0	0.0569	0.0330			4.74	1.65			6.39	8.95	0.17	0.42
0.8	0	0.0710	0.0398			5.93	1.99			7.91	11.08	0.22	0.42
1	0	0.0759	0.0421			6.34	2.10			8.44	11.81	0.23	0.42
1	0.2	0.0064	-0.0027			0.54	-0.13			0.40	0.57	0.01	0.42
1	0.4	-0.0152	-0.0126			-1.26	-0.63			-1.89	-2.65	-0.05	-0.42
1	0.6	-0.0178	-0.0097			-1.48	-0.48			-1.97	-2.75	-0.05	-0.42
1	0.8	-0.0122	-0.0037			-1.02	-0.18			-1.20	-1.68	-0.03	-0.42
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.42
1	0.4	-0.0152	-0.0126			-1.26	-0.63			-1.89	-2.65	-0.05	-0.42
0.8	0.4	-0.0141	-0.0119			-1.18	-0.59			-1.77	-2.48	-0.05	-0.42
0.6	0.4	-0.0108	-0.0095			-0.90	-0.48			-1.37	-1.92	-0.04	-0.42
0.4	0.4	-0.0051	-0.0056			-0.43	-0.28			-0.71	-0.99	-0.02	-0.42
0.2	0.4	0.0029	-0.0001			0.24	0.00			0.24	0.33	0.01	0.42

max negative moment, $M_{uy}(-)$ = -2.75 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.05 in^2/ft
minimum steel req'd = -0.42 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 11.81 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.23 in^2/ft
minimum steel req'd = 0.42 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 4 - Actiflo™ **JOB NO:** 10723A.10
DESIGN TASK: Wall 6A - Hydrodynamic (Water 2-Sides)

Shear Summary

a = 9.5
b = 16
a / b = 0.5938

Loads: q , M , or F			
0.326	0.195		
Shear Coefficient Multipliers			
5.216	3.120		

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.6299	0.0530			3.29	0.17			3.45	4.83	13.09
0	0.8	0.6334	0.1616			3.30	0.50			3.81	5.33	13.09
0	0.6	0.5392	0.2202			2.81	0.69			3.50	4.90	13.09
0	0.4	0.4388	0.2546			2.29	0.79			3.08	4.32	13.09
0	0.2	0.1701	0.1522			0.89	0.47			1.36	1.91	13.09
0	0.00	-0.0469	-0.0124			-0.24	-0.04			-0.28	-0.40	13.09
0.2	0	0.0609	0.0940			0.32	0.29			0.61	0.86	13.09
0.4	0	0.2695	0.2242			1.41	0.70			2.11	2.95	13.09
0.6	0	0.4219	0.3044			2.20	0.95			3.15	4.41	13.09
0.8	0	0.5114	0.3468			2.67	1.08			3.75	5.25	13.09
1	0	0.5406	0.3600			2.82	1.12			3.94	5.52	13.09

Concrete strength reduction factor for shear, ϕ = 0.75

d = 11.5 in
maximum shear, V_u = 5.52 k/ft **OK**
$\phi V_c = \phi * 2 * (f\,'c)^{1/2} * b * d$ = (0.75*2*(4000)ˆ½ *12*11.5)/1000 = 13.09 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

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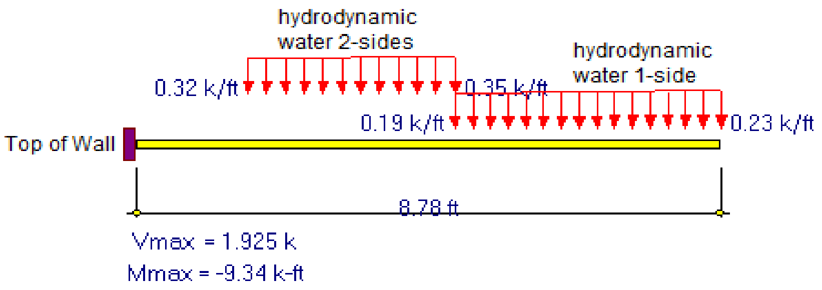
BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Willamette Springs WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 4 - Actiflo™	**JOB NO.**	10721A.10
DESIGN TASK					Wall 6B - Hydrodynamic (Water 2-Sides) - Cantilever		

WALL DESIGN LOADS, PROPERTIES & GEOMETRY



Service Level Load Diagram, Shear & Moment

M = Service moment = 9.34 ft-k

Mu = Factored moment = 13.08 ft-k

V_u = Factored Shear = 2.70 kips

h = Member thick = 12.00 in

b = Member width = 12.00 in

Cover = Reinforcing cover = 2.00 in

Is this mat of rebar closest to surface (Y / N)? = Y

d = Depth to flexural reinforcing = 9.69 in

f'_c = Specified compressive strength of concrete = 4,000 psi

f_y = Specified yield strength of reinforcement = 60,000 psi

FLEXURAL REINFORCING

ϕ, bending = 1.00

$m = f_y / (0.85 * f'_c)$ = 17.65

$R_n = M_u / (\phi * b * d^2)$ = 139 psi

$A_{s,\ req} = (b*d /m) * (1 - (1 - ((2*m*R_n) / f_y))^{1/2})$ = 0.28 in^2

Use # 5 @ 12"

d_b = Bar diameter = 0.625 in

$A_s = (\pi / 4) * d_b^2 * (12" / Spacing)$ = 0.31 in^2 ***<-- Rebar OK***

SHEAR CAPACITY

ϕ, shear = 1.00

V_u = Factored Shear = 2.70 kips

$\phi V_c = \phi * 2 * (f'_c)^{1/2} * b * d$ = 14.70 kips ***<-- Shear OK***

Area 4 - Actiflo™
Wall 7 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	9.50	15.30	16.00	***0.96***	37	126	***0.29***	***<- OK***
1.2F+1.4E	1.00	11.60	11.60	16.00	***0.73***	45	126	***0.36***	***<- OK***
									<- OK

Vertical Span (Mid-Height)

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	7.02	11.30	17.50	***0.65***	0	126	***0.00***	***<- OK***
1.2F+1.4E	1.00	8.58	8.58	17.50	***0.49***	0	126	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	13.20	21.25	33.50	***0.63***	50	126	***0.39***	***<- OK***
1.2F+1.4E	1.00	15.90	15.90	33.50	***0.47***	59	126	***0.47***	***<- OK***

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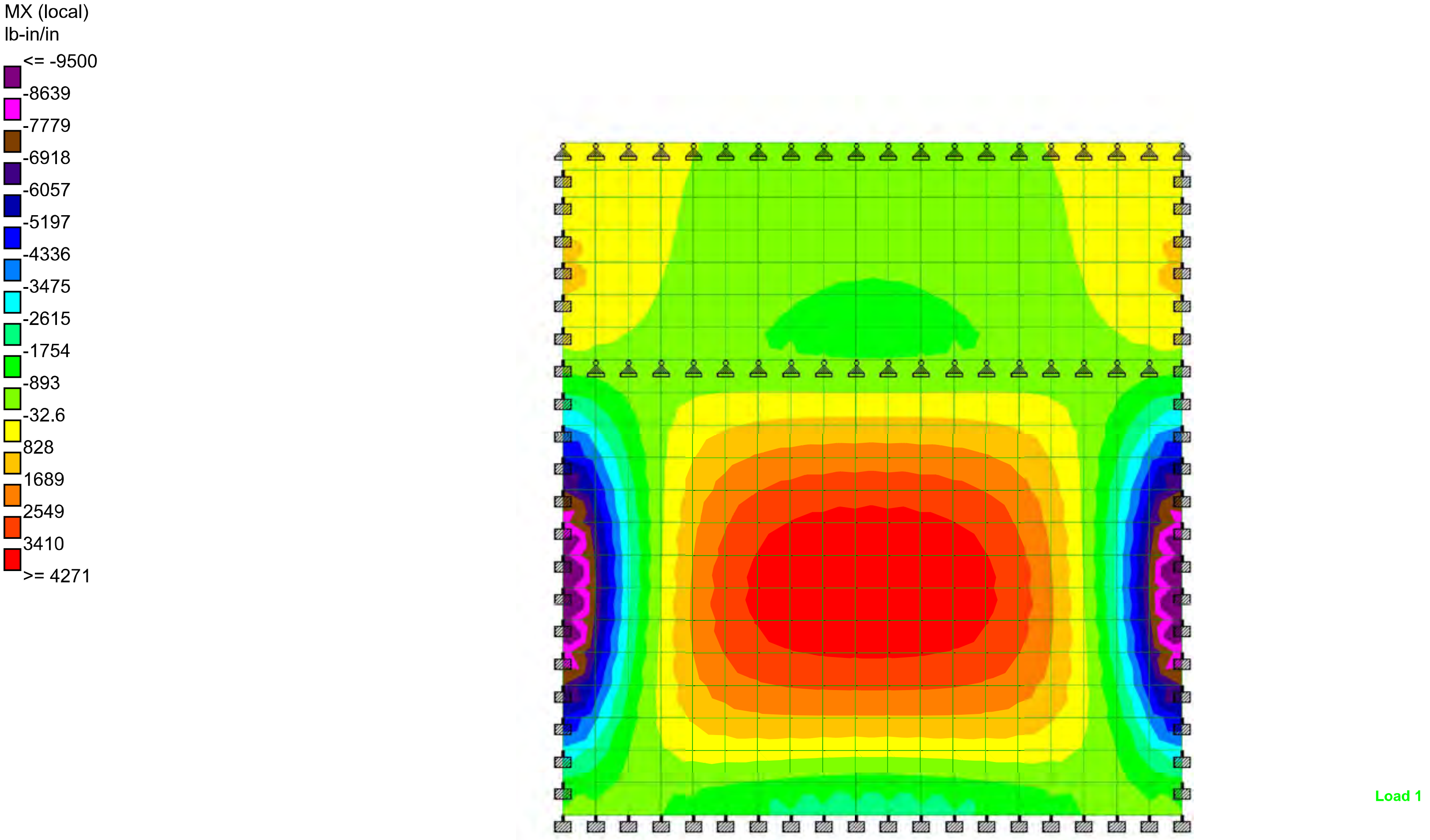
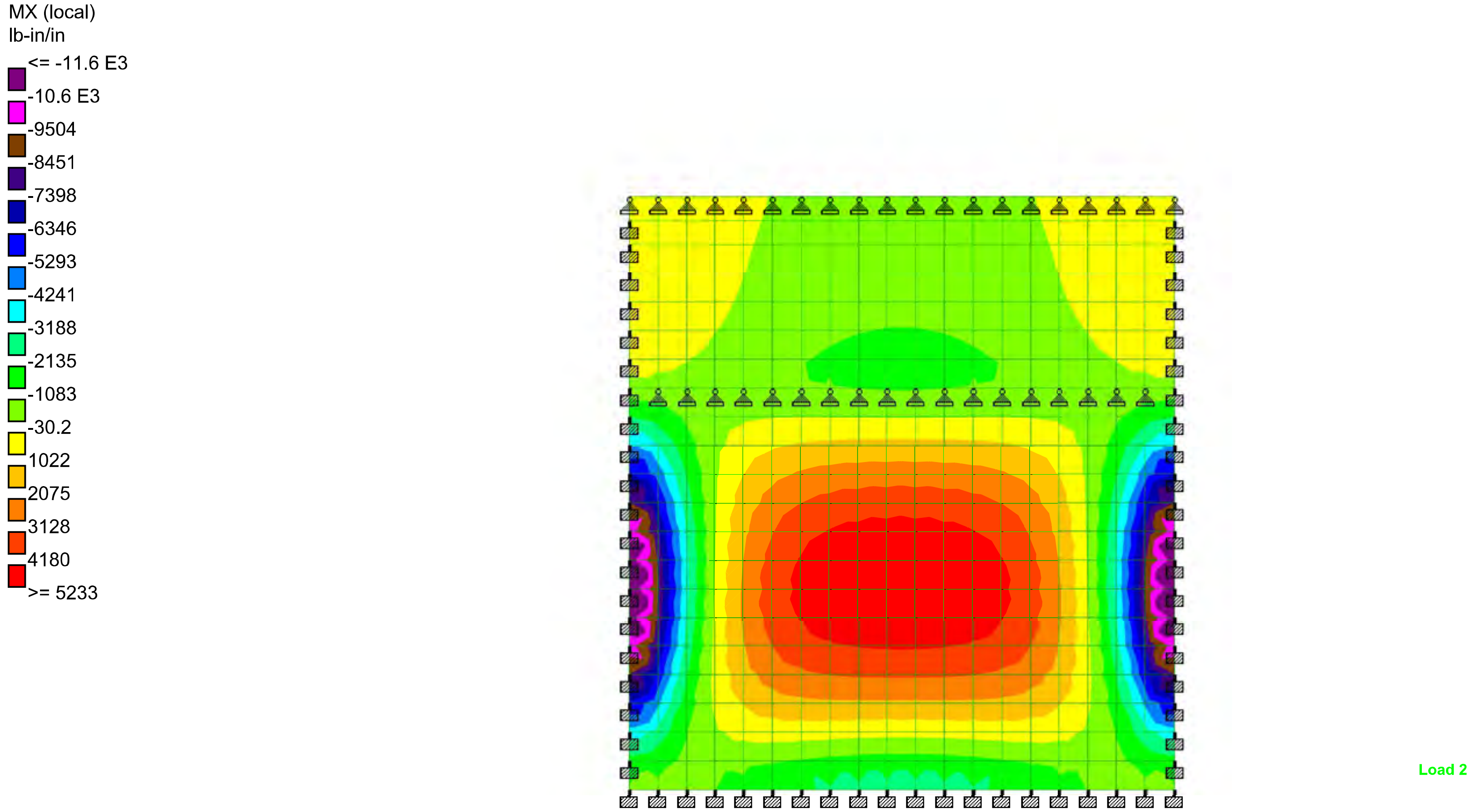
	Part Wall 7		
Job Title Area 4 - ActiFlo Load Case: 1.4F	Ref		
	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 7.std	Date/Time 09-Aug-2017 15:54	



Software licensed to Carollo Engineers CONNECTED User: Caleb Che	Job No	10721A.10	Sheet No	1	Rev
	Part	Wall 7			
Job Title Area 4 - ActiFlo	Ref				
Load Case: 1.2F+1.4E	By	CC	Date 04-Aug-17	Chd	
Client Willamette River WTP	File	Wall 7.std	Date/Time	09-Sep-2017 23:10	



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	Part Wall 7		
Job Title Area 4 - ActiFlo	Ref		
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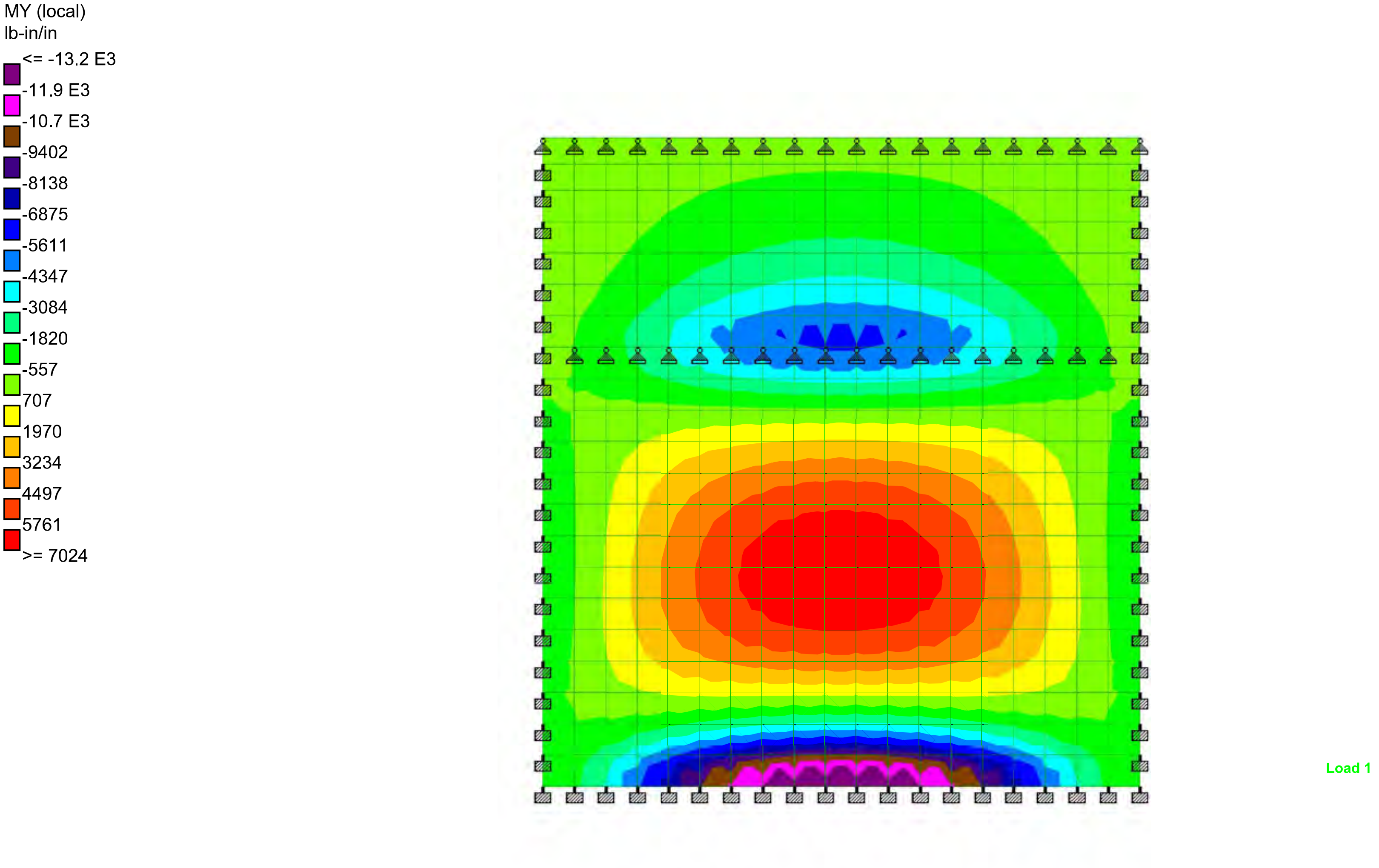
Client Willamette River WTP	File Wall 7.std	Date/Time 09-Aug-2017 15:54	



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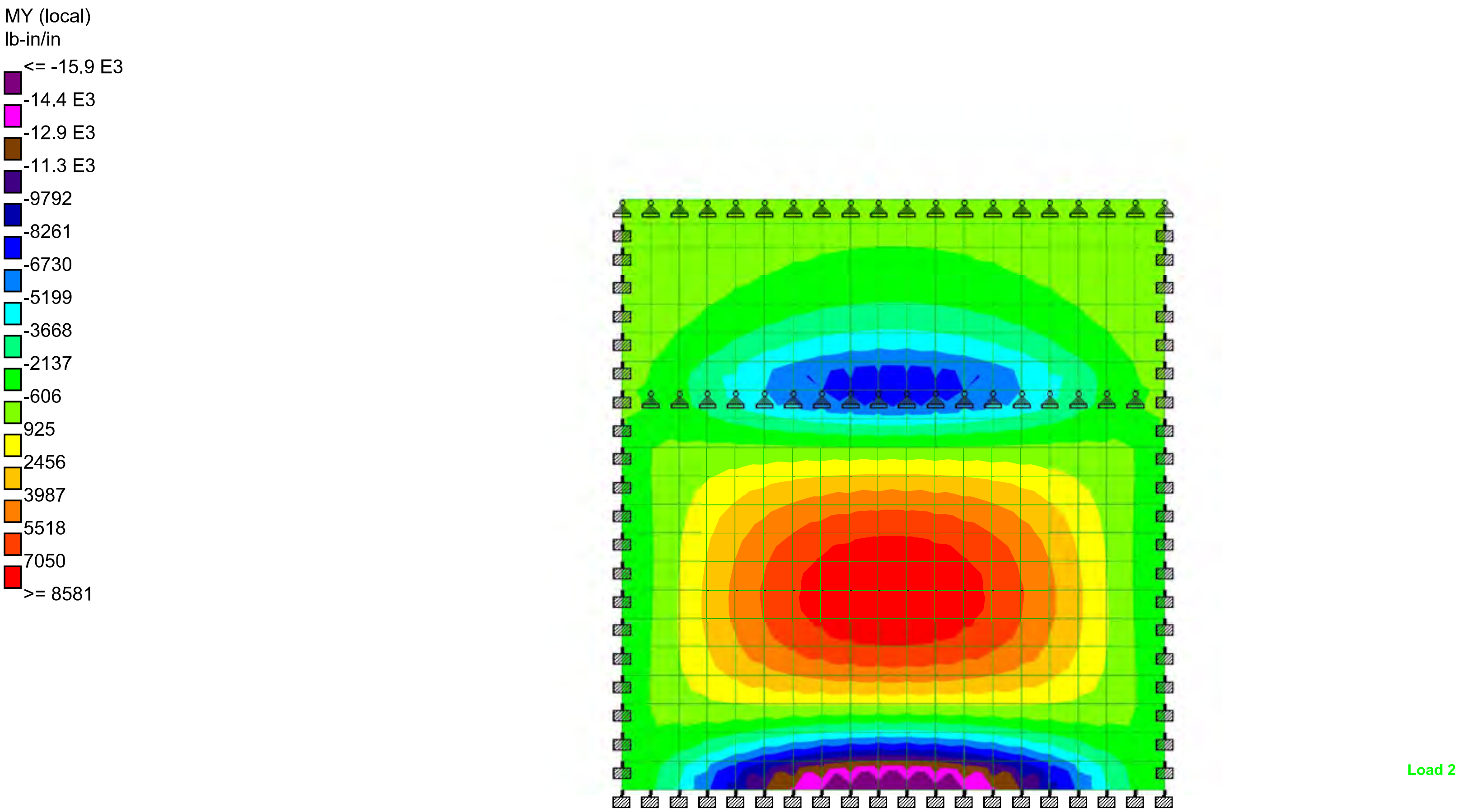
Part Wall 7			
Ref			
By CC	Date 04-Aug-17	Chd	
File Wall 7.std	Date/Time 09-Sep-2017 23:10		

Job Title Area 4 - ActiFlo

Load Case: 1.2F+1.4E

Client Willamette River WTP



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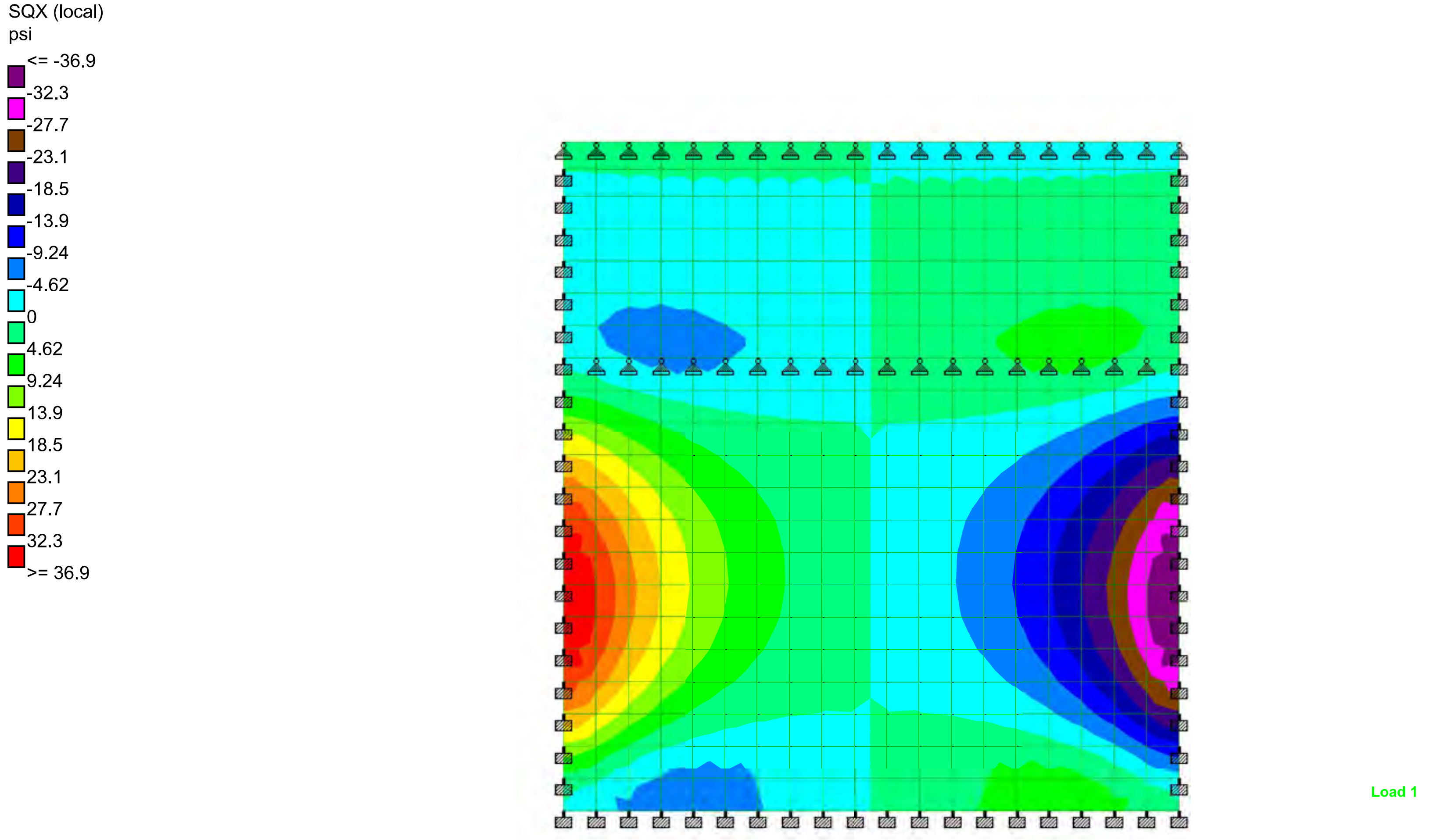
Job Title Area 4 - ActiFlo	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 7		
	Ref		
Load Case: 1.4F	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 7.std	Date/Time 09-Aug-2017 15:54	



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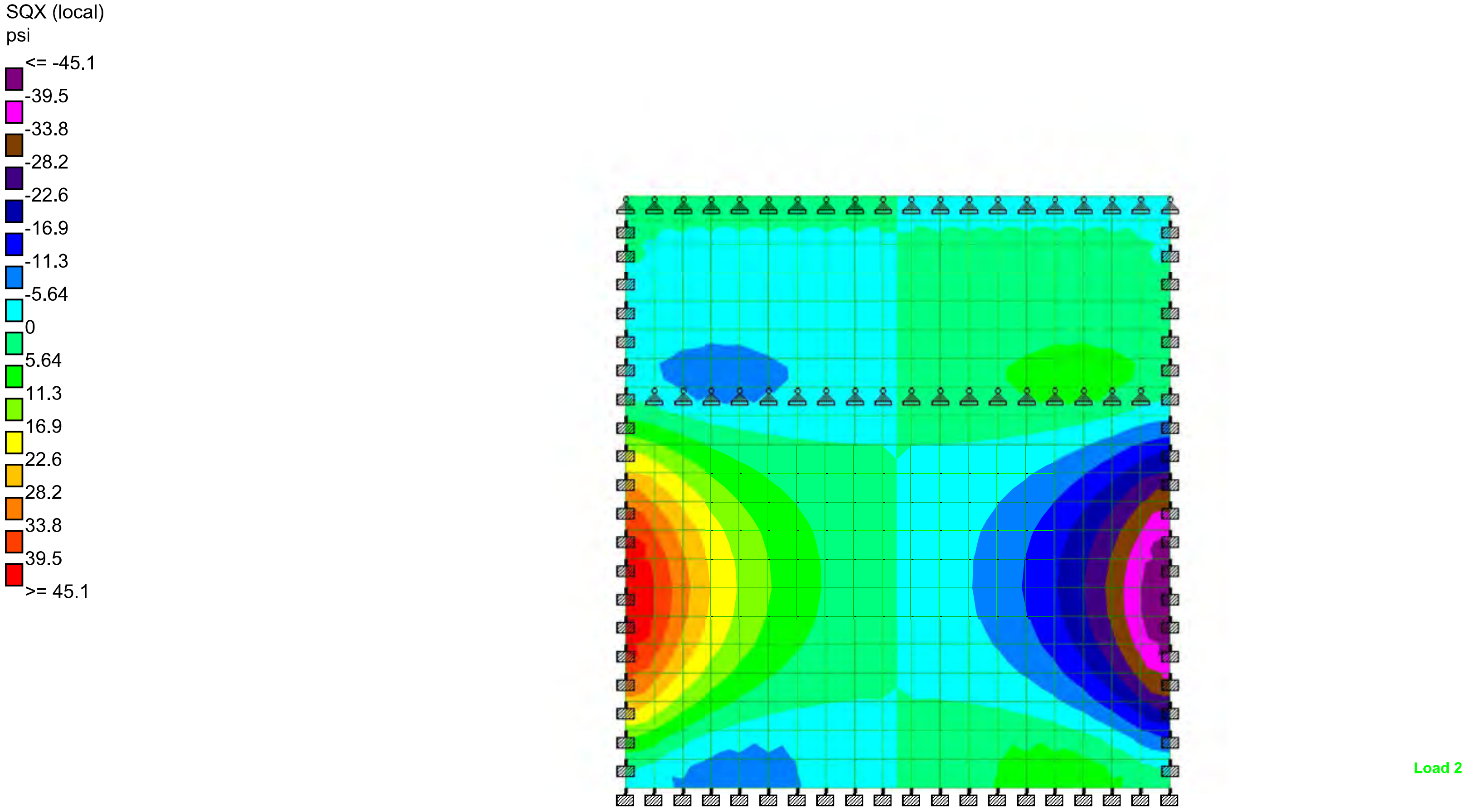
Job Title Area 4 - ActiFlo	Job No **10721A.10**		Sheet No **1**		Rev
Load Case: 1.2F+1.4E	Part Wall 7				
	Ref				
	By CC	Date 04-Aug-17		Chd	
Client Willamette River WTP	File Wall 7.std		Date/Time 09-Sep-2017 23:10		



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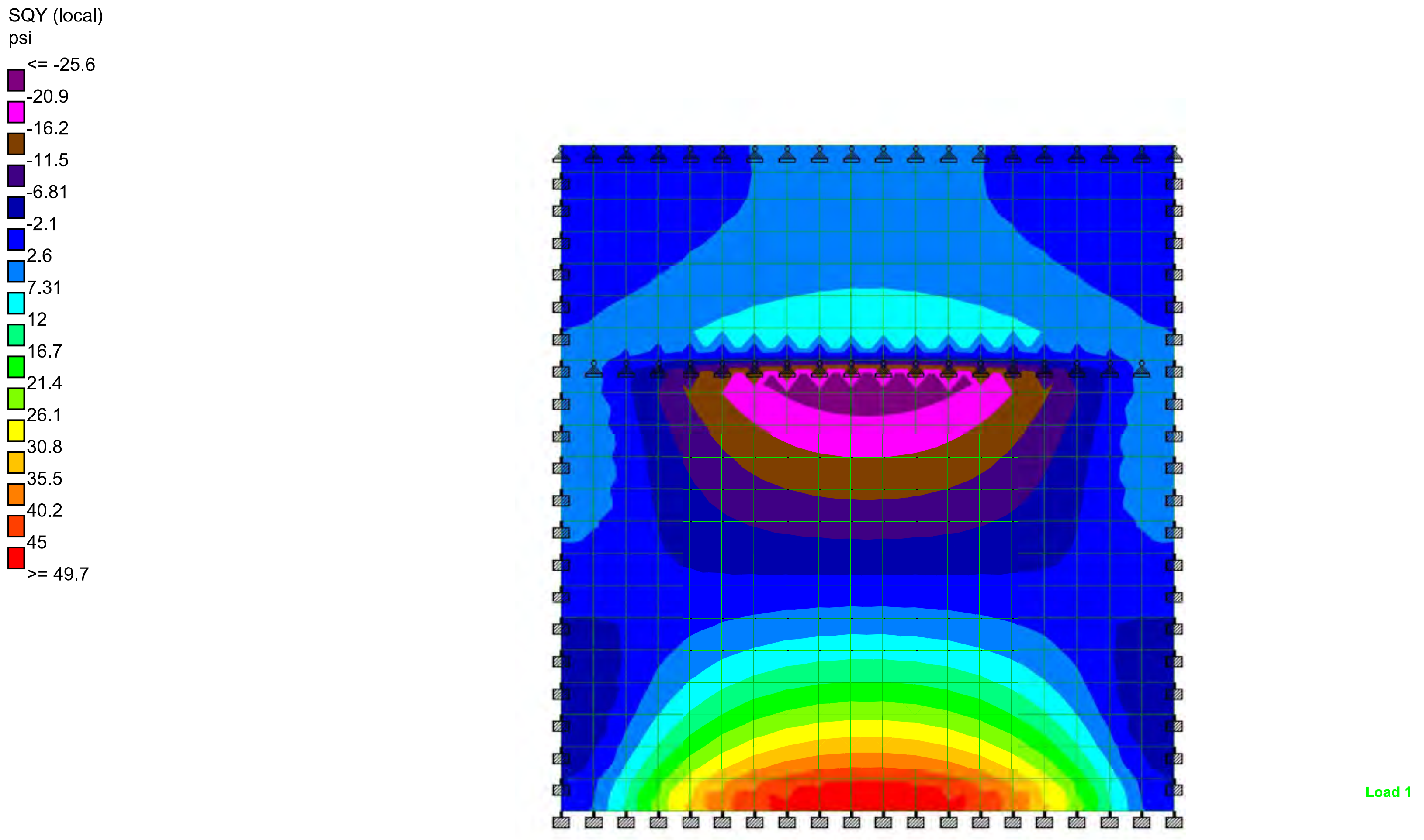
Job Title Area 4 - ActiFlo Load Case: 1.4F	Part Wall 7		
	Ref		
	By CC	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 7.std	Date/Time 09-Aug-2017 15:54	



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Job Title Area 4 - ActiFlo	Part Wall 7		
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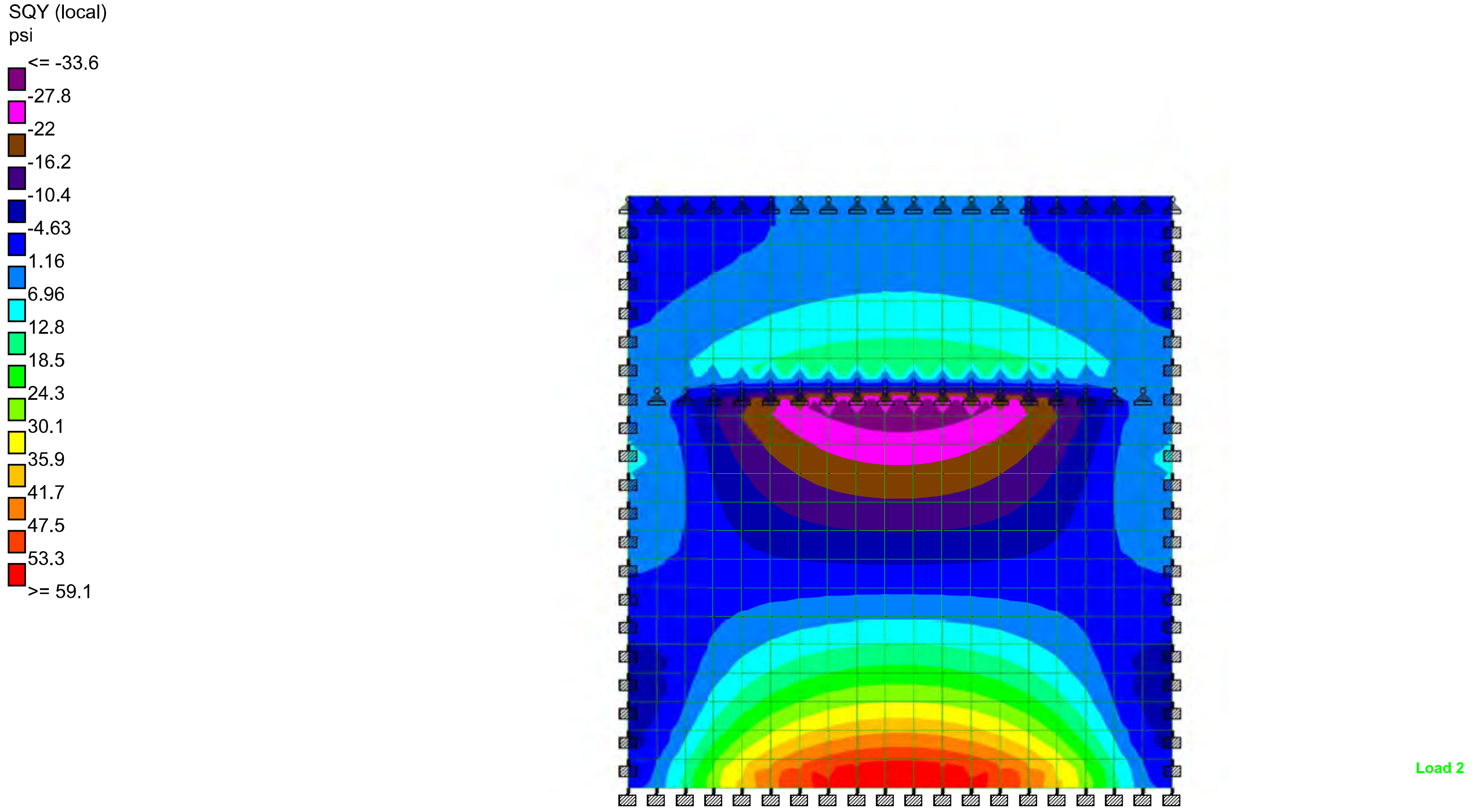
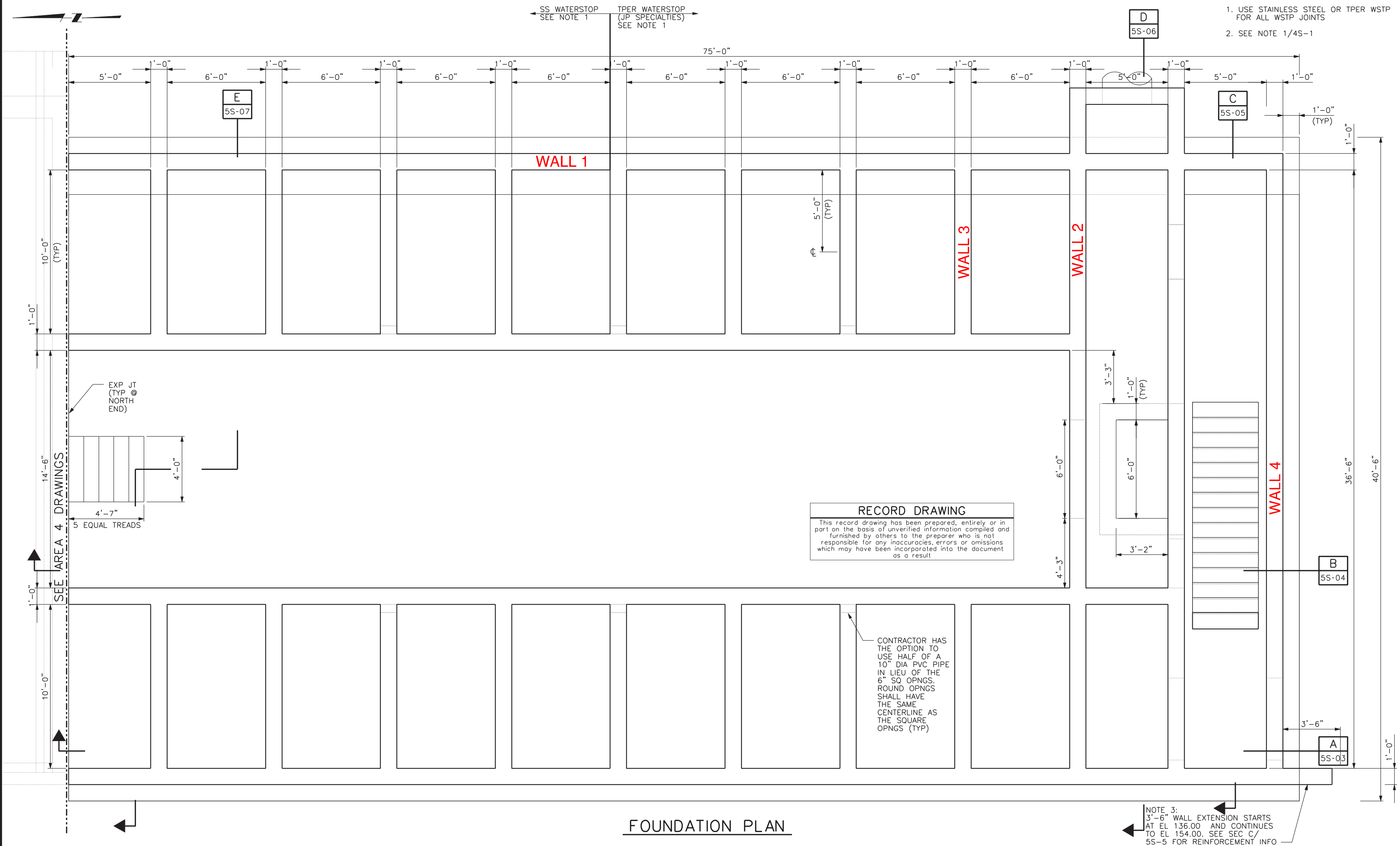


Area 5 - Ozonation Concrete Structure
ACI 350 Evaluation

WALL IDENTIFICATION

Job No: 1076081 File: P:\Wilsonville, City Of\Willamette WTP D-B\FILE-TRANSFER\cad_drawings\str\w05s01.dgn Plot Date: 04/24/2003 01:06:59 PM

NOTES:
1. USE STAINLESS STEEL OR TPER WSTP FOR ALL WSTP JOINTS
2. SEE NOTE 1/4S-1



RECORD DRAWING

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CONTRACTOR HAS THE OPTION TO USE HALF OF A 10" DIA PVC PIPE IN LIEU OF THE 6" SQ OPNGS. ROUND OPNGS SHALL HAVE THE SAME CENTERLINE AS THE SQUARE OPNGS (TYP)

NOTE 3:
3'-6" WALL EXTENSION STARTS AT EL 136.00 AND CONTINUES TO EL 154.00. SEE SEC C/5S-5 FOR REINFORCEMENT INFO

FOUNDATION PLAN

REV	DATE	BY	DESCRIPTION
R	10/03	BP	RECORD DRAWING

SCALE
OZONATION

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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Oregon

City of
WILSONVILLE
in OREGON

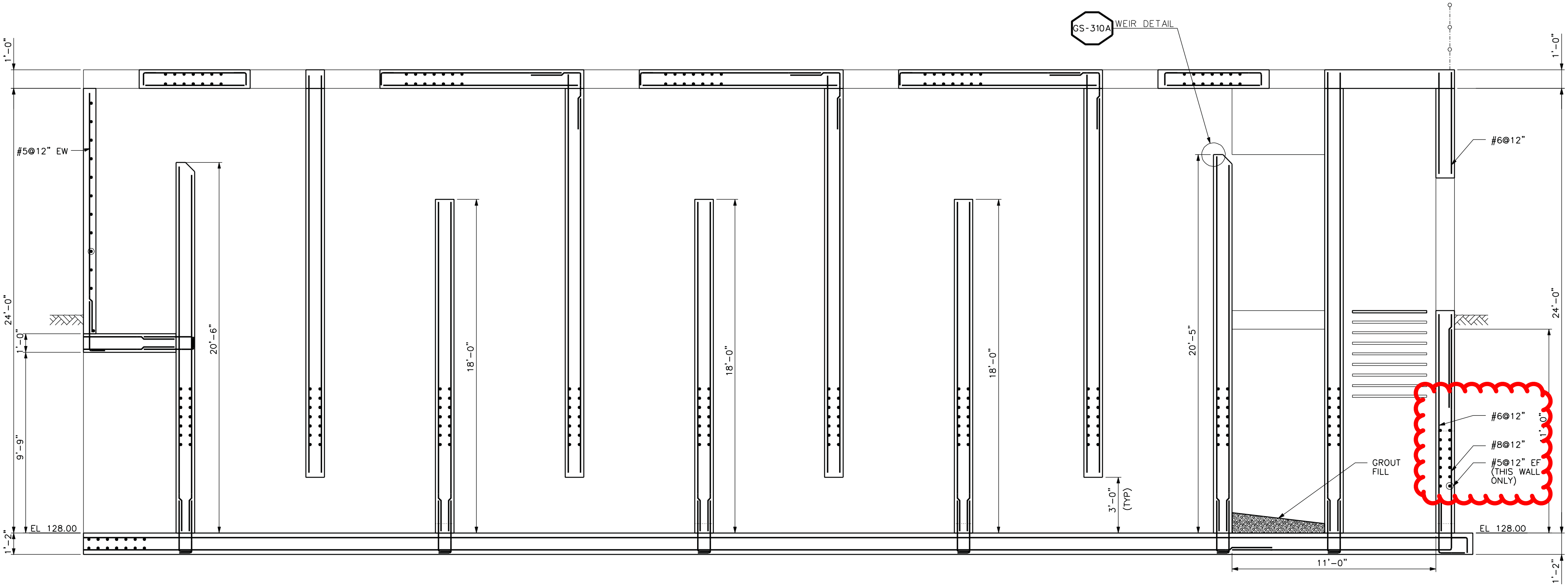
CITY OF WILSONVILLE
WILLAMETTE RIVER WATER TREATMENT PLANT
OZONATION
STRUCTURAL
FOUNDATION PLAN

SHEET
5S-01

Job No: 1076081 File: P:\Wilsonville, City Of\Willamette WTP D-B\Rcrd Dwgs\str\ustn\wi05s03.dgn Plot Date: 03/28/2003 09:22:46 AM

NOTES:

1. ALL REINFORCING SHOWN SHALL BE #5@6" UNLESS NOTED OTHERWISE



SECTION A
5S-01
5S-02

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REV	DATE	BY	DESCRIPTION
R	10/03	BR	RECORD DRAWING

SCALE 3/8"=1'-0"

WARNING 0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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DRAWN B. CROOK
CHECKED

SUBMITTED BY
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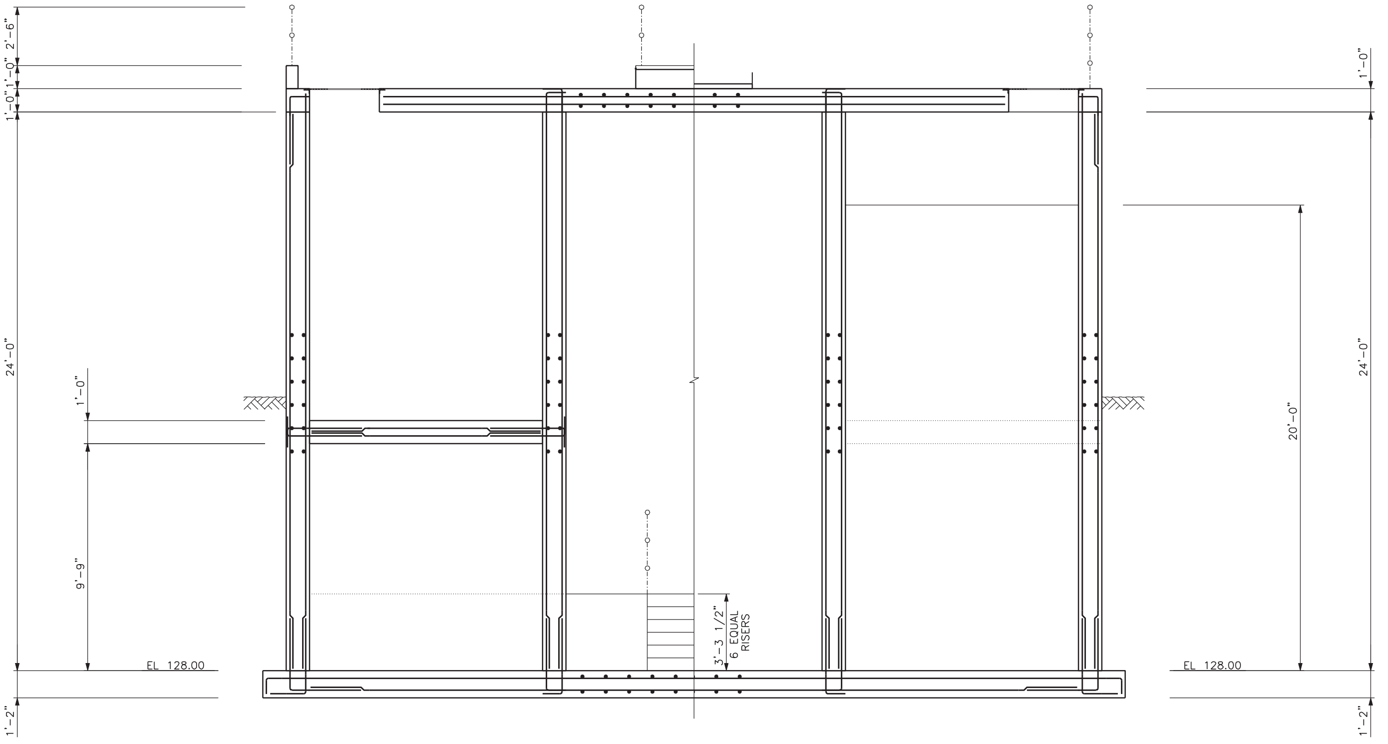
CITY OF WILSONVILLE
WILLAMETTE RIVER WATER TREATMENT PLANT
OZONATION
STRUCTURAL
SECTION

SHEET
5S-03

NOTES:

1. ALL REINFORCING SHOWN SHALL BE #5@6" UNLESS NOTED OTHERWISE



SECTION E
5S-01
5S-02

RECORD DRAWING

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Job No: 1076081
File: P:\Wilsonville, City Of\Willamette WTP D-B\FILE-TRANSFER\cad_drawings\str\wi05s07.dwg
Plot Date: 01/24/2003 01:17:45 PM

REV	DATE	BY	DESCRIPTION
R	10/03	BR	RECORD DRAWING

SCALE 3/8"=1'-0"

WARNING
0 ½ 1
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DRAWN B. CROOK
CHECKED

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STRUCTURAL
SECTION

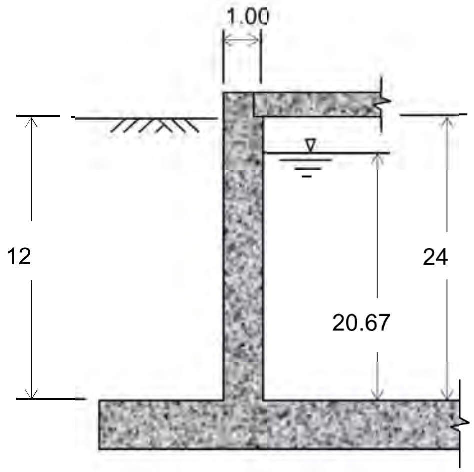
SHEET
5S-07

BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 1 Pressures

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**
tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **10** ft
tank wall thickness, t_w = **12** inch
wall height to underside of roof, H_w = **24** ft

liquid height, H_L = **20.67** ft
liquid specific gravity = **1**
liquid density, γ_L = (sp.gr.)*γ_w = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION
(wall fixity = pinned at roof & fixed at floor)

Soil Data

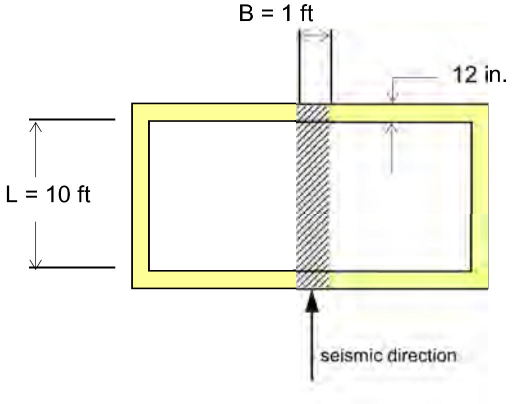
The site has no groundwater.

soil height above top of foundation base = **12** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf
0
concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.5**
Response modification factor, R_{wc} = **1**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 5 - Ozonation	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 1 Pressures		

Weights:

unit 1-ft width wall mass, W_w = (12/12) * (24) * 0.15 = 3.60 kip

wall c.g. relative to base, h_w = 24 / 2 = 12.000 ft

unit width liquid mass, W_L = (10) * (1) * (20.67) * 32.17 = 12.90 kip

Seismic:

1). structure stiffness and dynamic property:

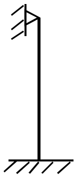
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.11191 $k\text{-}sec^2/ft^2$

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.18943 $k\text{-}sec^2/ft^2$

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 10.364 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 404.84 k/ft/ft

$\omega_i = \sqrt{\frac{k}{m_w + m_i}} =$ (404.84 / (0.1119 + 0.1894))ˆ½ = 36.6536 rad/sec

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 36.6536 = 0.1714 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} =$ (3.16*32.2*tanh(3.16*(2.067)))ˆ½ = 10.0825

$\omega_c = \frac{\lambda}{\sqrt{L}} =$ 10.0825 / (10)ˆ½ = 3.1884 rad/sec,

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 3.1884 = 1.9707 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.499 g

effective mass coeff., $\varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021$, but ≤ 1.0 = 0.9322

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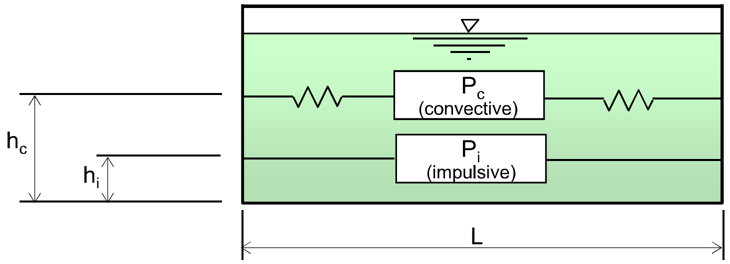
DESIGN TASK:					Wall 1 Pressures		



Dynamic Model

$L =$ 10 ft
$B =$ 1 ft
$H_L =$ 20.67 ft
$W_L =$ 12.9 kip

$L / H_L =$ 0.48379
$H_L / L =$ 2.06700

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) =$$ 12.9*(tanh(0.866*(0.4838)) / 0.866*(0.4838)) = 12.19 kip

hi (EBP) = HL * (0.5-0.09375*(L/HL)) = 20.67*(0.5-0.09375*(0.4838)) = 9.398 ft

hi (IBP) = HL * 0.45 = 9.302 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_{wi}}\right)W_i =$$ (0.611 * 1.25 / 2.5)*12.19 = 3.7 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) =$$ 12.9*(0.264*(0.4838)*tanh(3.16*(2.067))) = 1.65 kip

$$h_{c\ (EBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 17.515 ft

$$h_{c\ (IBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 17.524 ft

$$\text{convective force, } P_c = \left(\frac{S_{ac}\ I}{R_{wc}}\right)W_c =$$ (0.4993 * 1.25 / 1)*1.65 = 1.0 kip

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DESIGN TASK:			Wall 1 Pressures		

SHEET:

5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 3.60 kip

wall c.g. relative to base, h_w = 12.000 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (\ 0.611*1.25*0.9322/2.5\ )*3.6 = \quad 1.03 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (\ 10\ /\ 2)\ *\ (\ 0.4993\ /\ 1.4\ *\ 1.25\ ) = \quad 2.23 \text{ ft}$$

7). vertical acceleration:

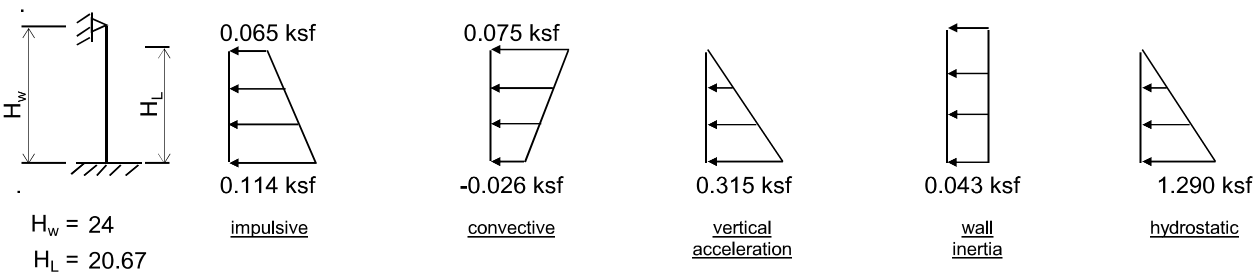
design horizontal accereration, S_{DS} = 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4*S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444*1*1/1 = \quad 0.2444 \text{ g}$$

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 3.70 kip

h_i = 9.398 ft

at y = H_L, p_{iy} = 0.065 ksf

at base y = 0, p_{iy} = 0.114 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 1.00 kip

h_c = 17.515 ft

at y = H_L, p_{cy} = 0.075 ksf

at base y = 0, p_{cy} = -0.026 ksf

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DESIGN TASK: Wall 1 Pressures

vertical acceleration:

$$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$$

$\ddot{u} =$ 0.2444
at $y = H_L$, p_{vy} = 0.000 ksf
at base $y = 0$, p_{vy} = 0.315 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ I\ \varepsilon\,\gamma_c\,(t_w/12)}{R_{wi}} =$$

p_{wy} = 0.2848 * γ_c * $(t_w/12)$
at $y = H_w$, p_{wy} = 0.043 ksf
at base $y = 0$, p_{wy} = 0.043 ksf

hydrostatic:

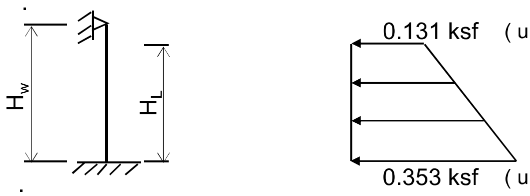
$$q_{hy} = \gamma_L\,(H_L - y) =$$

at $y = H_L$, q_{hy} = 0.000 ksf
at base $y = 0$, q_{hy} = 1.290 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{\left(p_{iy} + p_{wy}\right)^2 + p_{cy}^2 + p_{vy}^2} =$$

at $y = H_w$, p_y = 0.131 ksf
at base $y = 0$, p_y = 0.353 ksf



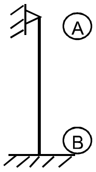
0.131 ksf (unfactored = 0.131 / 1.4 = 0.094 ksf)

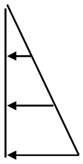
0.353 ksf (unfactored = 0.353 / 1.4 = 0.252 ksf)

resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

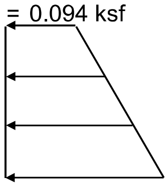
wall height, H_w = 24 ft
liquid height, H_L = 20.67 ft





1.290 ksf
hydrostatic

unfactored load = 0.094 ksf

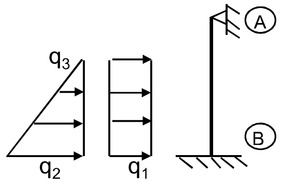


unfactored load = 0.252 ksf
resultant dynamic pressures

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 5 - Ozonation	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 1 Pressures		

10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 24 ft

soil height above top of base = 12 ft

groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

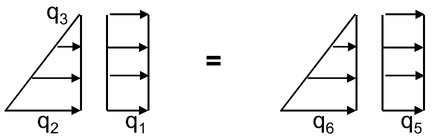
live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:

LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.6600 ksf

unfactored soil, q3 = 0.0000 ksf



equivalent soil loadings:

unfactored q5 = 0.1000 ksf

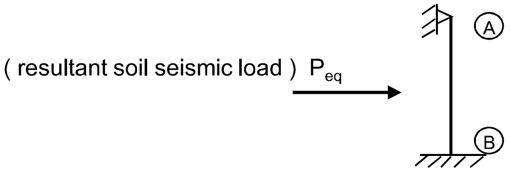
unfactored q6 = 0.6600 ksf

soil seismic:

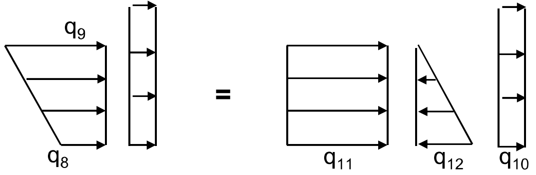
resultant factored soil seismic load per foot of wall width, $P_{u\,(eq)}$ = **3.825** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **8** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0000 ksf

equivalent soil seismic, q9 = 0.6375 ksf

wall seismic (see wall page 5), q10 = 0.0427 ksf

equivalent soil seismic, q11 = q9 = 0.6375 ksf

equivalent soil seismic, q12 = q8 - q9 = -0.6375 ksf

unfactored equivalent soil seismic, q8 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q9 =0.6375 / 1.4 = 0.4554 ksf

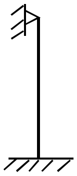
unfactored wall seismic , q10 = 0.0427 / 1.4 = 0.0305 ksf

unfactored equivalent soil seismic, q11 =0.6375 / 1.4 = 0.4554 ksf

unfactored equivalent soil seismic, q12 =-0.6375 / 1.4 = -0.4554 ksf

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP
CHKD:		**DESCRIPTION:**	Area 5 - Ozonation	**JOB NO:**	10721A.10
DESIGN TASK:	Wall 1 Pressures			**SHEET:**	

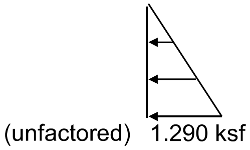
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



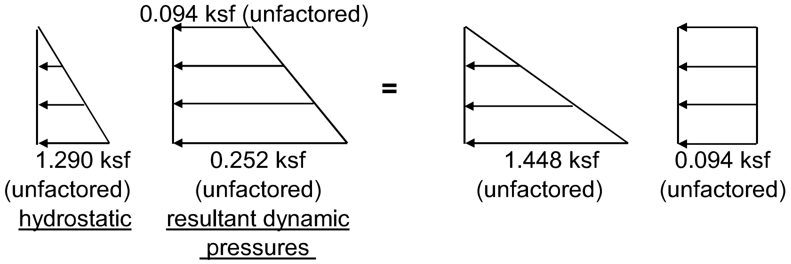
Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

wall height = 24 ft
water depth = 20.67 ft



b). load case 2: hydrostatic + dynamic:



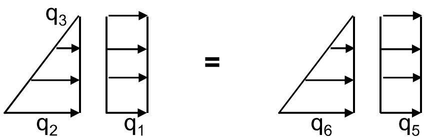
wall height = 24 ft
water depth = 20.67 ft

c). load case 3: static soil + LL surcharge:

wall height = 24 ft
soil height on wall = 12 ft

equivalent static soil & surcharge loadings...

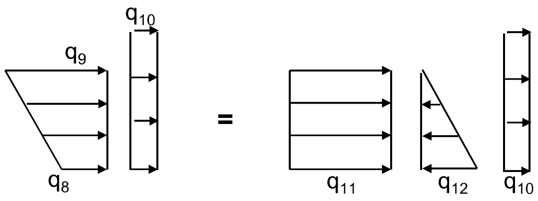
LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.660 ksf
unfactored soil, q3 = 0.000 ksf



equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.660 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 24 ft
soil height on wall = 12 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.455 ksf
unfactored equivalent soil seismic, q10 = 0.031 ksf
unfactored equivalent soil seismic, q11 = 0.455 ksf
unfactored equivalent soil seismic, q12 = -0.455 ksf

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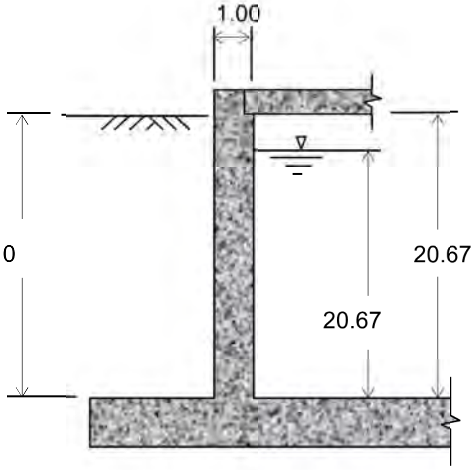
DESIGN TASK:			Wall 2 Pressures		

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **6** ft
tank wall thickness, t_w = **12** inch
wall height to underside of roof, H_w = **20.67** ft

liquid height, H_L = **20.67** ft
liquid specific gravity = **1**
liquid density, γ_L = (sp.gr.)*γ_w = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 k-sec^2/ft^4



WALL SECTION
(wall fixity = pinned at roof & fixed at floor)

Soil Data

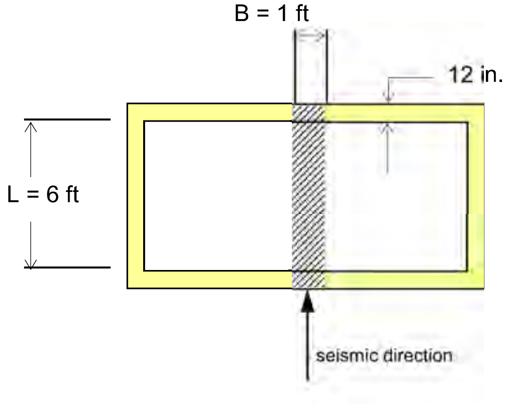
The site has no groundwater.

soil height above top of foundation base = **0** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0** k/ft^3
live load lateral surcharge = **0.100** ksf
0
concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 k-sec^2/ft^4

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.5**
Response modification factor, R_{wc} = **1**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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CHKD:		**DESCRIPTION:**		Area 5 - Ozonation		**JOB NO:**	10721A.10
DESIGN TASK:				Wall 2 Pressures			

Weights:

unit 1-ft width wall mass, W_w = (12/12) * (20.67) * 0.15 = 3.10 kip

wall c.g. relative to base, h_w = 20.67 / 2 = 10.335 ft

unit width liquid mass, W_L = (6) * (1) * (20.67) * 32.17 = 7.74 kip

Seismic:

1). structure stiffness and dynamic property:

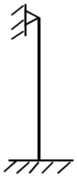
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.09638 $k\text{-}sec^2/ft^2$

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.11779 $k\text{-}sec^2/ft^2$

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 10.026 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 552.63 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (552.63 / (0.0964 + 0.1178))\hat{}½ = 50.7968 \text{ rad/sec}$$

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 50.7968 = 0.1237 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = \quad (3.16*32.2*\tanh(3.16*(3.445)))\hat{}½ = 10.0825$$

$$\omega_c = \frac{\lambda}{\sqrt{L}} = \quad 10.0825 / (6)\hat{}½ = 4.1162 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 4.1162 = 1.5265 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.645 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ , \quad \text{but} \le 1.0 = \quad 0.9669$$

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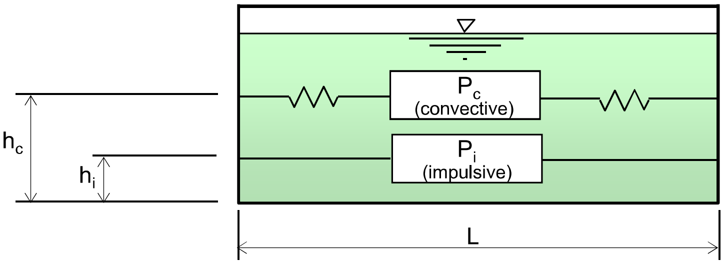
DESIGN TASK:	Wall 2 Pressures			**SHEET:**	



Dynamic Model

L =	6	ft
B =	1	ft
H_L =	20.67	ft
W_L =	7.74	kip
L / H_L =	0.29028	
H_L / L =	3.44500	

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L \left(\frac{\tanh\left(0.866 \frac{L}{H_L}\right)}{0.866 \frac{L}{H_L}} \right) = \quad 7.74*(\tanh(0.866*(0.2903)) / 0.866*(0.2903)) = \quad 7.58 \text{ kip}$$

hi (EBP) = HL * (0.5-0.09375*(L/HL)) = 20.67*(0.5-0.09375*(0.2903)) = 9.773 ft

hi (IBP) = HL * 0.45 = 9.302 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai} \ \mathrm{I}}{R_{wi}} \right) W_i = \quad (0.611 * 1.25 / 2.5)*7.58 = \quad 2.3 \text{ kip}$$

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L \left(0.264 \left(\frac{L}{H_L} \right) \tanh\left(3.16 \left(\frac{H_L}{L} \right) \right) \right) = \quad 7.74*(0.264*(0.2903)*\tanh(3.16*(3.445))) = \quad 0.59 \text{ kip}$$

$$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 18.771 \text{ ft}$$

$$h_{c\ (IBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 18.771 \text{ ft}$$

$$\text{convective force, } P_c = \left(\frac{S_{ac} \ \mathrm{I}}{R_{wc}} \right) W_c = \quad (0.6446 * 1.25 / 1)*0.59 = \quad 0.5 \text{ kip}$$

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DESIGN TASK:					Wall 2 Pressures		

5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 3.10 kip

wall c.g. relative to base, h_w = 10.335 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right)W_w =$ (0.611*1.25*0.9669/2.5)*3.1 = 0.92 kip

6). maximum wave slosh height displacement:

$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) =$ (6 / 2) * (0.6446 / 1.4 * 1.25) = 1.73 ft

Wave height is greater than the freeboard of 0-ft. Check possible effects on the roof.

7). vertical acceleration:

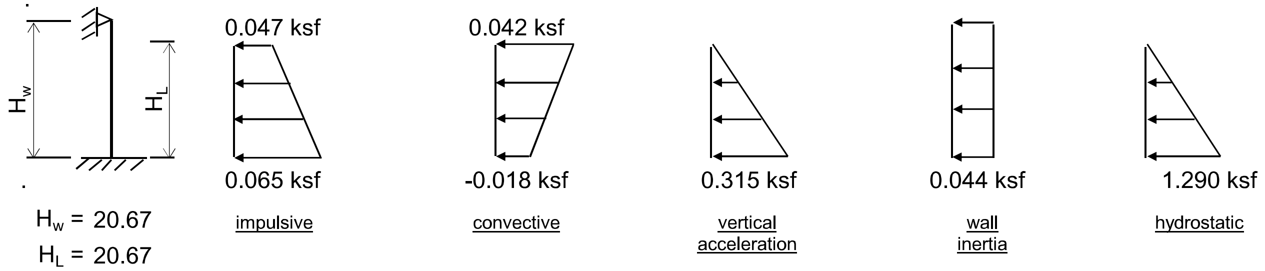
design horizontal accereration, S_{DS} = 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4{*}S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 0.2444*1*1/1 = 0.2444 g

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



H_w = 20.67

H_L = 20.67

impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 2.30 kip

h_i = 9.773 ft

at y = H_L, p_{iy} = 0.047 ksf

at base y = 0, p_{iy} = 0.065 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 0.50 kip

h_c = 18.771 ft

at y = H_L, p_{cy} = 0.042 ksf

at base y = 0, p_{cy} = -0.018 ksf

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DESIGN TASK: Wall 2 Pressures

vertical acceleration:

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

$\ddot{u}$ = 0.2444
at y = H_L, p_{vy} = 0.000 ksf
at base y = 0, p_{vy} = 0.315 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ \ I\ \ \varepsilon\,\gamma_c\ (t_w/12)}{R_{wi}} =$$

p_{wy} = 0.2954 * γ_c * (t_w/12)
at y = H_w, p_{wy} = 0.044 ksf
at base y = 0, p_{wy} = 0.044 ksf

hydrostatic:

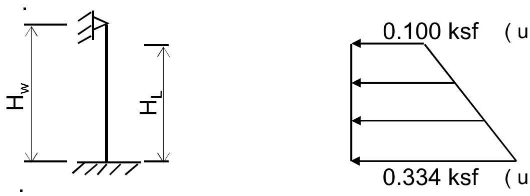
$q_{hy} = \gamma_L\,(H_L - y) =$

at y = H_L, q_{hy} = 0.000 ksf
at base y = 0, q_{hy} = 1.290 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y = 0.100 ksf
at base y = 0, p_y = 0.334 ksf



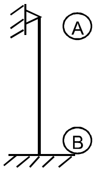
0.100 ksf (unfactored = 0.1 / 1.4 = 0.071 ksf)

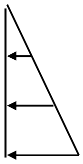
0.334 ksf (unfactored = 0.334 / 1.4 = 0.239 ksf)

resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

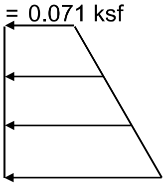
wall height, H_w = 20.67 ft
liquid height, H_L = 20.67 ft





1.290 ksf
hydrostatic

unfactored load = 0.071 ksf



unfactored load = 0.239 ksf
resultant dynamic pressures

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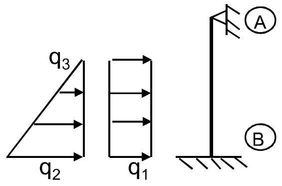
DESIGN TASK:	Wall 2 Pressures				

10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 20.67 ft

soil height above top of base = 0 ft

groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

live load lateral surcharge = 0.100 ksf

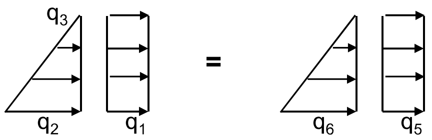
equivalent static soil loadings:

LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.0000 ksf

unfactored soil, q3 = 0.0000 ksf

0.000



equivalent soil loadings:

unfactored q5 = 0.1000 ksf

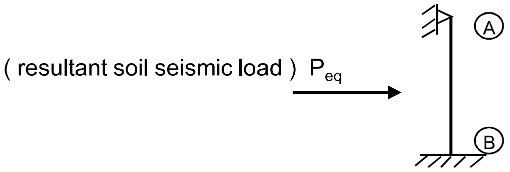
unfactored q6 = 0.0000 ksf

soil seismic:

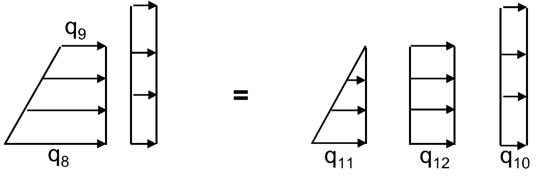
resultant factored soil seismic load per foot of wall width, $P_{u\ (eq)}$ = **0** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **0** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0000 ksf

equivalent soil seismic, q9 = 0.0000 ksf

wall seismic (see wall page 5), q10 = 0.0443 ksf

equivalent soil seismic, q11 = q8 - q9 = 0.0000 ksf

equivalent soil seismic, q12 = q9 = 0.0000 ksf

unfactored equivalent soil seismic, q8 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q9 =0 / 1.4 = 0.0000 ksf

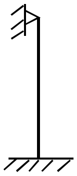
unfactored wall seismic , q10 = 0.0443 / 1.4 = 0.0316 ksf

unfactored equivalent soil seismic, q11 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q12 =0 / 1.4 = 0.0000 ksf

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP
CHKD:		**DESCRIPTION:**	Area 5 - Ozonation	**JOB NO:**	10721A.10
DESIGN TASK:	Wall 2 Pressures			**SHEET:**	

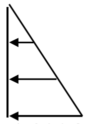
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

wall height = 20.67 ft
water depth = 20.67 ft

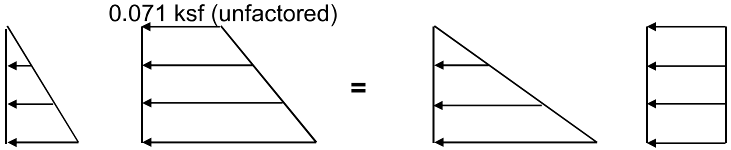


(unfactored) 1.290 ksf

b). load case 2: hydrostatic + dynamic:

wall height = 20.67 ft
water depth = 20.67 ft

0.071 ksf (unfactored)

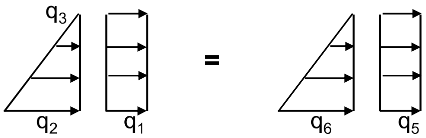


1.290 ksf	0.239 ksf		1.458 ksf	0.071 ksf
(unfactored)	(unfactored)		(unfactored)	(unfactored)
hydrostatic	resultant dynamic pressures			

c). load case 3: static soil + LL surcharge:

wall height = 20.67 ft
soil height on wall = 0 ft

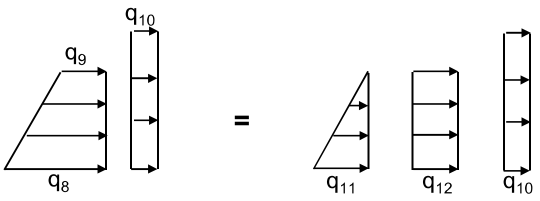
equivalent static soil & surcharge loadings...



LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.000 ksf
unfactored soil, q3 = 0.000 ksf
0.000
equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.000 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.67 ft
soil height on wall = 0 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.000 ksf
unfactored equivalent soil seismic, q10 = 0.032 ksf
unfactored equivalent soil seismic, q11 = 0.000 ksf
unfactored equivalent soil seismic, q12 = 0.000 ksf

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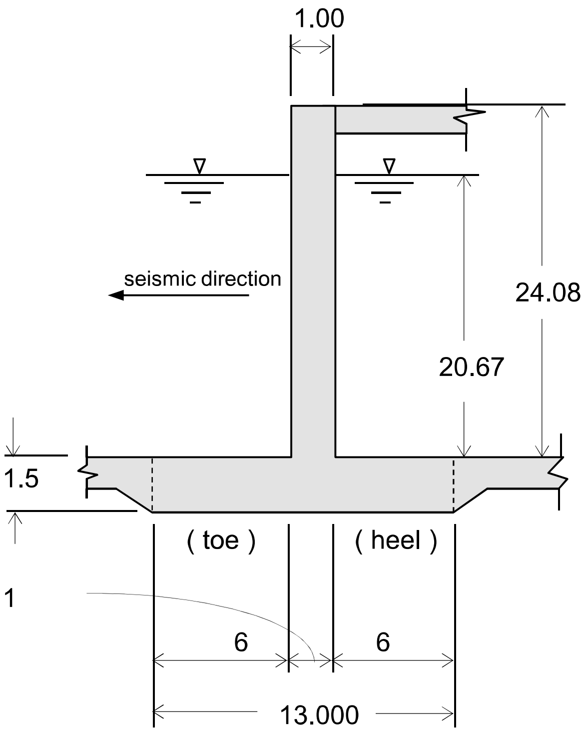
DESIGN TASK:					Wall 3 Pressure (water 2-Sides)		

Hydrodynamic analysis of an interior wall with equal water each side per ASCE 7-10 and the 2012 IBC code:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B =	1	ft
tank inside length in direction of seismic, L =	**6**	ft
inside serpentine wall thickness, t_w =	**12**	inch
wall height to underside of roof, H_w =	**24**	ft
roof thickness, tr =	**1**	inch
liquid height, H_L =	**20.67**	ft
liquid specific gravity =	**1**	
liquid density, γ_L = (sp.gr.)*γ_w =	0.0624	k/ft^3
acceleration due to gravity, g =	32.17	ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ =	0.00194	k-sec^2/ft^4
foundation footing thickness, t_f =	1.5	ft
foundation projection toe side, l_t =	6	ft
foundation projection heel side, l_h =	6	ft
allowable soil bearing pressure static =	**2**	ksf
allowable soil bearing pressure seismic =	**2.67**	ksf
yield strength of reinforcement, f_y =	**60**	ksi
concrete strength, f'_c =	**4**	ksi
concrete density, γ_c =	0.150	k/ft^3
concrete modulus of elasticity, E_c =	3605.0	ksi
concrete mass density, $\rho_c = \gamma_c / g$ =	0.004663	k-sec^2/ft^4

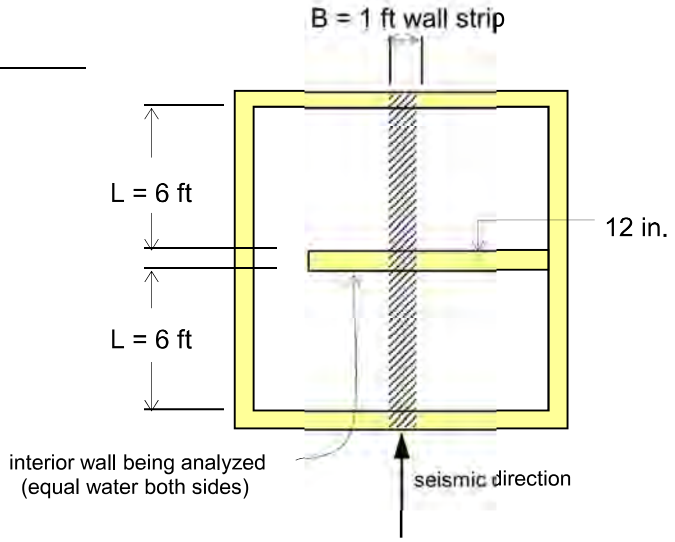


Interior Wall Section
(wall fixity = pinned at roof & fixed at floor)

Seismic data from the IBC code:

Structure Risk Category =	**3**
Seismic importance factor, I =	**1.25**
Response modification factor, R_i =	**2.5**
Response modification factor, R_c =	**1.5**

Note:
Hydrodynamic seismic forces on the interior wall will be the sum of half the impulsive and convective forces from water on <u>each</u> side of the wall.



Interior Wall Plan

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DESIGN TASK:					Wall 3 Pressure (water 2-Sides)		

Weights:

unit 1-ft width wall mass, W_w =	(12/12) * (24) * 0.15 =	3.60	kip
wall c.g. relative to base, h_w =	24 / 2 =	12.000	ft
unit width liquid mass, W_L =	6*1*20.67*0.0624 =	7.74	kip

~~Seismic:~~

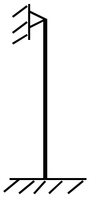
Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g

Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Note: Hydrodynamic seismic forces on the interior wall will be the sum of half the impulsive and convective forces from water on <u>each</u> side of the wall.

1). <u>wall stiffness and dynamic property:</u>

Note: Wi and hi are impulsive component variables calculated on page 3.



wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.11191 $\text{k-sec}^2/\text{ft}^2$

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.11779 $\text{k-sec}^2/\text{ft}^2$

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 10.858 ft

wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, $k = Ec*(tw*Hw/h)^3 / (12*(4*Hw-h)*(Hw-h)^2)$ = 381.23 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (381.23 / (0.1119 + 0.1178))\hat{}\tfrac{1}{2} = 40.73918 \text{ rad/sec}$$

period of vibration of the wall plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2*π / 40.73918 = 0.1542 sec

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 *g

2). <u>Dynamic properties, Spectral amplification factors, and Effective mass coefficient:</u>

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = 10.0825 \qquad \omega_c = \frac{\lambda}{\sqrt{L}} = \quad 10.0825/(6)\hat{}\tfrac{1}{2} = 4.1162 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2*π / 4.1162 = 1.5265 sec

Long transition period (from map figure 22-12 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.6446 *g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ , \quad \text{but} \le 1.0 = \quad 0.9669$$

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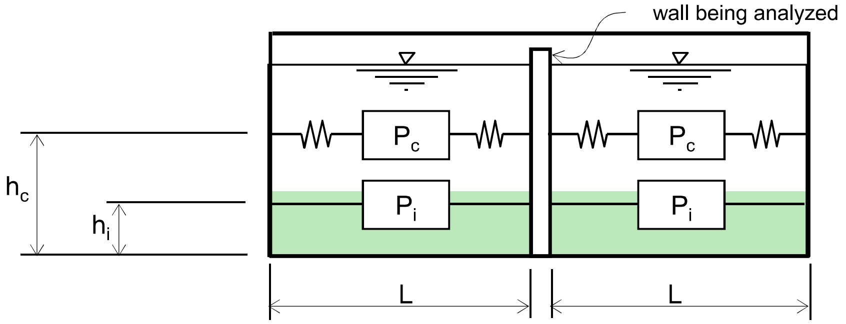
DESIGN TASK:					Wall 3 Pressure (water 2-Sides)		



Dynamic Model

L =	6	ft
B =	1	ft
H_L =	20.67	ft
W_L =	7.74	kip
L / H_L =	0.29028	
H_L / L =	3.44500	

3). lateral fluid impulsive force:

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) = \quad 7.58 \text{ kip}$$

hi (EBP) = HL * (0.5-0.09375*(L/HL)) = 20.67*(0.5-0.09375*(0.2903)) = 9.773 ft

hi (IBP) = HL * 0.45 = 9.302 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_i}\right)W_i = \quad (0.611 * 1.25 / 2.5) * 7.58 = \quad 2.32 \text{ kip}$$

impulsive force moment excluding bottom pressure , $M_{i(EBP)} = P_i{*}h_{i(EBP)}$ = 2.32 * 9.773 = 22.67 ft-k

impulsive force moment including bottom pressure , $M_{i(IBP)} = P_i{*}h_{i(IBP)}$ = 2.32 * 9.302 = 21.58 ft-k

4). lateral fluid convective force:

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) = \quad 0.59 \text{ kip}$$

$$h_{c\ (EBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) = \quad 18.771 \text{ ft}$$

$$h_{c\ (IBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) = \quad 18.771 \text{ ft}$$

$$\text{convective force, } P_c = \left(\frac{S_{ac}\ I}{R_c}\right)W_c = \quad (0.6446 * 1.25 / 1.5) * 0.59 = \quad 0.32 \text{ kip}$$

convective force moment excluding bottom pressure , $M_{c(EBP)} = P_c{*}h_{c(EBP)}$ = 0.32 * 18.771 = 6.01 ft-k

convective force moment including bottom pressure , $M_{c(IBP)} = P_c{*}h_{c(IBP)}$ = 0.32 * 18.771 = 6.01 ft-k

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5). lateral inertia force of the accelerating wall:

mass of a unit 1-ft width wall, W_w = 3.60 kip

wall c.g. relative to base, h_w = 12.000 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ \ I\ \ \varepsilon}{R_i}\right)W_w =$ (0.611 * 1.25 * 0.9669 / 2.5) * 3.6 = 1.06 kip

wall inertia force moment, $M_w = P_w{*}h_w$ = 1.06 * 12 = 12.72 ft-k

6). total base shear:

$$V = \sqrt{(P_i + P_w)^2 + P_c^2}$$

V = ((2.32 + 1.06)² + (0.32)²)^½ = 3.40 kip

7). total moment at the base excluding bottom pressure (EBP):

$$M_b = \sqrt{(M_i + M_w)^2 + M_c^2}$$

M_b = ((22.67 + 12.72)² + (6.01)²)^½ = 35.90 ft-k

8). total moment at the base including bottom pressure (IBP):

$$M_o = \sqrt{(M_i + M_w)^2 + {M_c}^2}$$

M_o = ((21.58 + 12.72)² + (6.01)²)^½ = 34.82 ft-k

9). maximum wave slosh height displacement: (see ASCE-10, 15.7.6.1 notes c and d)

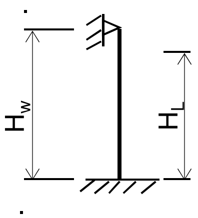
(Risk Category = 3) I = 1.25 ,use TL = 4 ,Sd1 = 0.656 ,Tc = 1.5265

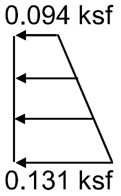
S_{ac} = 1.5 * Sd1 / Tc = 0.6446 *g

$d_{(max)} = 0.42\ (\ L\ )(\ S_{ac}\ \ I\ ) =$ 0.42 * (6) * (0.6446 * 1.25) = 2.03 ft

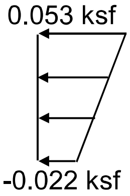
(minimum freeboard see table 15.7-3 of ASCE 7) , d(min) = 0.7 * d(max) = 1.42 ft

10). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:

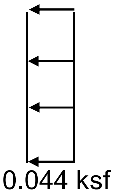




impulsive



convective



wall inertia

H_w = 24
H_L = 20.67

impulsive: Note: this accounts for the impulsive pressure on each side of the wall.

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{B\,H_L^2} =$$

P_i = 2.32 kip
h_i = 9.773 ft
at y = H_L, p_{iy} = 0.094 ksf
at base y = 0, p_{iy} = 0.131 ksf

convective: Note: this accounts for the convective pressure on each side of the wall.

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{B\,H_L^2} =$$

P_c = 0.32 kip
h_c = 18.771 ft
at y = H_L, p_{cy} = 0.053 ksf
at base y = 0, p_{cy} = -0.022 ksf

wall inertia:

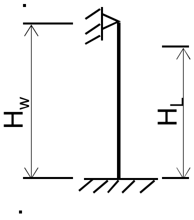
$$p_{wy} = \frac{S_{ai}\ \ I\ \ \varepsilon\ \gamma_c\ (t_w/12)}{R_i} =$$

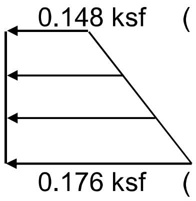
p_{wy} = 0.2954 * γ_c * t_w
at y = H_w, p_{wy} = 0.044 ksf
at base y = 0, p_{wy} = 0.044 ksf

combine the effects of the hydrodynamic pressures on the wall:

$$p_y = \sqrt{\left(p_{iy} + p_{wy}\right)^2 + p_{cy}^2} =$$

at y = H_w, p_y = 0.148 ksf
at base y = 0, p_y = 0.176 ksf





(unfactored = 0.148 / 1.4 = 0.106 ksf)
(unfactored = 0.176 / 1.4 = 0.126 ksf)

resultant dynamic pressures

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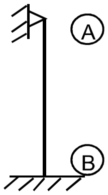
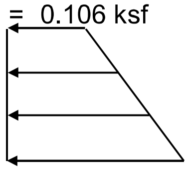
DESIGN TASK: Wall 3 Pressure (water 2-Sides)

11). wall design pressures for hydrodynamic seismic:

wall height, H_w = 24 ft
liquid height, H_L = 20.67 ft



unfactored load = 0.106 ksf



unfactored load = 0.126 ksf

unfactored resultant dynamic pressures

Area 5 - Ozonation
Wall 1 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.23	3.96	4.88	25.50	***0.19***	33	126	***0.26***	***<- OK***
1.2F+1.4E	1.00	4.32	4.32	25.50	***0.17***	35	126	***0.28***	***<- OK***
1.6(H+L)	1.08	2.05	2.21	25.50	***0.09***	20	126	***0.15***	***<- OK***
1.6H+1.4E	1.00	2.74	2.74	25.50	***0.11***	22	126	***0.18***	***<- OK***

Vertical Span

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.23	3.47	4.27	28.50	***0.15***	33	126	***0.26***	***<- OK***
1.2F+1.4E	1.00	3.71	3.71	28.50	***0.13***	35	126	***0.28***	***<- OK***
1.6(H+L)	1.08	1.96	2.11	28.50	***0.07***	19	126	***0.15***	***<- OK***
1.6H+1.4E	1.00	2.28	2.28	28.50	***0.08***	21	126	***0.17***	***<- OK***

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	Part Wall 1		
	Ref		
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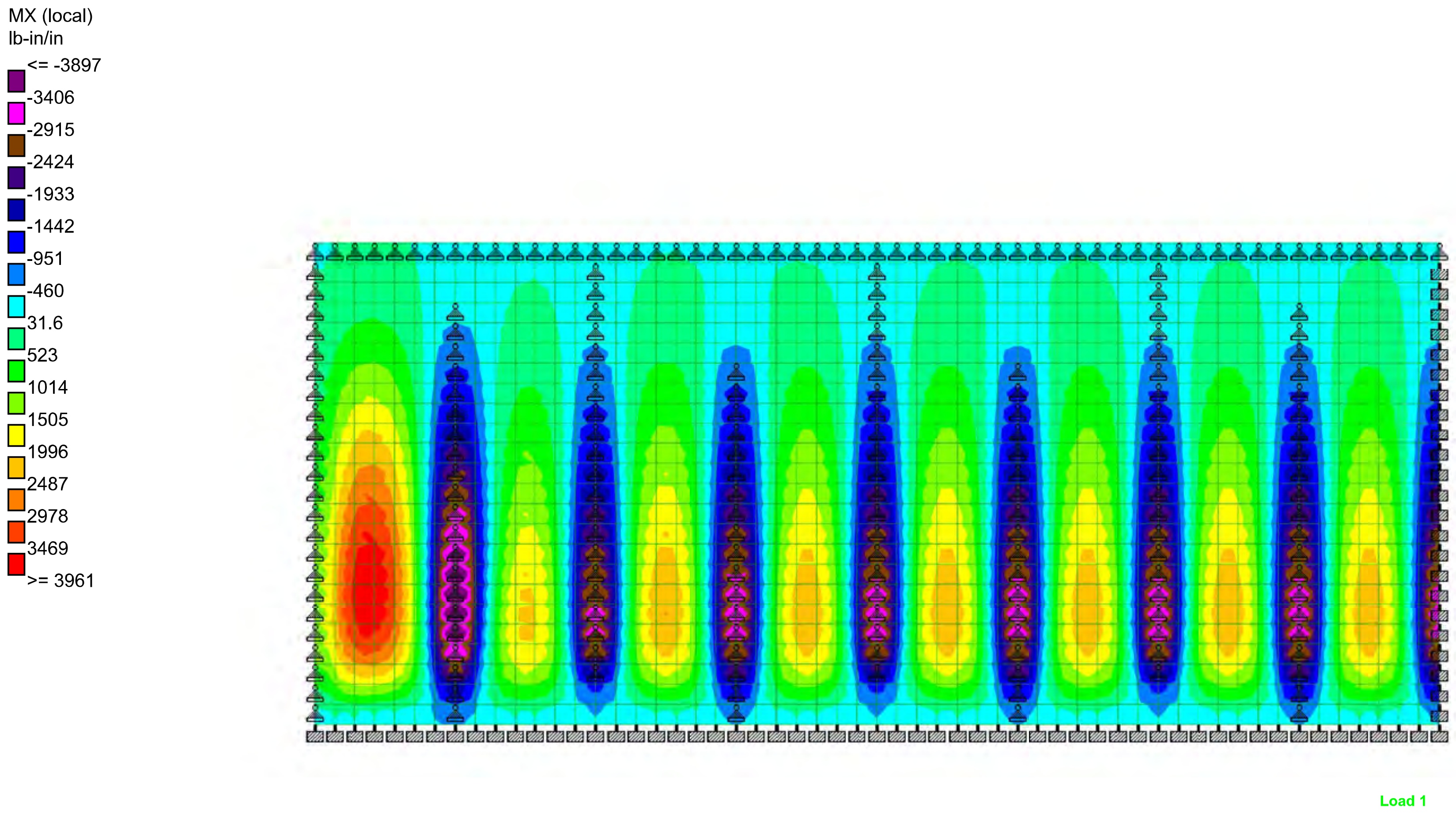
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 09:04	



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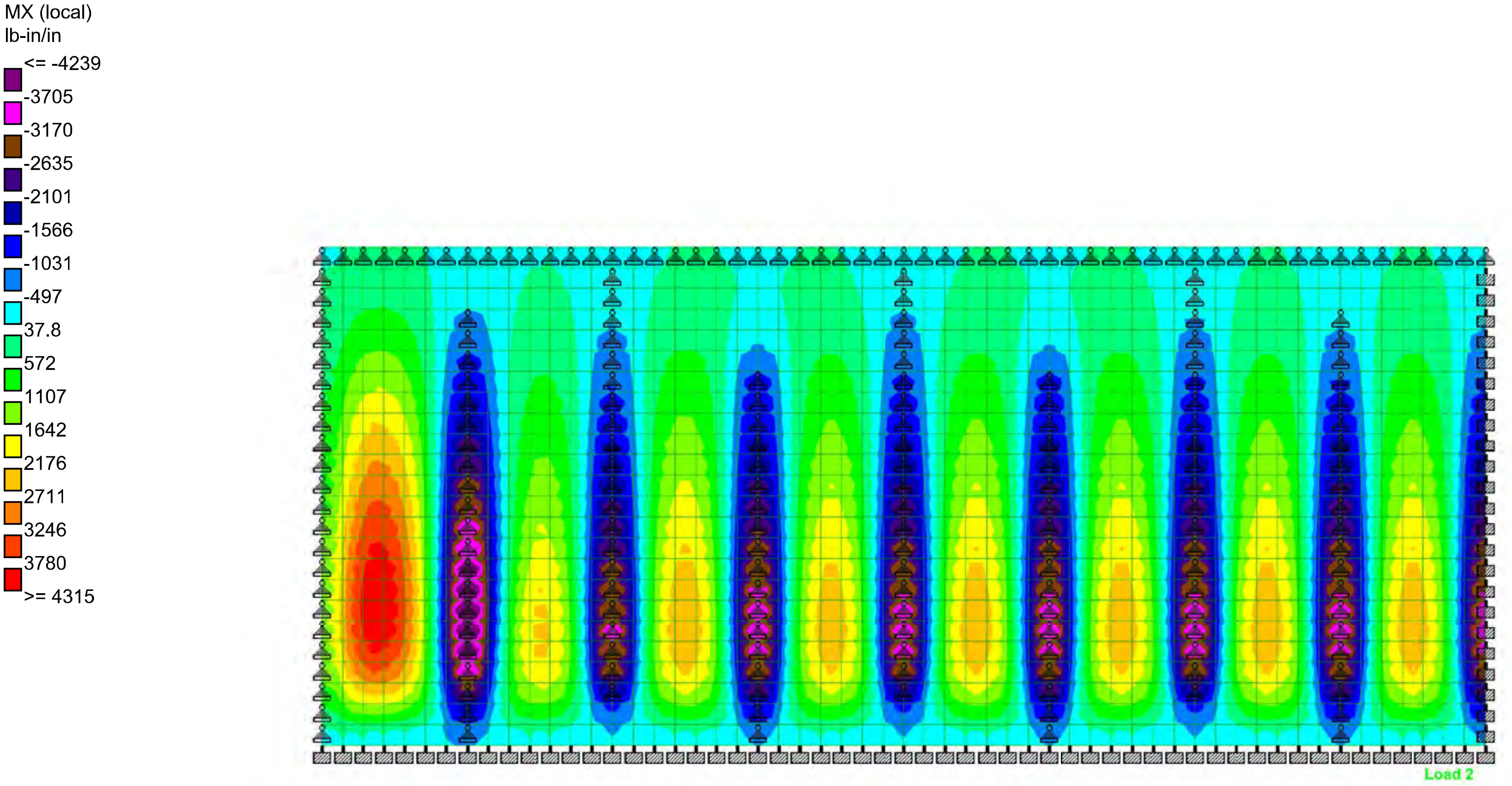

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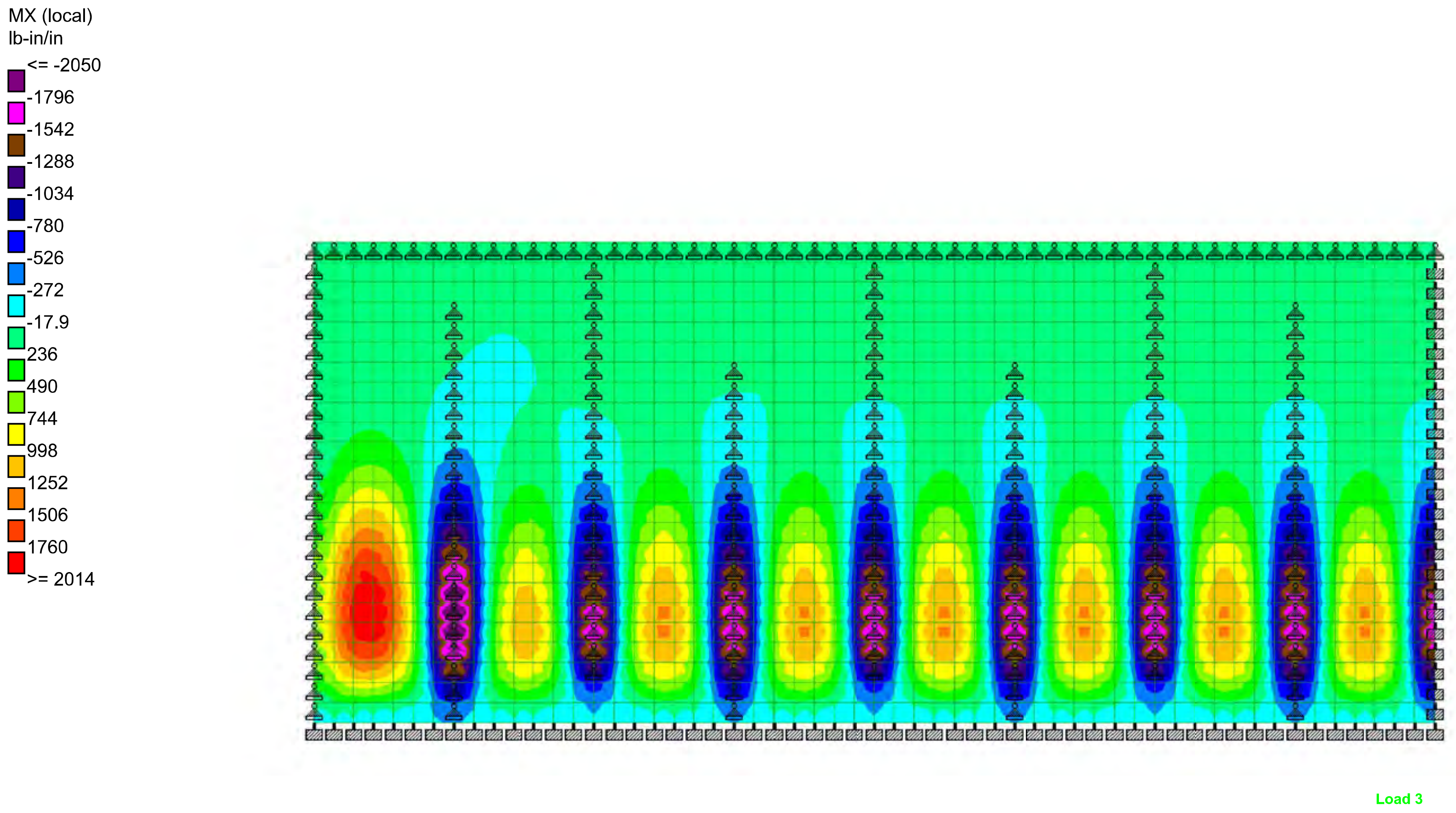

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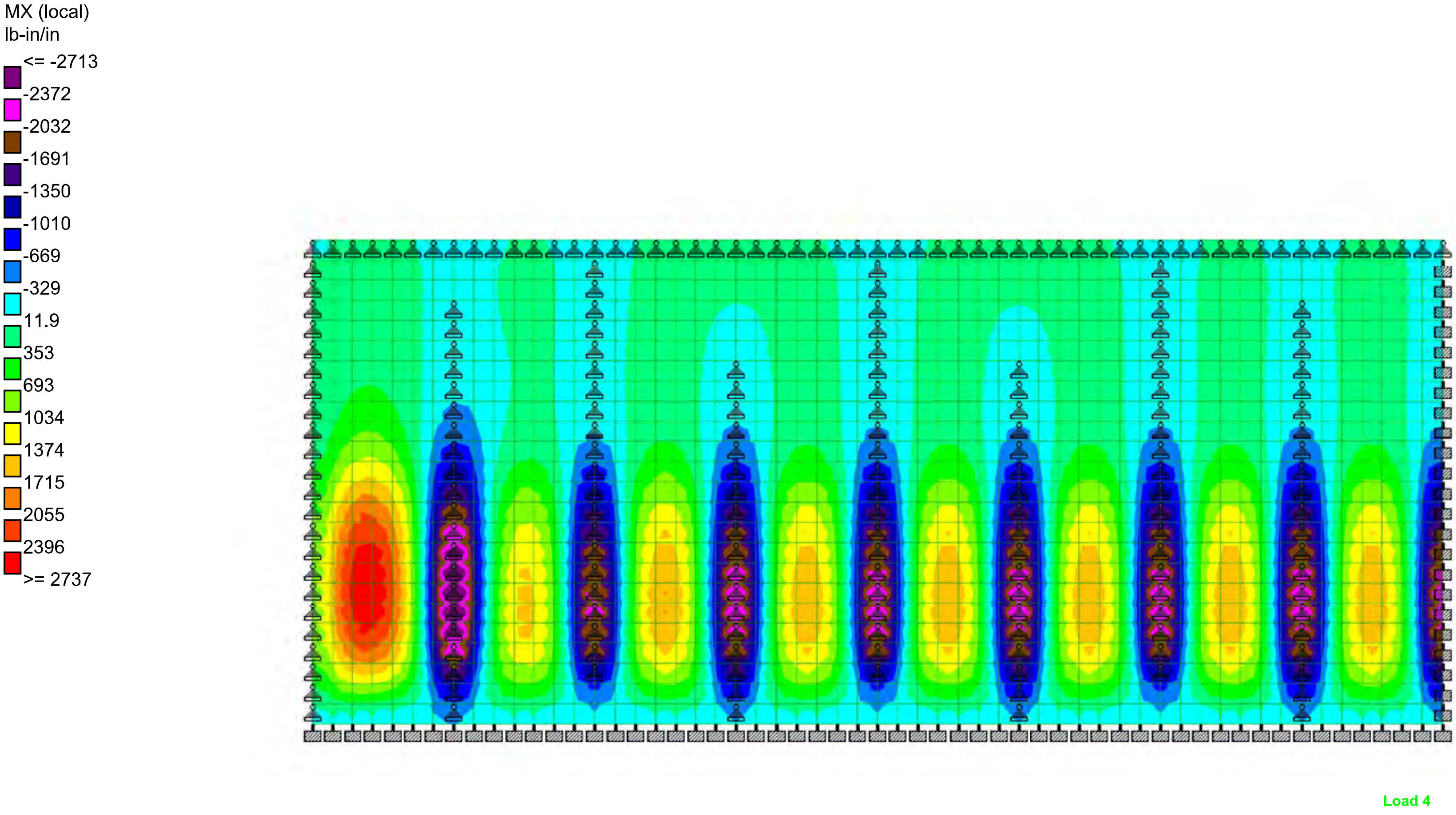

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	By	Date 04-Aug-17	Chd
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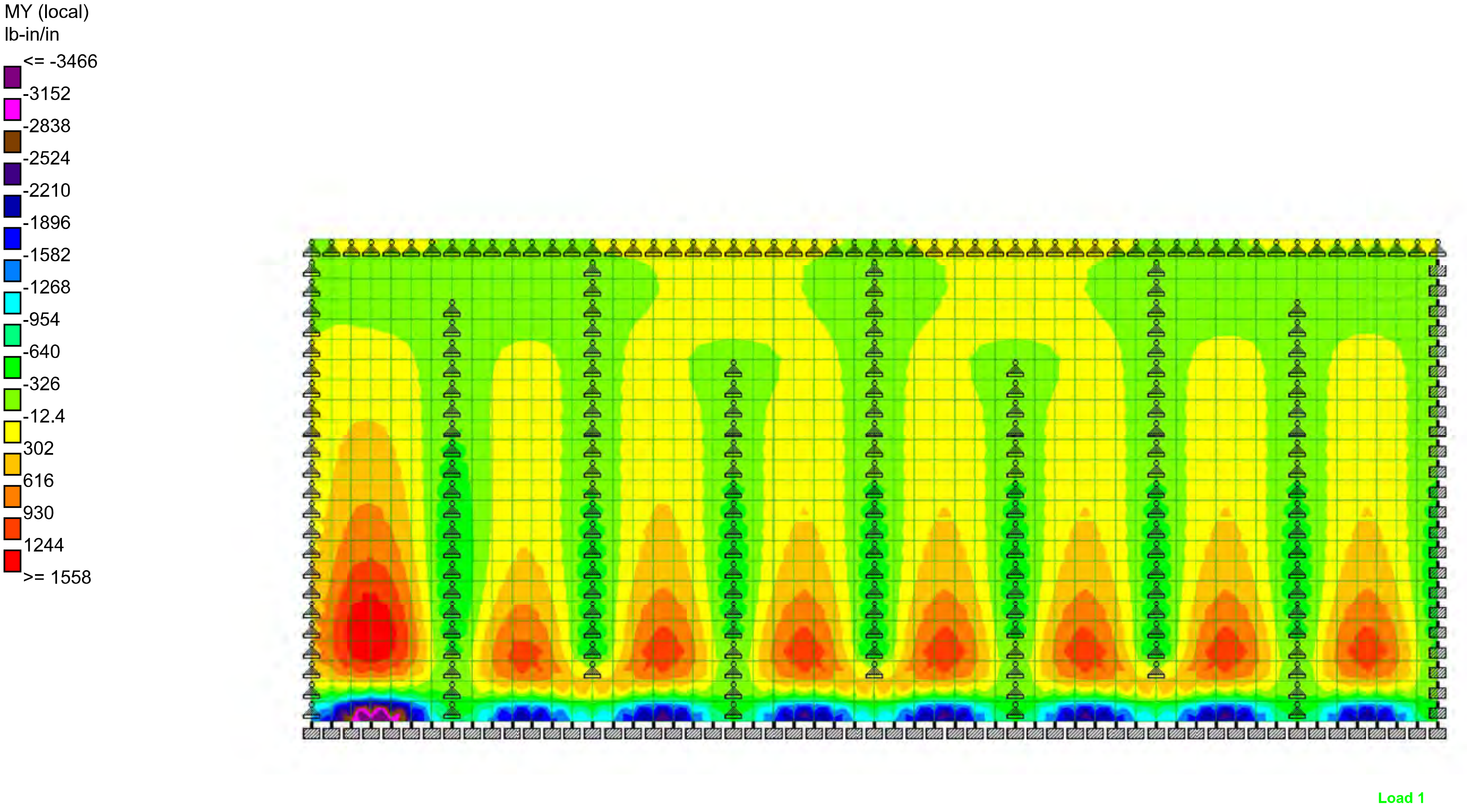

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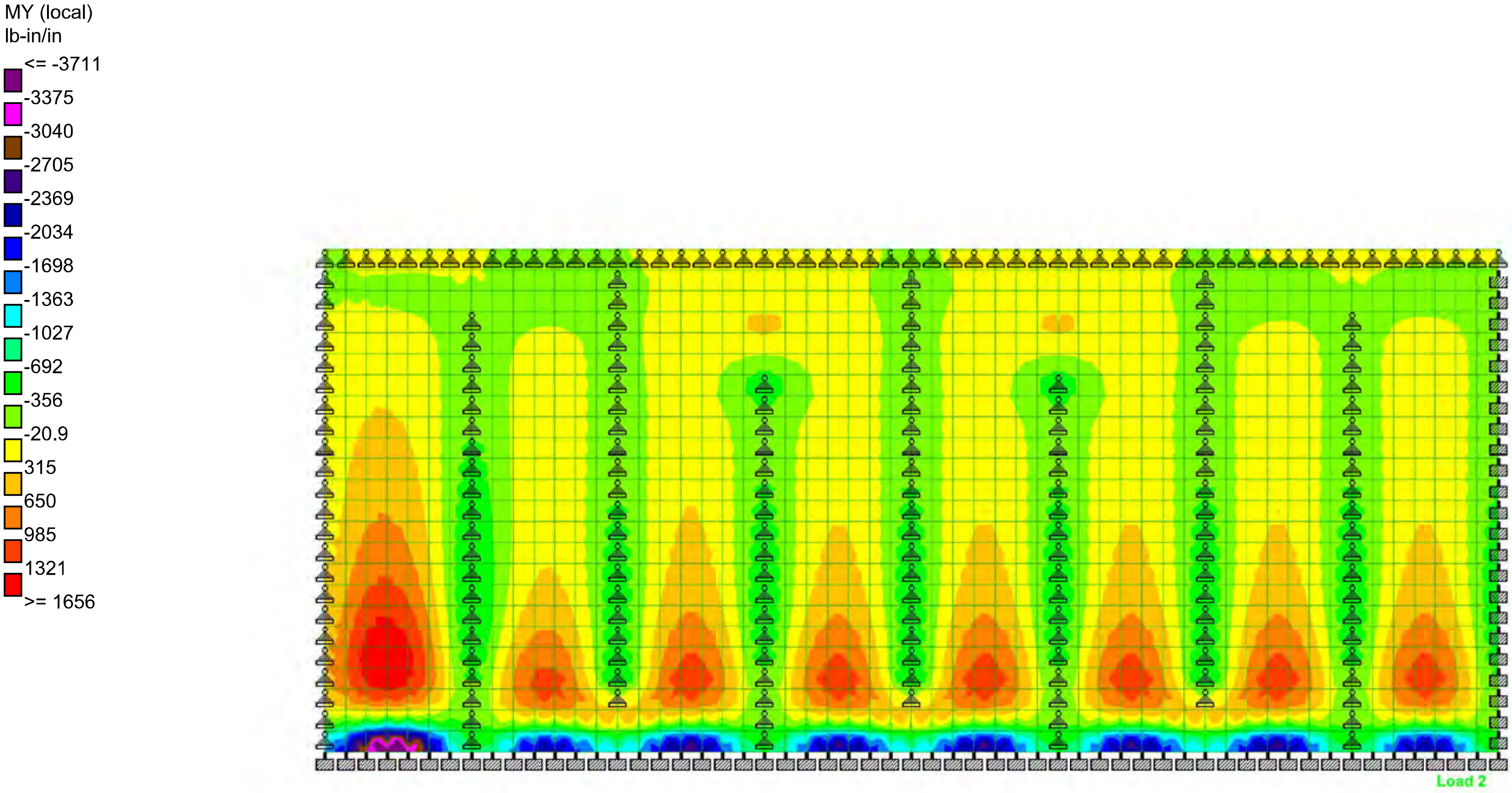

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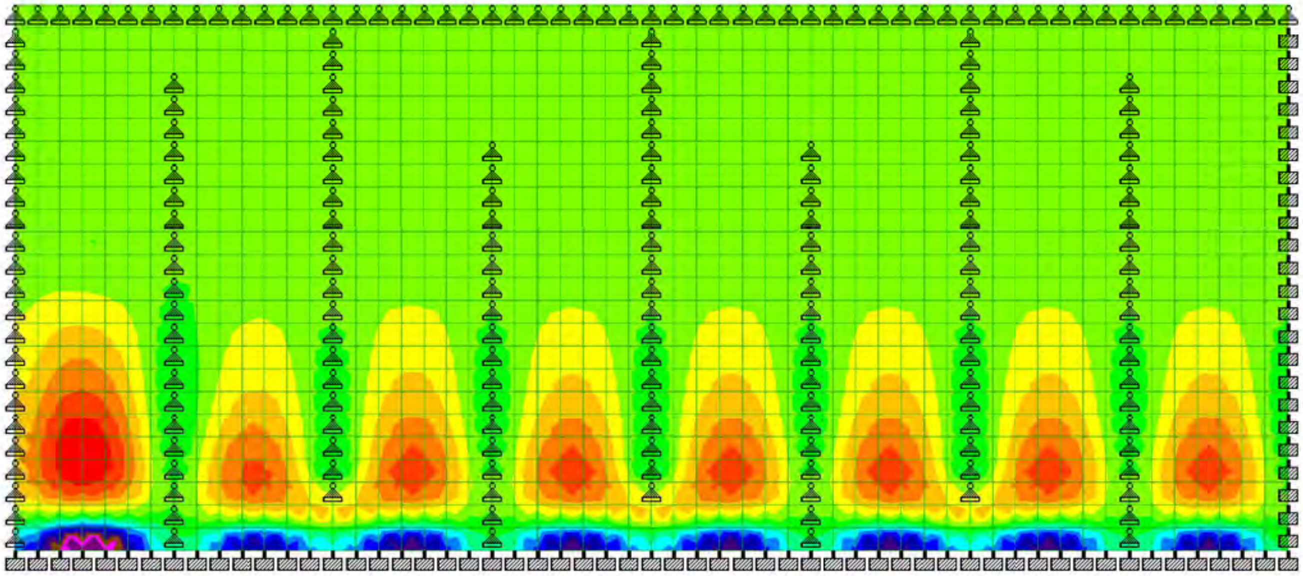
MY (local)
lb-in/in

<= -1964
🟪 -1781
🟪 -1598
🟫 -1414
🟪 -1231
🟦 -1047
🟦 -864
🟦 -681
🟦 -497
🟩 -314
🟩 -130
🟩 53
🟨 236
🟨 420
🟧 603
🟥 787
🟥 >= 970



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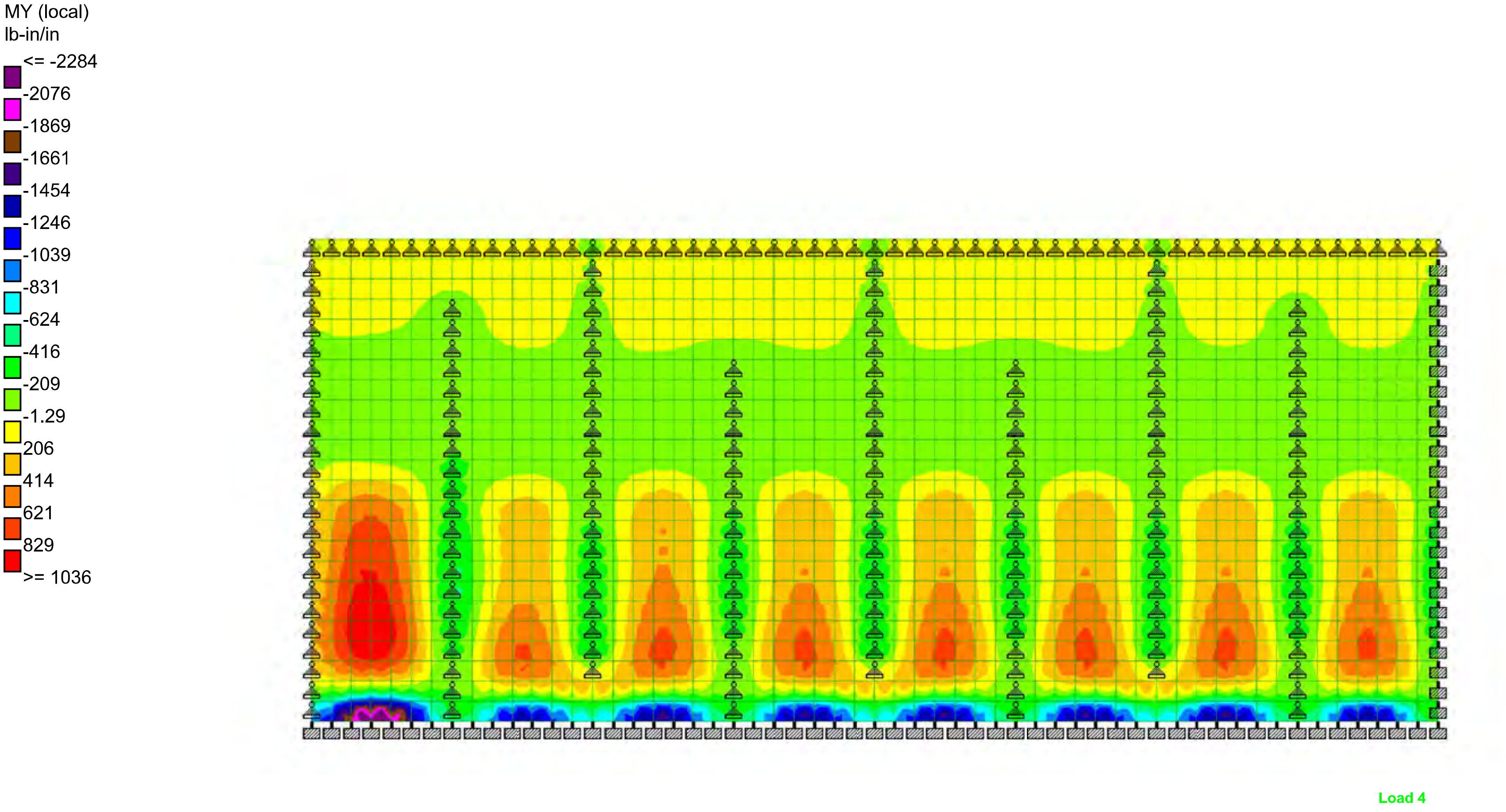
Client Willamette River WTP	File Wall 1.std		Date/Time 10-Aug-2017 09:04	



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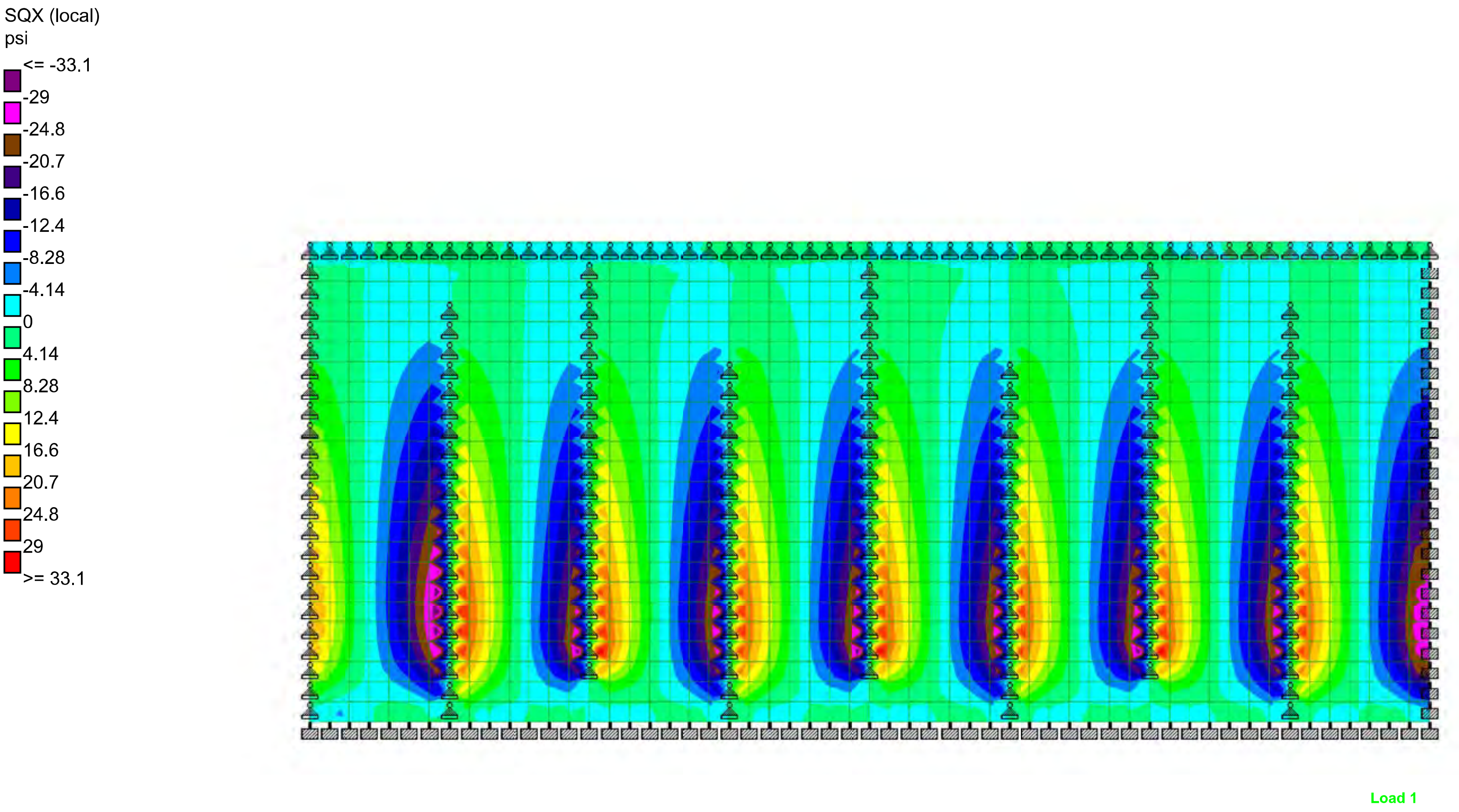

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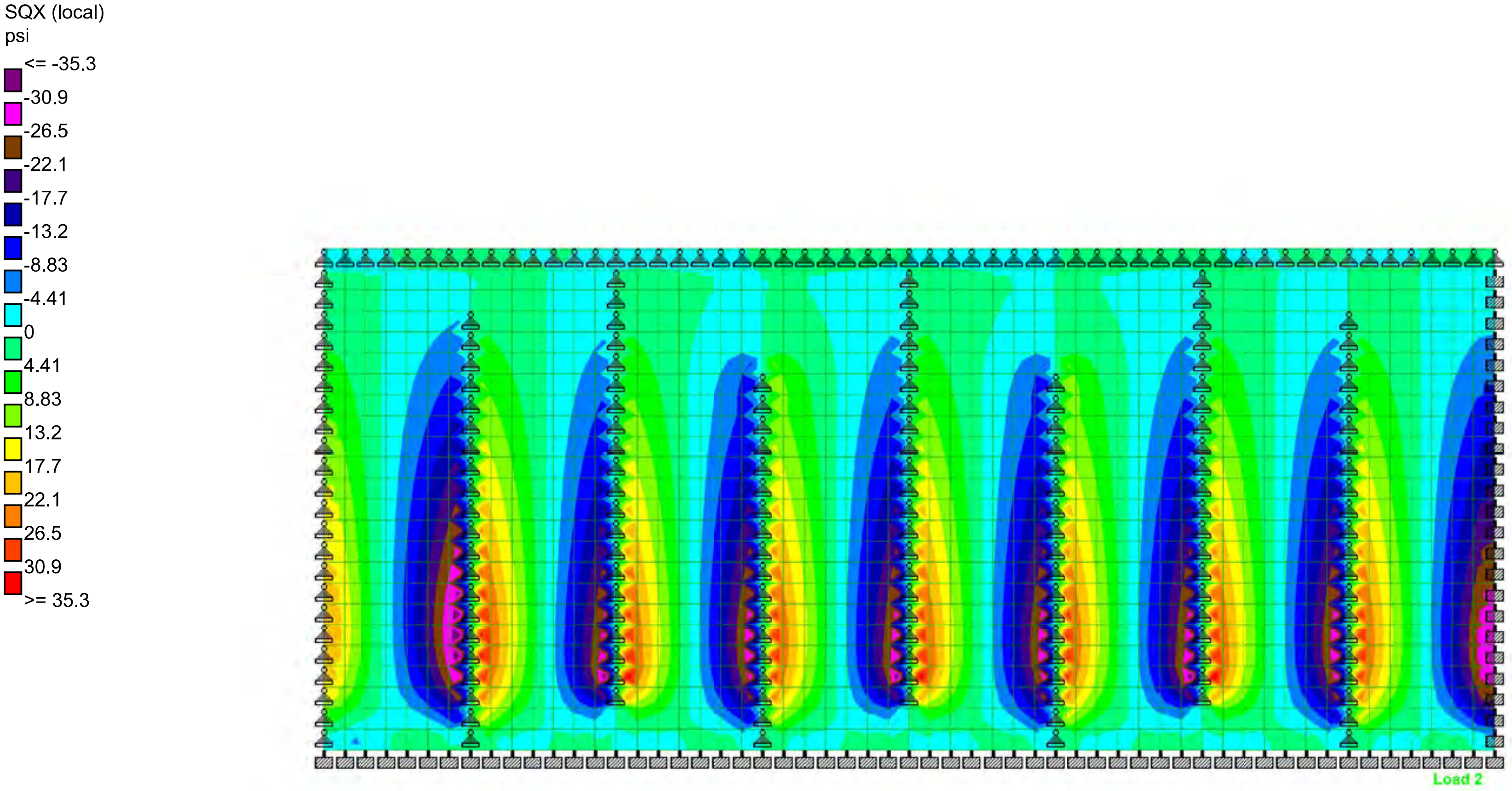

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Job Title Area 5 - Ozonation	Ref		
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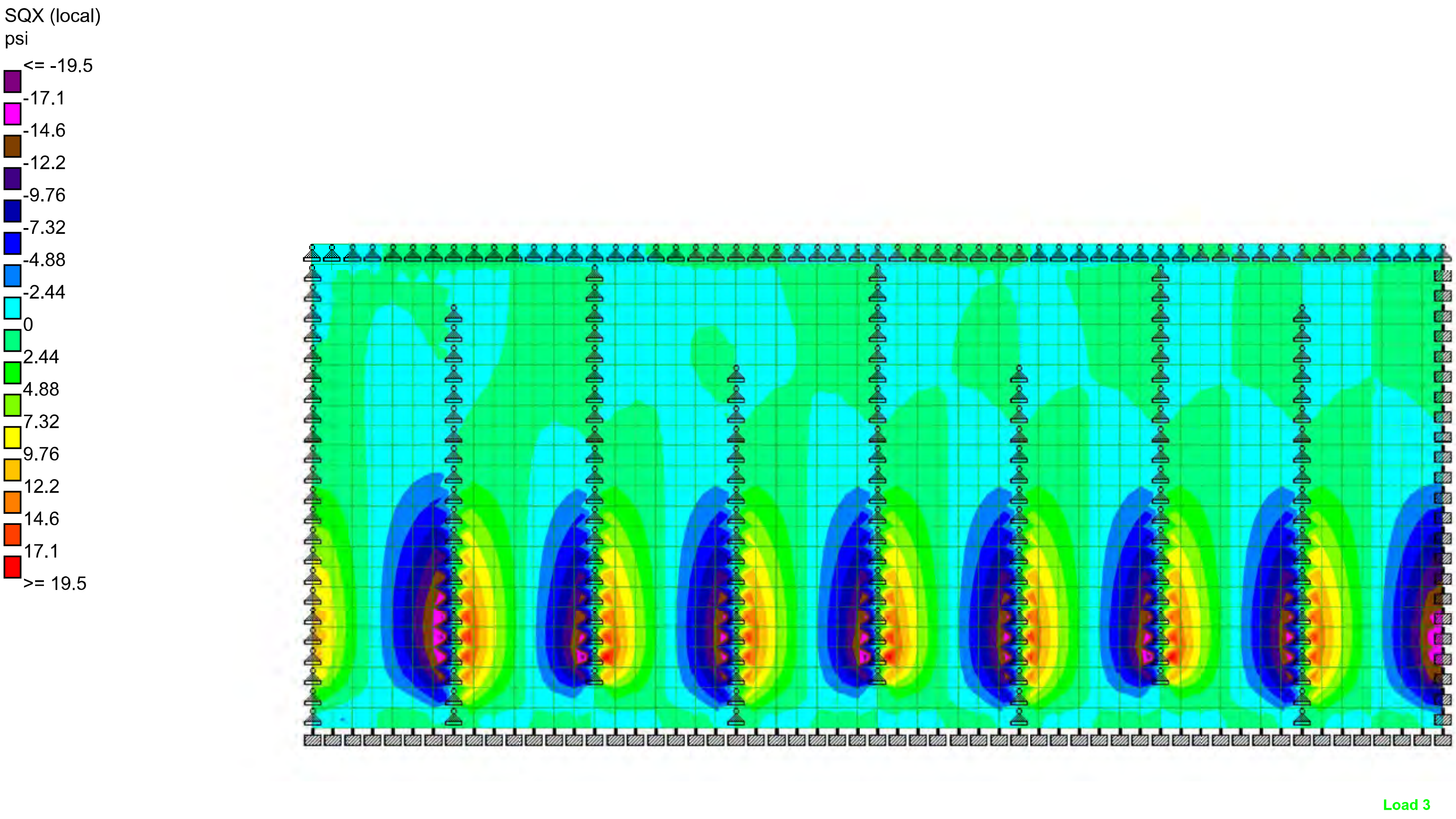
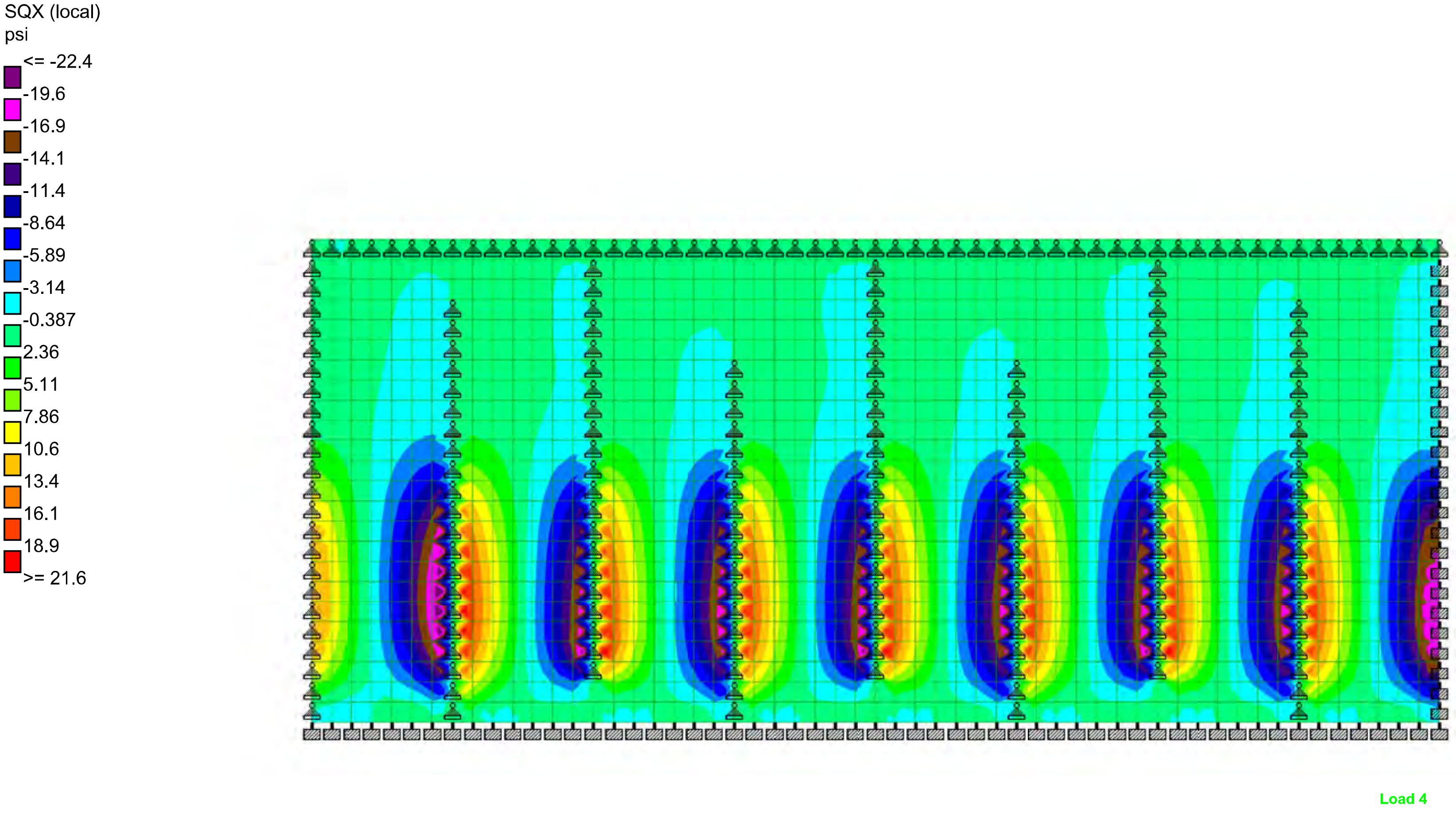
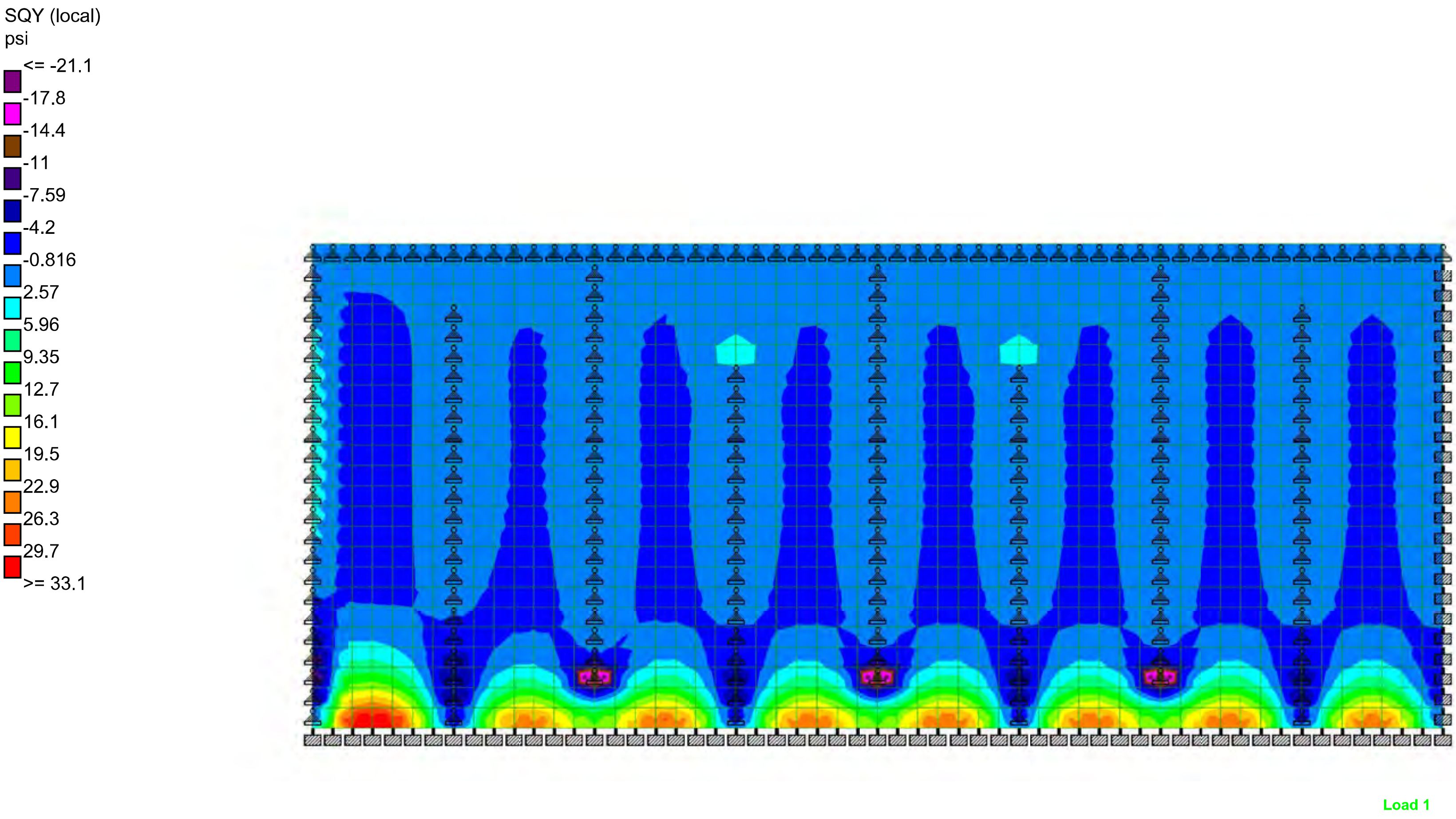
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 09:04	



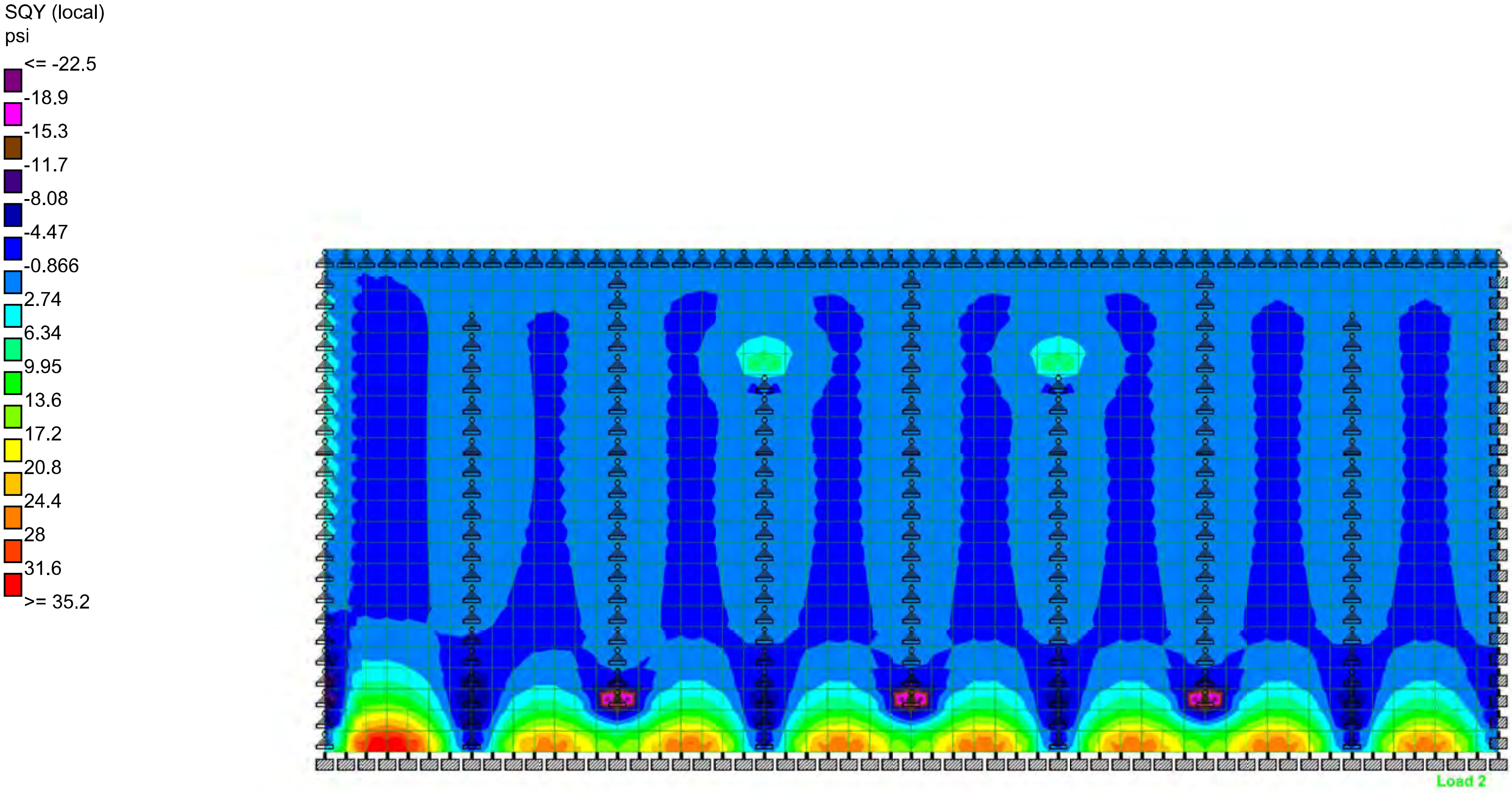
Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
Job Title Area 5 - Ozonation	Ref		
Load Case: 1.6H+1.4E	By	Date 04-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 09:04	



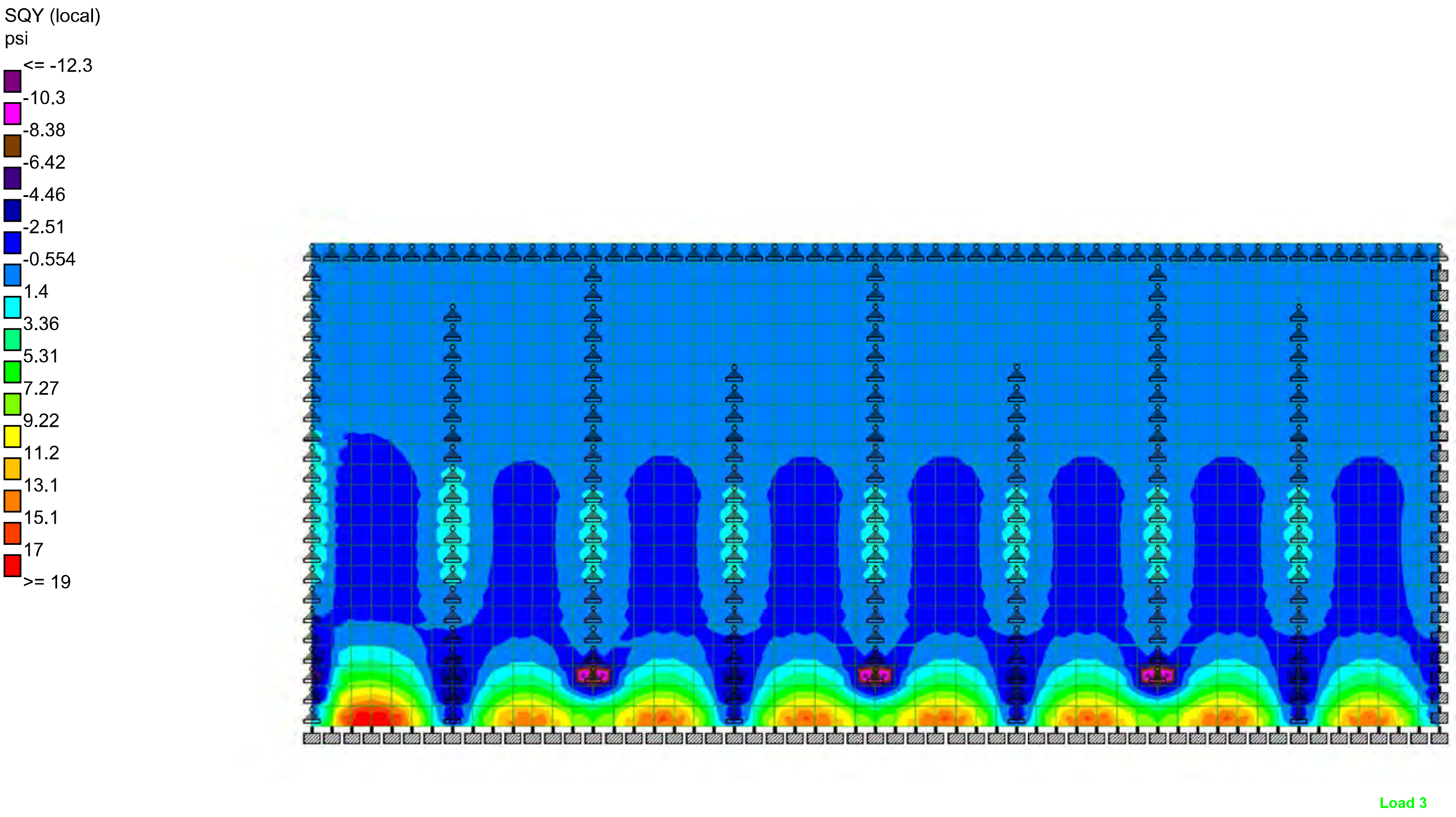
Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**		Rev
	Part Wall 1			
Job Title Area 5 - Ozonation Load Case: 1.4F	Ref			
	By	Date 04-Aug-17		Chd
Client Willamette River WTP	File Wall 1.std		Date/Time 10-Aug-2017 09:04	



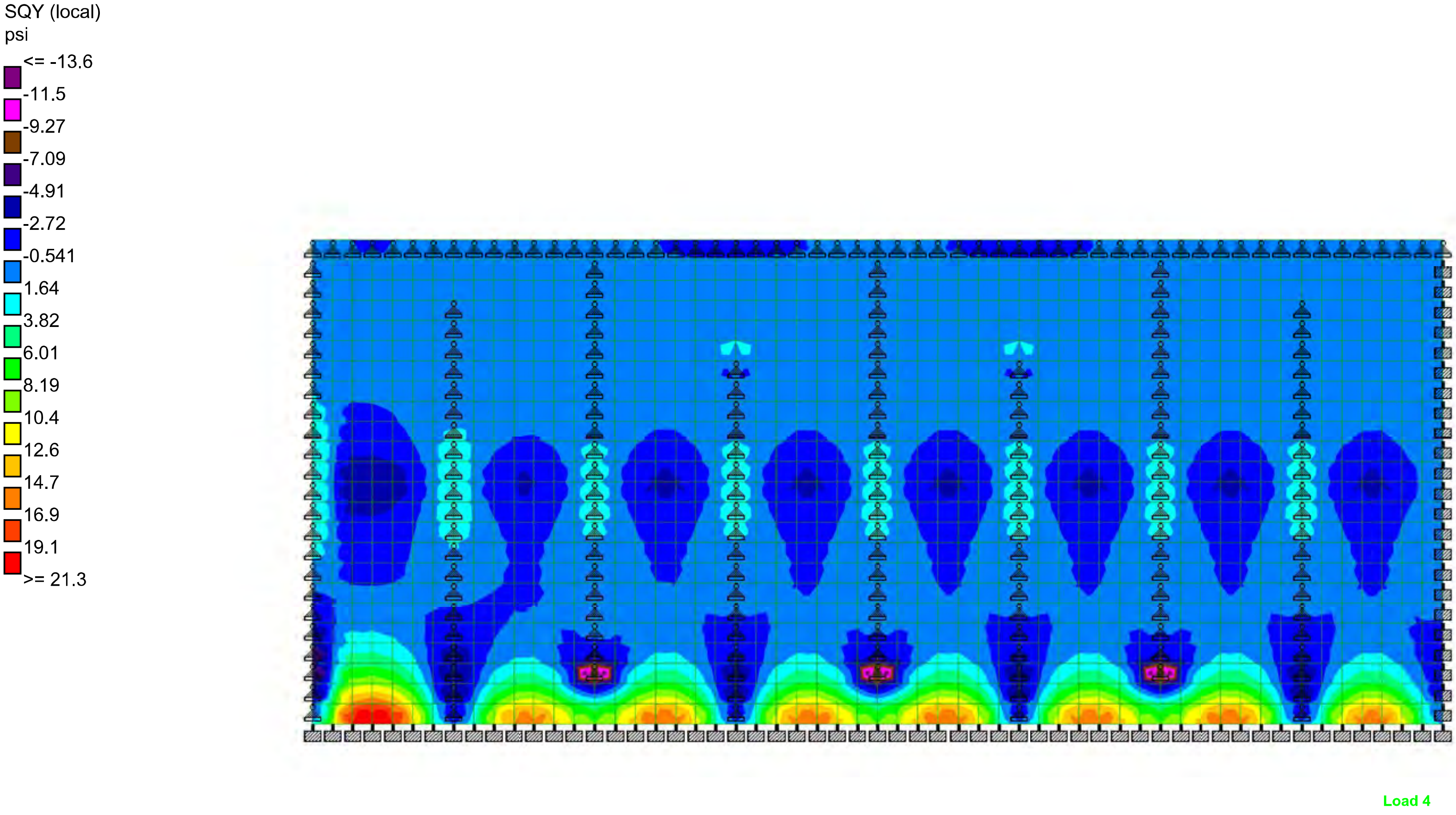
Software licensed to Carollo Engineers CONNECTED User: Caleb Che		Job No **10721A.10**	Sheet No **1**		Rev
		Part Wall 1			
Job Title	Area 5 - Ozonation	Ref			
	Load Case: 1.2F+1.4E	By	Date 04-Aug-17		Chd
Client	Willamette River WTP	File	Wall 1.std	Date/Time	09-Sep-2017 23:44



Software licensed to Carollo Engineers		Job No **10721A.10**	Sheet No **1**		Rev
Job Title Area 5 - Ozonation		Part Wall 1			
		Ref			
Load Case: 1.6(H+L)		By	Date 04-Aug-17		Chd
Client Willamette River WTP		File Wall 1.std		Date/Time 10-Aug-2017 09:04	



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**		Rev
	Part Wall 1			
Job Title Area 5 - Ozonation	Ref			
Load Case: 1.6H+1.4E	By	Date 04-Aug-17		Chd
Client Willamette River WTP	File Wall 1.std		Date/Time 10-Aug-2017 09:04	



Area 5 - Ozonation
Wall 2 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.23	8.33	10.25	25.50	***0.40***	5.48	14.51	***0.38***	***<- OK***
1.2F+1.4E	1.00	9.01	9.01	25.50	***0.35***	5.91	14.51	***0.41***	***<- OK***
1.4E (Water 2-Sides)	1.00	1.31	1.31	25.50	***0.05***	0.83	14.51	***0.06***	***<- OK***

Vertical Span

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.23	7.81	9.61	28.50	***0.34***	7.08	14.51	***0.49***	***<- OK***
1.2F+1.4E	1.00	8.25	8.25	28.50	***0.29***	7.44	14.51	***0.51***	***<- OK***
1.4E (Water 2-Sides)	1.00	0.92	0.92	28.50	***0.03***	0.79	14.51	***0.05***	***<- OK***

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Engineers...Working Wonders With Water™

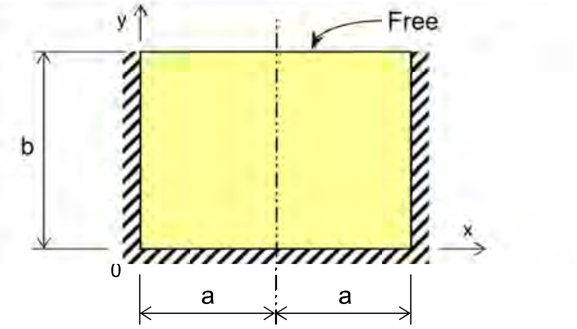
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrostatic

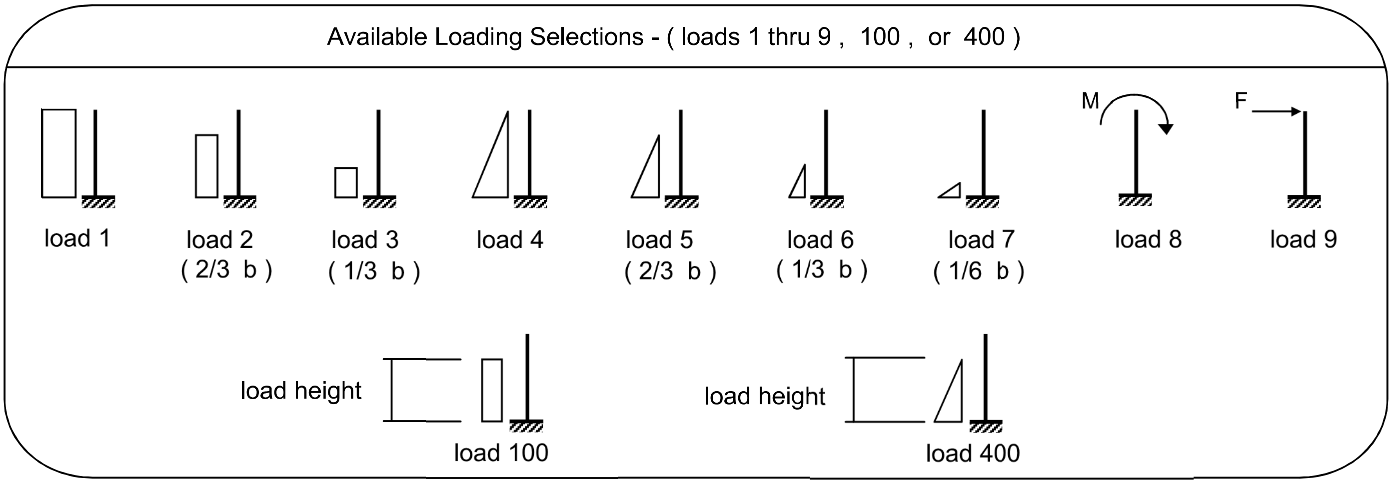
Rectangular Plate:

plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 5 = 10 ft
plate dimension, a = **5** ft
plate dimension, b = **20.5** ft

plate sides ratio, a/b = 0.2439





Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	concrete load factors for shear
A	**4**		**1.290**	**1.73**	**1.4**
B					
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrostatic

M_x - Moment Summary

a = 5
b = 20.5
a / b = 0.2439

Loads: q , M , or F: 1.290

Moment Coefficient Multipliers: 542.123

Boundary Case 1

		Moment Coefficients				M_x Moments, ft-k/ft				SUMMARY			
										Final Moments		Reinforcing: (d = 9")	
										M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0021				1.11				1.11	1.92	0.05	0.36
0	0.8	0.0043				2.36				2.36	4.08	0.10	0.36
0	0.6	0.0079				4.30				4.30	7.43	0.19	0.36
0	0.4	0.0110				5.95				5.95	10.29	0.26	0.36
0	0.2	0.0099				5.39				5.39	9.32	0.23	0.36
0	0	0.0000				0.00				0.00	0.00	0.00	0.36
0.2	0	0.0004				0.21				0.21	0.36	0.01	0.36
0.4	0	0.0010				0.52				0.52	0.90	0.02	0.36
0.6	0	0.0015				0.83				0.83	1.44	0.04	0.36
0.8	0	0.0019				1.04				1.04	1.80	0.04	0.36
1	0	0.0020				1.09				1.09	1.89	0.05	0.36
1	0.2	-0.0046				-2.49				-2.49	-4.31	-0.11	-0.36
1	0.4	-0.0055				-2.98				-2.98	-5.16	-0.13	-0.36
1	0.6	-0.0040				-2.18				-2.18	-3.76	-0.09	-0.36
1	0.8	-0.0023				-1.23				-1.23	-2.12	-0.05	-0.36
1	1	-0.0013				-0.70				-0.70	-1.22	-0.03	-0.36
0.8	1	-0.0011				-0.60				-0.60	-1.04	-0.03	-0.36
0.8	0.8	-0.0020				-1.07				-1.07	-1.86	-0.05	-0.36
0.8	0.6	-0.0036				-1.97				-1.97	-3.41	-0.08	-0.36
0.8	0.4	-0.0049				-2.66				-2.66	-4.61	-0.11	-0.36
0.8	0.2	-0.0042				-2.28				-2.28	-3.94	-0.10	-0.36

max negative moment, $M_{ux}(-)$ = -5.16 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.13 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 10.29 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.26 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrostatic

M_y - Moment Summary

a = 5
b = 20.5
a / b = 0.2439

Loads: q , M , or F			
1.290			
Moment Coefficient Multipliers			
542.123			

Boundary Case 1

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.36
0	0.8	0.0008				0.46				0.46	0.80	0.02	0.36
0	0.6	0.0016				0.88				0.88	1.52	0.04	0.36
0	0.4	0.0022				1.20				1.20	2.07	0.05	0.36
0	0.2	0.0019				1.06				1.06	1.83	0.04	0.36
0	0	0.0000				0.00				0.00	0.00	0.00	0.36
0.2	0	0.0019				1.04				1.04	1.80	0.04	0.36
0.4	0	0.0050				2.71				2.71	4.68	0.11	0.36
0.6	0	0.0078				4.22				4.22	7.30	0.17	0.36
0.8	0	0.0096				5.21				5.21	9.01	0.21	0.36
1	0	0.0103				5.58				5.58	9.65	0.23	0.36
1	0.2	-0.0030				-1.62				-1.62	-2.80	-0.07	-0.36
1	0.4	-0.0020				-1.06				-1.06	-1.84	-0.04	-0.36
1	0.6	-0.0009				-0.50				-0.50	-0.87	-0.02	-0.36
1	0.8	-0.0002				-0.10				-0.10	-0.17	0.00	-0.36
1	1	0.0000				0.00				0.00	0.00	0.00	0.36
1	0.4	-0.0020				-1.06				-1.06	-1.84	-0.04	-0.36
0.8	0.4	-0.0018				-0.96				-0.96	-1.66	-0.04	-0.36
0.6	0.4	-0.0012				-0.65				-0.65	-1.13	-0.03	-0.36
0.4	0.4	-0.0004				-0.19				-0.19	-0.33	-0.01	-0.36
0.2	0.4	0.0008				0.43				0.43	0.74	0.02	0.36

max negative moment, $M_{uy}(-)$ = -2.80 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.07 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 9.65 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.23 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrostatic

Shear Summary

a = 5
b = 20.5
a / b = 0.2439

Loads: q , M , or F

1.290			

Shear Coefficient Multipliers

26.445			

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.0144				0.38				0.38	0.53	10.81
0	0.8	0.0508				1.34				1.34	1.88	10.81
0	0.6	0.0990				2.62				2.62	3.66	10.81
0	0.4	0.1481				3.92				3.92	5.48	10.81
0	0.2	0.1475				3.90				3.90	5.46	10.81
0	0.00	0.0313				0.83				0.83	1.16	10.81
0.2	0	0.0301				0.80				0.80	1.11	10.81
0.4	0	0.1029				2.72				2.72	3.81	10.81
0.6	0	0.1531				4.05				4.05	5.67	10.81
0.8	0	0.1819				4.81				4.81	6.73	10.81
1	0	0.1911				5.05				5.05	7.08	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in

maximum shear, V_u = 7.08 k/ft **OK**

$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water™

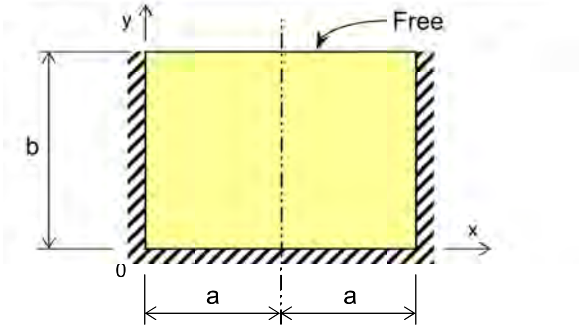
BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

Rectangular Plate:

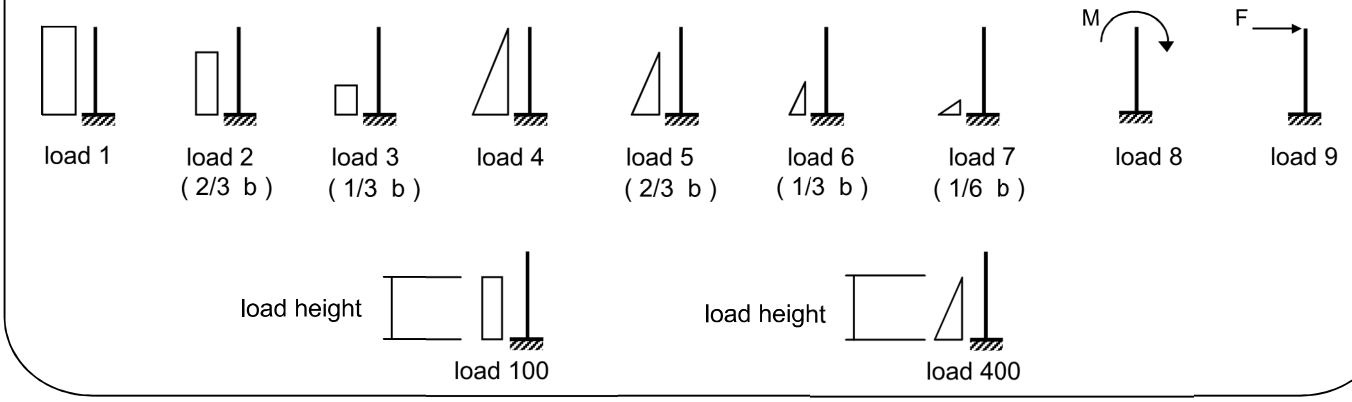
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 5 = 10 ft
plate dimension, a = **5** ft
plate dimension, b = **20.5** ft

plate sides ratio, a/b = 0.2439



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads 100 or 400	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	concrete load factors for shear
A	**4**		**1.290**	**1.2**	**1.2**
B	**1**		**0.071**	**1.4**	**1.4**
C	**4**		**0.168**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

M_x - Moment Summary

	Loads: q , M , or F					SUMMARY			
a = 5	1.290	0.071	0.168		Boundary Case 1	Final Moments		Reinforcing: (d = 9")	
b = 20.5	Moment Coefficient Multipliers								
a / b = 0.2439	542.123	29.838	70.602						

		Moment Coefficients				M_x Moments, ft-k/ft				M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0021	0.0199	0.0021		1.11	0.59	0.14		1.85	2.37	0.06	0.36
0	0.8	0.0043	0.0196	0.0043		2.36	0.58	0.31		3.25	4.08	0.10	0.36
0	0.6	0.0079	0.0196	0.0079		4.30	0.58	0.56		5.44	6.76	0.17	0.36
0	0.4	0.0110	0.0188	0.0110		5.95	0.56	0.77		7.28	9.01	0.23	0.36
0	0.2	0.0099	0.0133	0.0099		5.39	0.40	0.70		6.49	8.00	0.20	0.36
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.2	0	0.0004	0.0005	0.0004		0.21	0.01	0.03		0.25	0.31	0.01	0.36
0.4	0	0.0010	0.0012	0.0010		0.52	0.04	0.07		0.62	0.77	0.02	0.36
0.6	0	0.0015	0.0019	0.0015		0.83	0.06	0.11		1.00	1.23	0.03	0.36
0.8	0	0.0019	0.0024	0.0019		1.04	0.07	0.14		1.25	1.54	0.04	0.36
1	0	0.0020	0.0026	0.0020		1.09	0.08	0.14		1.31	1.62	0.04	0.36
1	0.2	-0.0046	-0.0063	-0.0046		-2.49	-0.19	-0.32		-3.00	-3.71	-0.09	-0.36
1	0.4	-0.0055	-0.0095	-0.0055		-2.98	-0.28	-0.39		-3.65	-4.52	-0.11	-0.36
1	0.6	-0.0040	-0.0100	-0.0040		-2.18	-0.30	-0.28		-2.76	-3.43	-0.09	-0.36
1	0.8	-0.0023	-0.0100	-0.0023		-1.23	-0.30	-0.16		-1.69	-2.11	-0.05	-0.36
1	1	-0.0013	-0.0104	-0.0013		-0.70	-0.31	-0.09		-1.10	-1.41	-0.03	-0.36
0.8	1	-0.0011	-0.0091	-0.0011		-0.60	-0.27	-0.08		-0.95	-1.21	-0.03	-0.36
0.8	0.8	-0.0020	-0.0089	-0.0020		-1.07	-0.26	-0.14		-1.48	-1.86	-0.05	-0.36
0.8	0.6	-0.0036	-0.0089	-0.0036		-1.97	-0.26	-0.26		-2.49	-3.09	-0.08	-0.36
0.8	0.4	-0.0049	-0.0085	-0.0049		-2.66	-0.25	-0.35		-3.26	-4.04	-0.10	-0.36
0.8	0.2	-0.0042	-0.0057	-0.0042		-2.28	-0.17	-0.30		-2.75	-3.39	-0.08	-0.36

max negative moment, $M_{ux}(-)$ = -4.52 ft-k/ft

max negative steel req'd, $A_s(-)$ = -0.11 in^2/ft

minimum steel req'd = -0.36 in^2/ft

Use

max positive moment, $M_{ux}(+)$ = 9.01 ft-k/ft

max positive steel req'd, $A_s(+)$ = 0.23 in^2/ft

minimum steel req'd = 0.36 in^2/ft

Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

M_y - Moment Summary

a = 5
b = 20.5
a / b = 0.2439

Loads: q , M , or F			
1.290	0.071	0.168	
Moment Coefficient Multipliers			
542.123	29.838	70.602	

Boundary Case 1

SUMMARY

Final Moments

Reinforcing: (d = 9.5")

		Moment Coefficients				M_y Moments, ft-k/ft				M_y	M_{uy}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0	0.8	0.0008	0.0039	0.0008		0.46	0.12	0.06		0.64	0.80	0.02	0.36
0	0.6	0.0016	0.0039	0.0016		0.88	0.12	0.11		1.11	1.38	0.03	0.36
0	0.4	0.0022	0.0037	0.0022		1.20	0.11	0.16		1.47	1.81	0.04	0.36
0	0.2	0.0019	0.0026	0.0019		1.06	0.08	0.14		1.27	1.57	0.04	0.36
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
0.2	0	0.0019	0.0022	0.0019		1.04	0.07	0.14		1.24	1.53	0.04	0.36
0.4	0	0.0050	0.0060	0.0050		2.71	0.18	0.35		3.24	3.99	0.09	0.36
0.6	0	0.0078	0.0096	0.0078		4.22	0.29	0.55		5.06	6.24	0.15	0.36
0.8	0	0.0096	0.0120	0.0096		5.21	0.36	0.68		6.25	7.71	0.18	0.36
1	0	0.0103	0.0129	0.0103		5.58	0.38	0.73		6.69	8.25	0.20	0.36
1	0.2	-0.0030	-0.0033	-0.0030		-1.62	-0.10	-0.21		-1.93	-2.38	-0.06	-0.36
1	0.4	-0.0020	-0.0028	-0.0020		-1.06	-0.08	-0.14		-1.29	-1.59	-0.04	-0.36
1	0.6	-0.0009	-0.0022	-0.0009		-0.50	-0.06	-0.07		-0.63	-0.79	-0.02	-0.36
1	0.8	-0.0002	-0.0018	-0.0002		-0.10	-0.05	-0.01		-0.17	-0.21	-0.01	-0.36
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.36
1	0.4	-0.0020	-0.0028	-0.0020		-1.06	-0.08	-0.14		-1.29	-1.59	-0.04	-0.36
0.8	0.4	-0.0018	-0.0025	-0.0018		-0.96	-0.08	-0.13		-1.16	-1.43	-0.03	-0.36
0.6	0.4	-0.0012	-0.0017	-0.0012		-0.65	-0.05	-0.09		-0.79	-0.97	-0.02	-0.36
0.4	0.4	-0.0004	-0.0004	-0.0004		-0.19	-0.01	-0.03		-0.23	-0.28	-0.01	-0.36
0.2	0.4	0.0008	0.0016	0.0008		0.43	0.05	0.06		0.53	0.65	0.02	0.36

max negative moment, $M_{uy}(-)$ = -2.38 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.06 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 8.25 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.20 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

Shear Summary

a = 5
b = 20.5
a / b = 0.2439

Loads: q , M , or F			
1.290	0.071	0.168	
Shear Coefficient Multipliers			
26.445	1.456	3.444	

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.0144	0.2423	0.0144		0.38	0.35	0.05		0.78	1.02	10.81
0	0.8	0.0508	0.2459	0.0508		1.34	0.36	0.17		1.88	2.36	10.81
0	0.6	0.0990	0.2452	0.0990		2.62	0.36	0.34		3.31	4.12	10.81
0	0.4	0.1481	0.2456	0.1481		3.92	0.36	0.51		4.78	5.91	10.81
0	0.2	0.1475	0.1881	0.1475		3.90	0.27	0.51		4.68	5.78	10.81
0	0.00	0.0313	0.0308	0.0313		0.83	0.04	0.11		0.98	1.21	10.81
0.2	0	0.0301	0.0231	0.0301		0.80	0.03	0.10		0.93	1.15	10.81
0.4	0	0.1029	0.1104	0.1029		2.72	0.16	0.35		3.24	3.99	10.81
0.6	0	0.1531	0.1743	0.1531		4.05	0.25	0.53		4.83	5.95	10.81
0.8	0	0.1819	0.2122	0.1819		4.81	0.31	0.63		5.74	7.08	10.81
1	0	0.1911	0.2246	0.1911		5.05	0.33	0.66		6.04	7.44	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 7.44 k/ft **OK**
$\phi V_c = \phi*2*(f\,'c)^{1/2}*b*d =$ (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

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Engineers...Working Wonders With Water™

BY:	C. Che	**DATE:**	Sep-17	**CLIENT**	Willamette River WTP
CHKD:		**DESCRIPTION:**	Area 5 - Ozonation		
DESIGN TASK:	Wall 2 - Hydrodynamic (Water 2-Sides)				

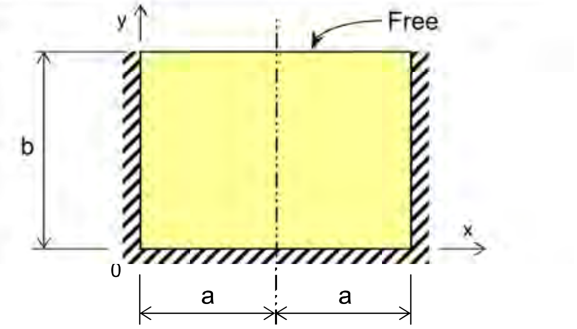
SHEET:
JOB NO: 10721A.10

Rectangular Plate:

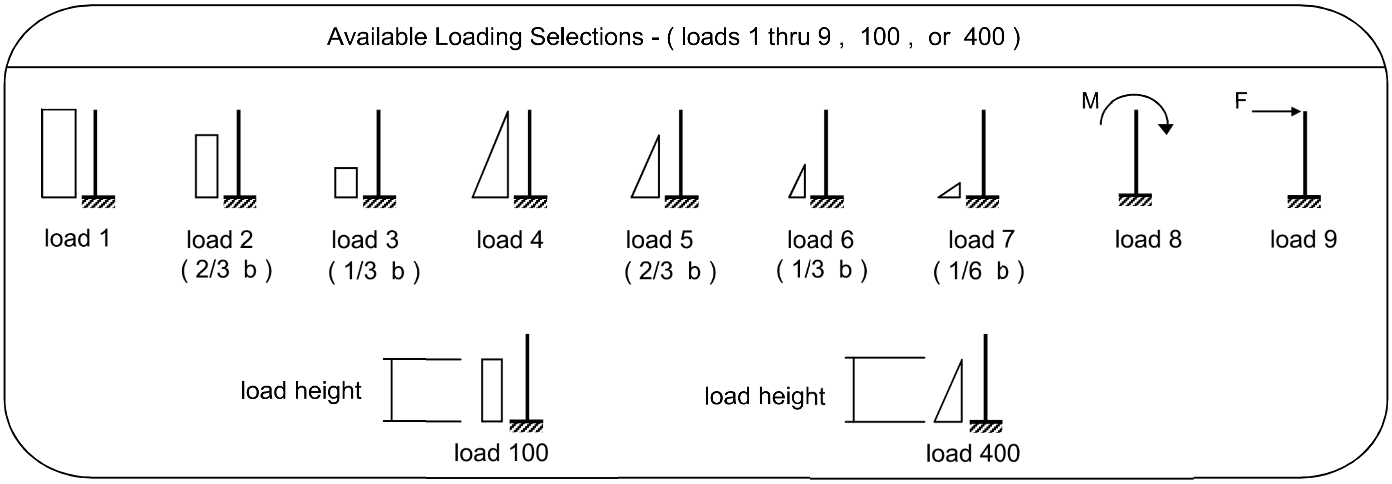
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 5 = 10 ft
plate dimension, a = **5** ft
plate dimension, b = **20.5** ft

plate sides ratio, a/b = 0.2439



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	concrete load factors for shear
A	**1**		**0.106**	**1.4**	**1.4**
B	**4**		**0.020**	**1.4**	**1.4**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic (Water 2-Sides)

M_x - Moment Summary

a = 5
b = 20.5
a / b = 0.2439

Loads: q , M , or F			
0.106	0.020		
Moment Coefficient Multipliers			
44.547	8.405		

Boundary Case 1

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0199	0.0021			0.89	0.02			0.90	1.26	0.03	0.36
0	0.8	0.0196	0.0043			0.87	0.04			0.91	1.27	0.03	0.36
0	0.6	0.0196	0.0079			0.87	0.07			0.94	1.31	0.03	0.36
0	0.4	0.0188	0.0110			0.84	0.09			0.93	1.30	0.03	0.36
0	0.2	0.0133	0.0099			0.59	0.08			0.68	0.95	0.02	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0005	0.0004			0.02	0.00			0.02	0.03	0.00	0.36
0.4	0	0.0012	0.0010			0.06	0.01			0.06	0.09	0.00	0.36
0.6	0	0.0019	0.0015			0.09	0.01			0.10	0.14	0.00	0.36
0.8	0	0.0024	0.0019			0.11	0.02			0.12	0.17	0.00	0.36
1	0	0.0026	0.0020			0.11	0.02			0.13	0.18	0.00	0.36
1	0.2	-0.0063	-0.0046			-0.28	-0.04			-0.32	-0.45	-0.01	-0.36
1	0.4	-0.0095	-0.0055			-0.42	-0.05			-0.47	-0.66	-0.02	-0.36
1	0.6	-0.0100	-0.0040			-0.45	-0.03			-0.48	-0.67	-0.02	-0.36
1	0.8	-0.0100	-0.0023			-0.45	-0.02			-0.46	-0.65	-0.02	-0.36
1	1	-0.0104	-0.0013			-0.46	-0.01			-0.47	-0.66	-0.02	-0.36
0.8	1	-0.0091	-0.0011			-0.41	-0.01			-0.42	-0.58	-0.01	-0.36
0.8	0.8	-0.0089	-0.0020			-0.39	-0.02			-0.41	-0.58	-0.01	-0.36
0.8	0.6	-0.0089	-0.0036			-0.40	-0.03			-0.43	-0.60	-0.01	-0.36
0.8	0.4	-0.0085	-0.0049			-0.38	-0.04			-0.42	-0.58	-0.01	-0.36
0.8	0.2	-0.0057	-0.0042			-0.26	-0.04			-0.29	-0.41	-0.01	-0.36

max negative moment, $M_{ux}(-)$ = -0.67 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.02 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 1.31 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.03 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic (Water 2-Sides)

M_y - Moment Summary

	Loads: q , M , or F				Boundary Case 1
a = 5 b = 20.5 a / b = 0.2439	0.106	0.020			
	Moment Coefficient Multipliers				
	44.547	8.405			

		Moment Coefficients				M_y Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0039	0.0008			0.17	0.01			0.18	0.25	0.01	0.36
0	0.6	0.0039	0.0016			0.17	0.01			0.19	0.26	0.01	0.36
0	0.4	0.0037	0.0022			0.17	0.02			0.19	0.26	0.01	0.36
0	0.2	0.0026	0.0019			0.12	0.02			0.13	0.19	0.00	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0022	0.0019			0.10	0.02			0.11	0.16	0.00	0.36
0.4	0	0.0060	0.0050			0.27	0.04			0.31	0.43	0.01	0.36
0.6	0	0.0096	0.0078			0.43	0.07			0.49	0.69	0.02	0.36
0.8	0	0.0120	0.0096			0.54	0.08			0.62	0.86	0.02	0.36
1	0	0.0129	0.0103			0.57	0.09			0.66	0.92	0.02	0.36
1	0.2	-0.0033	-0.0030			-0.15	-0.03			-0.17	-0.24	-0.01	-0.36
1	0.4	-0.0028	-0.0020			-0.13	-0.02			-0.14	-0.20	0.00	-0.36
1	0.6	-0.0022	-0.0009			-0.10	-0.01			-0.10	-0.15	0.00	-0.36
1	0.8	-0.0018	-0.0002			-0.08	0.00			-0.08	-0.11	0.00	-0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
1	0.4	-0.0028	-0.0020			-0.13	-0.02			-0.14	-0.20	0.00	-0.36
0.8	0.4	-0.0025	-0.0018			-0.11	-0.01			-0.13	-0.18	0.00	-0.36
0.6	0.4	-0.0017	-0.0012			-0.07	-0.01			-0.08	-0.12	0.00	-0.36
0.4	0.4	-0.0004	-0.0004			-0.02	0.00			-0.02	-0.03	0.00	-0.36
0.2	0.4	0.0016	0.0008			0.07	0.01			0.08	0.11	0.00	0.36

max negative moment, $M_{uy}(-)$ = -0.24 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.01 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 0.92 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.02 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 5 - Ozonation **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic (Water 2-Sides)

Shear Summary

a = 5		Loads: q , M , or F				Boundary Case 1				SUMMARY		
b = 20.5		0.106	0.020							Final Shears		
a / b = 0.2439		Shear Coefficient Multipliers										
		2.173	0.410									
		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.2423	0.0144			0.53	0.01			0.53	0.75	10.81
0	0.8	0.2459	0.0508			0.53	0.02			0.56	0.78	10.81
0	0.6	0.2452	0.0990			0.53	0.04			0.57	0.80	10.81
0	0.4	0.2456	0.1481			0.53	0.06			0.59	0.83	10.81
0	0.2	0.1881	0.1475			0.41	0.06			0.47	0.66	10.81
0	0.00	0.0308	0.0313			0.07	0.01			0.08	0.11	10.81
0.2	0	0.0231	0.0301			0.05	0.01			0.06	0.09	10.81
0.4	0	0.1104	0.1029			0.24	0.04			0.28	0.39	10.81
0.6	0	0.1743	0.1531			0.38	0.06			0.44	0.62	10.81
0.8	0	0.2122	0.1819			0.46	0.07			0.54	0.75	10.81
1	0	0.2246	0.1911			0.49	0.08			0.57	0.79	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 0.83 k/ft **OK**
$\phi V_c = \phi*2*(f'c)^{1/2}*b*d =$ $(0.75*2*(4000)^{1/2}*12*9.5)/1000 =$ 10.81 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

carollo engineers

BY: C. Che **DATE** Sep-17 **CLIENT** Willamette Springs WTP **SHEET**
CHKD BY **DESCRIPTION** Area 5 - Ozonation **JOB NO.** 10721A.10
DESIGN TASK Wall 3 - Hydrodynamic (Water 2-Sides) - Horizontal Span At Bottom

WALL DESIGN LOADS, PROPERTIES & GEOMETRY

Mu = Factored moment = 2.21 ft-k

V_u = Factored Shear = 0.88 kips

h = Member thick = 12.00 in
b = Member width = 12.00 in

Cover = Reinforcing cover = 3.00 in

Is this mat of rebar closest to surface (Y / N)? = N

d = Depth to flexural reinforcing = 8.69 in

f'_c = Specified compressive strength of concrete = 4,000 psi

f_y = Specified yield strength of reinforcement = 60,000 psi

FLEXURAL REINFORCING

ϕ, bending = 1.00

$m = f_y / (0.85 * f'_c)$ = 17.65

$R_n = M_u / (\phi * b * d^2)$ = 29 psi

$A_s = (b * d / m) * (1 - (1 - ((2 * m * R_n) / f_y))^{1/2})$ = 0.05 in^2

$A_{s\text{-min}}$ = 200 * (12 in) * d / f_y or (4 / 3) * A_s = 0.07 in^2

minimum bar shrinkage/temperatur ratio = 0.00500
$A_{s\text{-temp}}$ = 0.36 in^2 *<-- For Double Layer Reinforcement*

$A_{s\text{-req}}$ = 0.36

Use # 5 **@ 6"**
d_b = Bar diameter = 0.625 in
$A_s = (\pi / 4) * d_b^2 * (12" / \text{Spacing})$ = 0.61 in^2 ***<-- Rebar OK***

SHEAR CAPACITY

ϕ, shear = 1.00

V_u = Factored Shear = 0.88 kips

$\phi V_c = \phi * 2 * (f'_c)^{1/2} * b * d$ = 13.19 kips ***<-- Shear OK***

Area 5 - Ozonation
Wall 4 - Moment & Shear

Horizontal Span - Ouside Face

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.6(H+L)	1.41	9.83	13.86	13.00	***1.07***	35	126	***0.28***	***<- NG***
1.6H+1.4E	1.00	17.70	17.70	13.00	***1.36***	65	126	***0.51***	***<- NG***

Vertical Span (Bottom) - Outside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.6(H+L)	1.41	16.00	22.56	35.00	***0.64***	48	126	***0.38***	***<- OK***
1.6H+1.4E	1.00	23.50	23.50	35.00	***0.67***	61	126	***0.48***	***<- OK***

Horizontal Span - Inside Face

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.6(H+L)	1.41	3.04	4.29	13.00	***0.33***	0	126	***0.00***	***<- OK***
1.6H+1.4E	1.00	5.88	5.88	13.00	***0.45***	0	126	***0.00***	***<- OK***

Vertical Span (Mid-Height) - Inside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.6(H+L)	1.41	6.83	9.63	20.50	***0.47***	0	126	***0.00***	***<- OK***
1.6H+1.4E	1.00	11.40	11.40	20.50	***0.56***	0	126	***0.00***	***<- OK***

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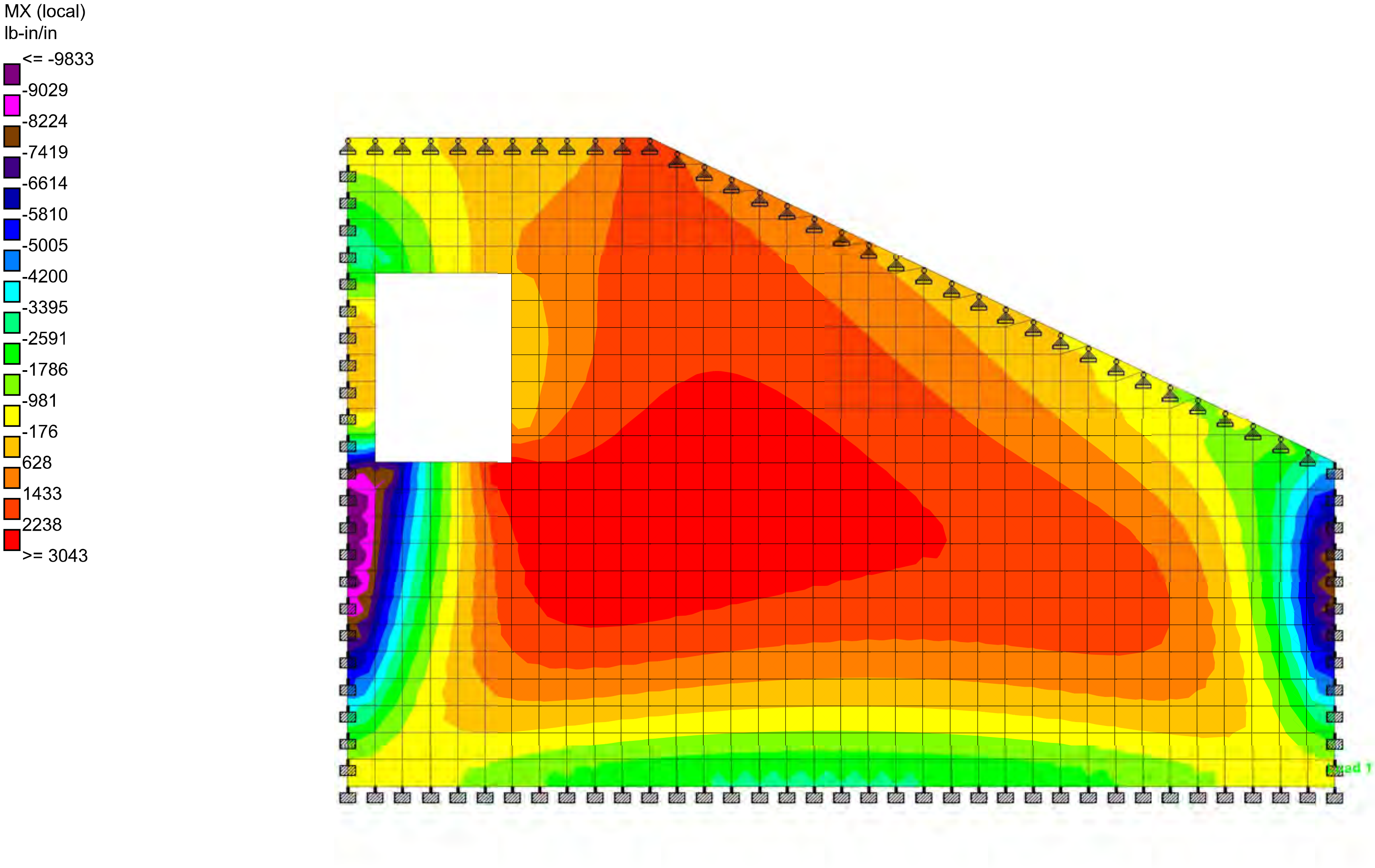
Job No	10721A.10	Sheet No	1	Rev	
Part	Wall 4				
Ref					
By	CC	Date	05-Aug-17	Chd	
File	Wall 4.std	Date/Time	11-Aug-2017 13:10		

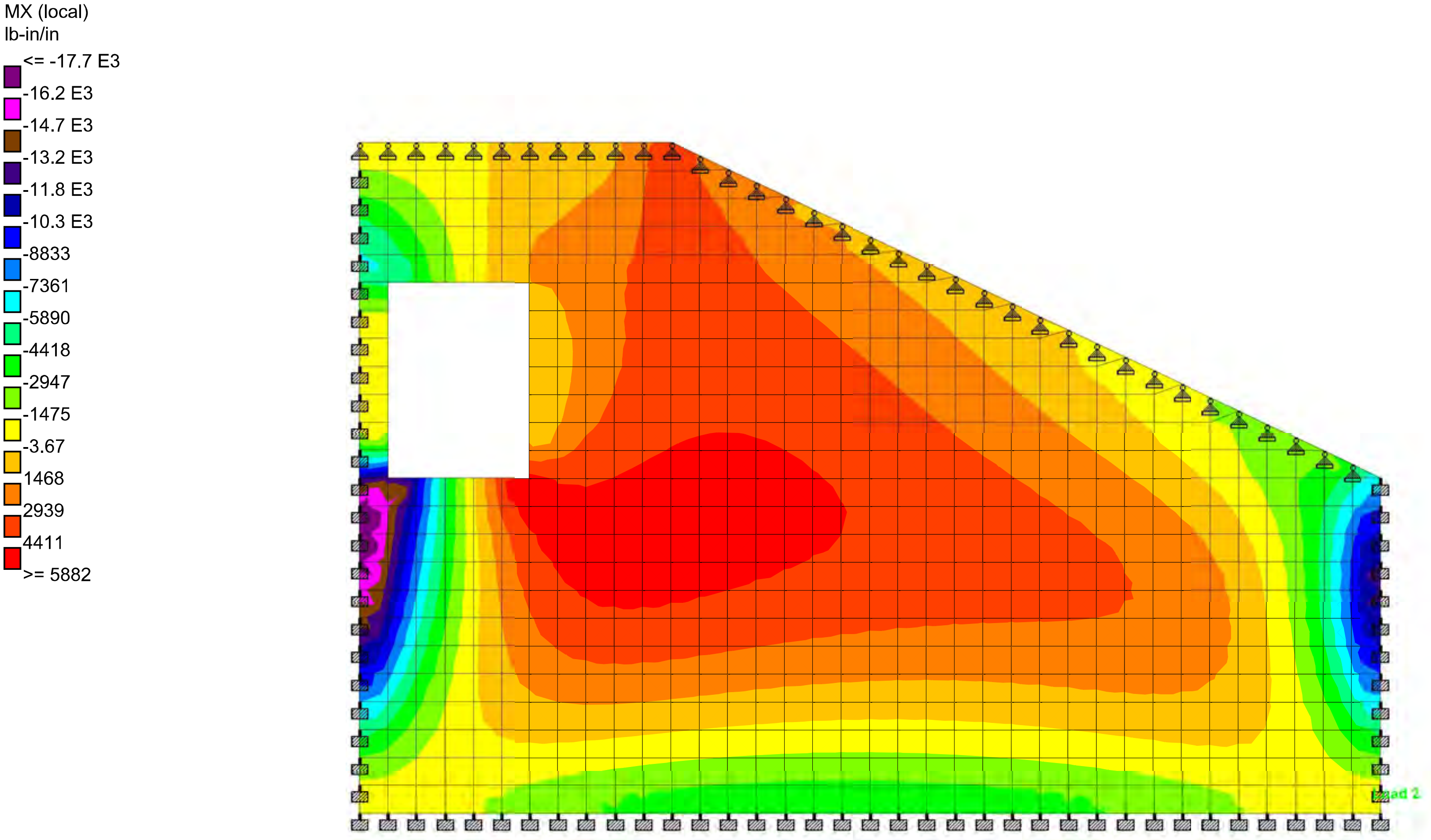
Job Title Area 5 - Ozonation

Load Case: 1.6(H+L)

Client Willametter River WTP



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 4		
Job Title Area 5 - Ozonation	Ref		
Load Case: 1.6H+1.4E	By CC	Date 05-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 11-Aug-2017 13:10	



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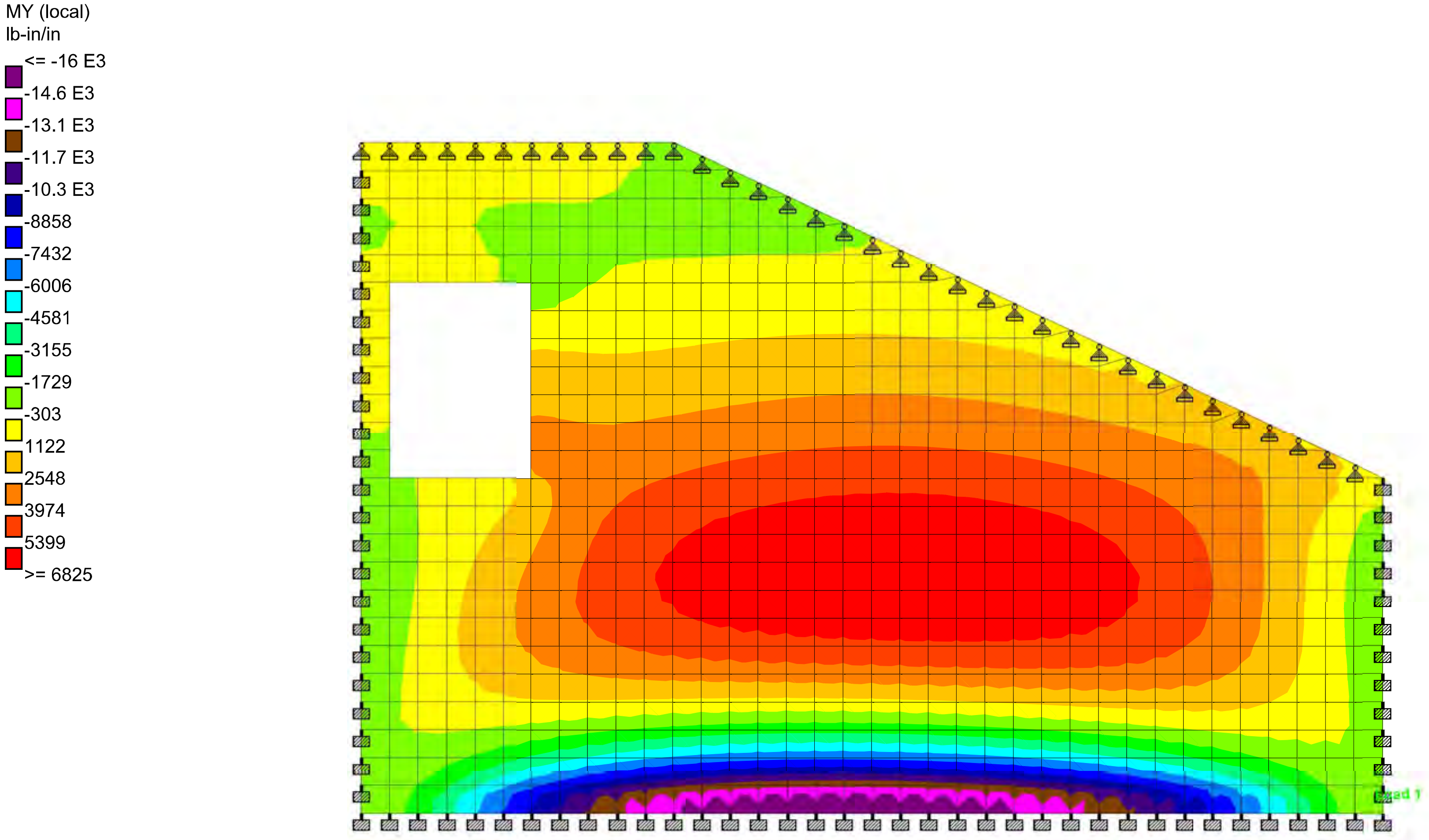
Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
Job Title Area 5 - Ozonation	Part Wall 4		
	Ref		
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 11-Aug-2017 13:10	



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	Part Wall 4		
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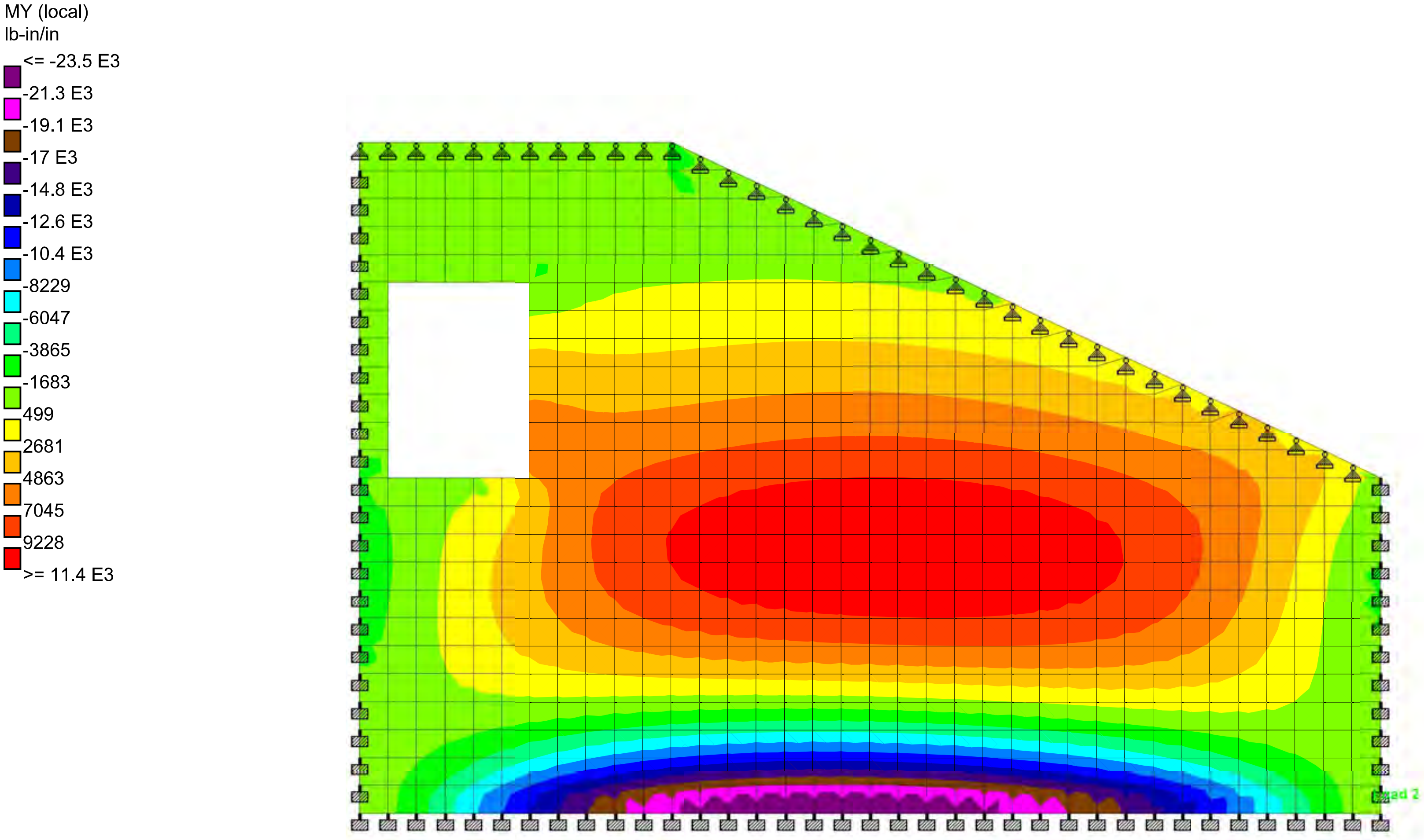

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	Part Wall 4		
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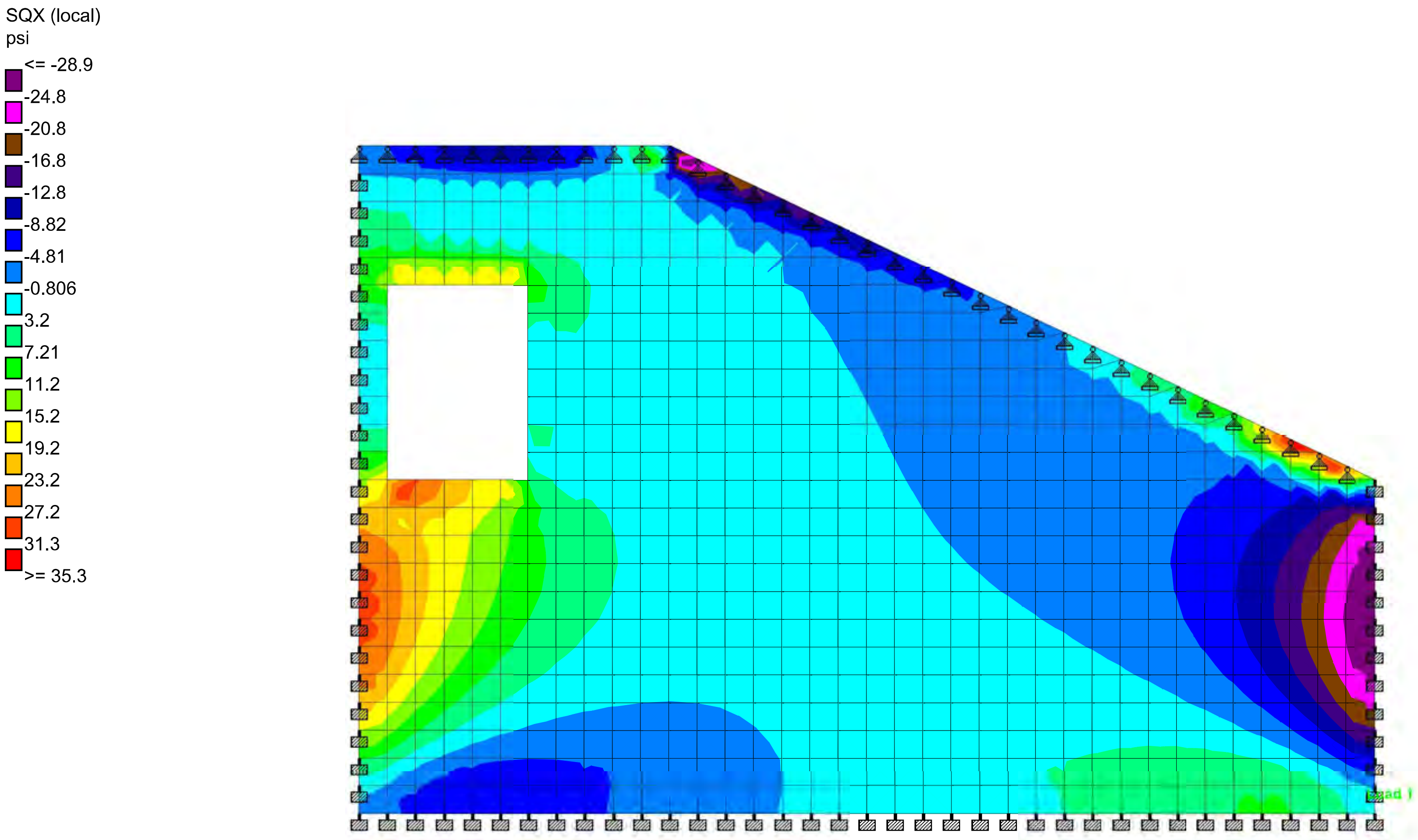

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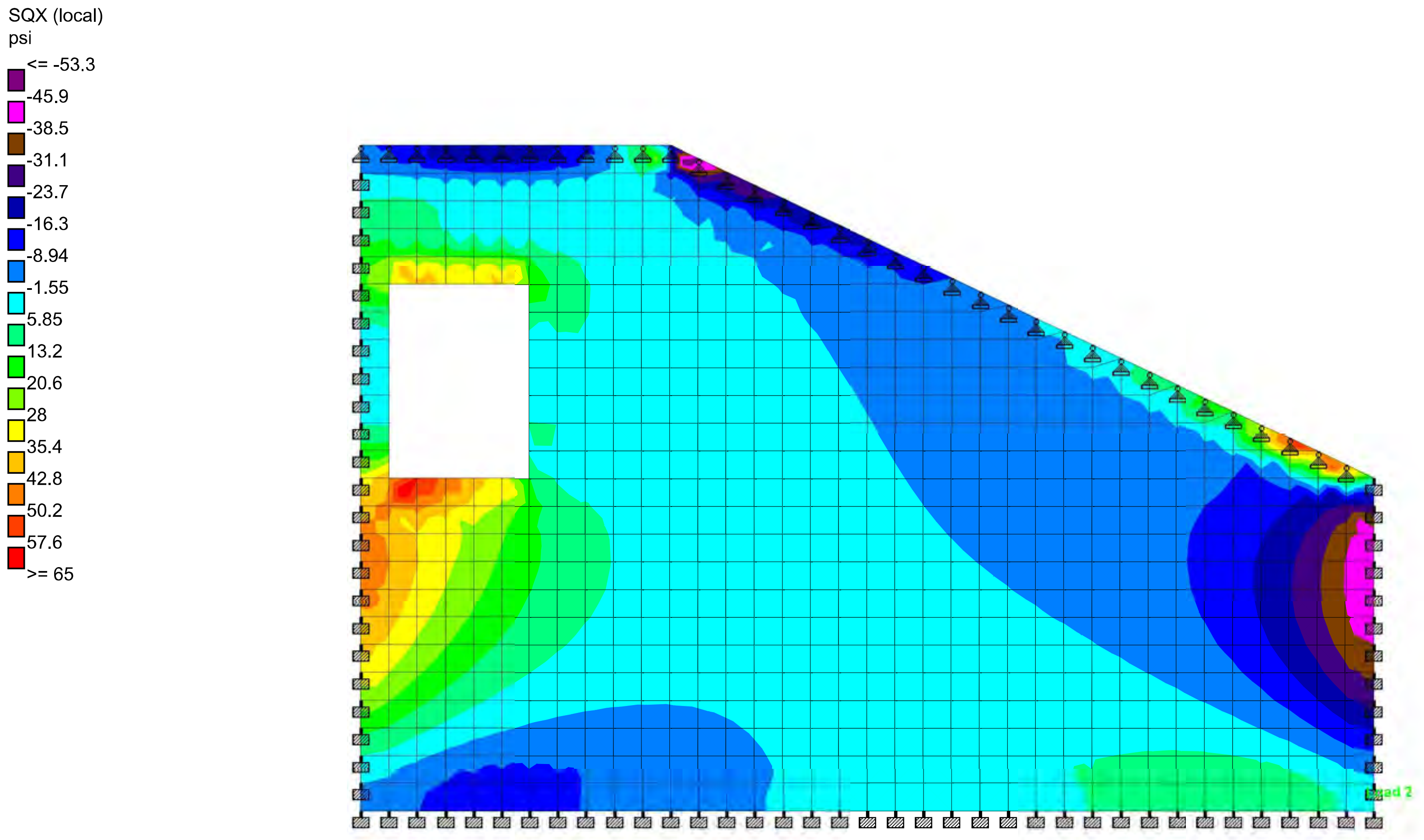

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Job No 10721A.10	Sheet No 1		Rev
Part Wall 4			
Ref			
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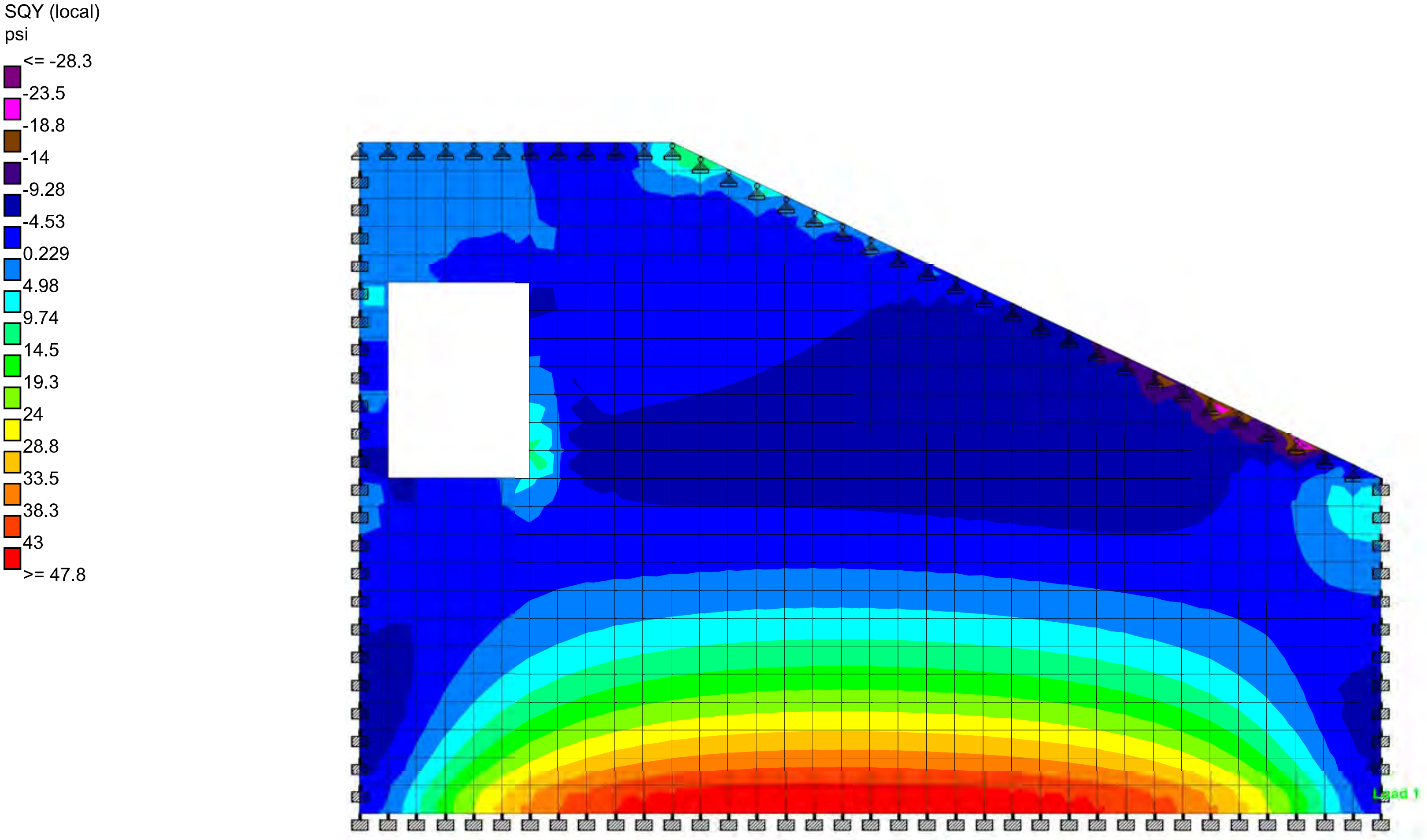
File Wall 4.std		Date/Time 11-Aug-2017 13:10	

Job Title Area 5 - Ozonation

Load Case: 1.6(H+L)

Client Willametter River WTP



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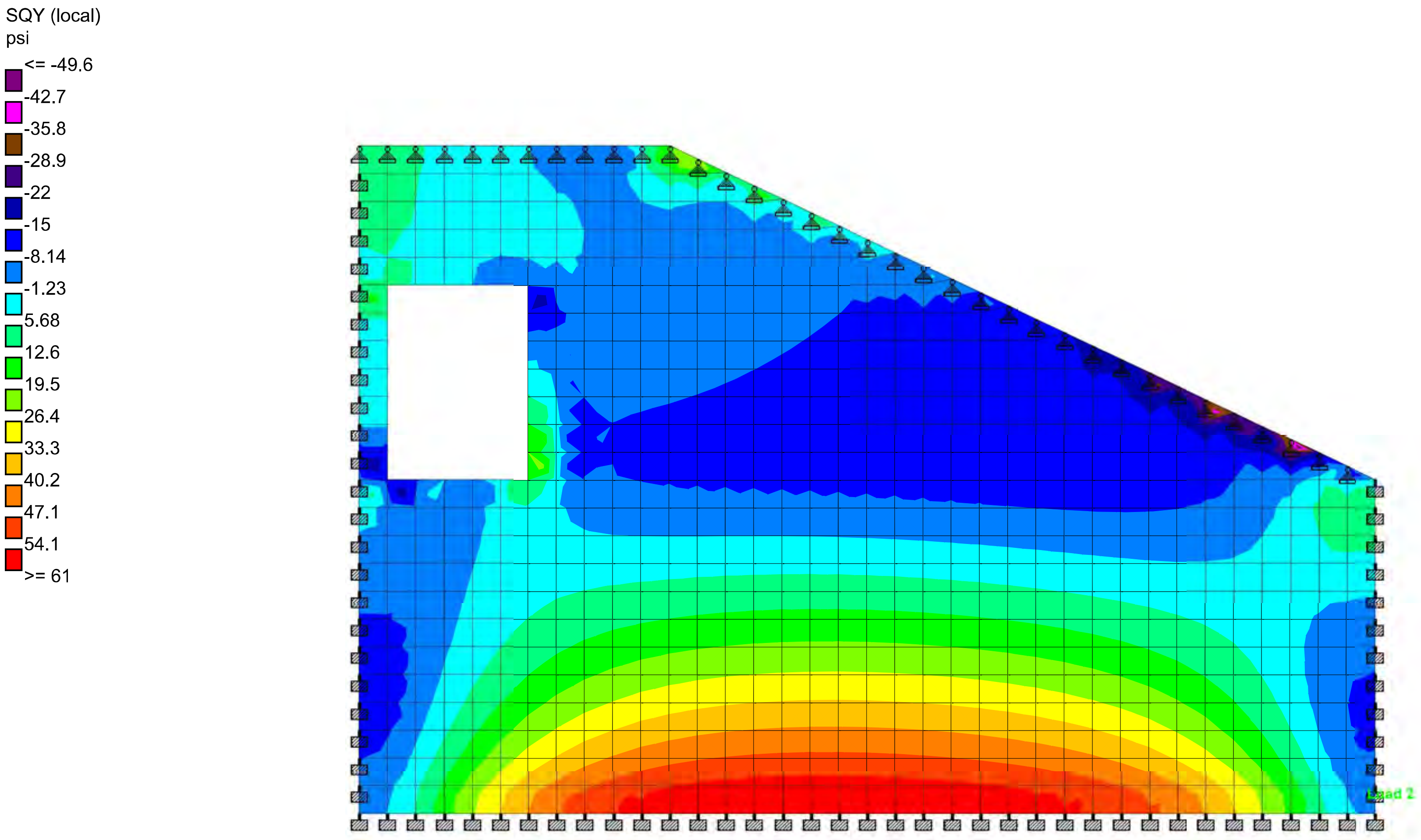
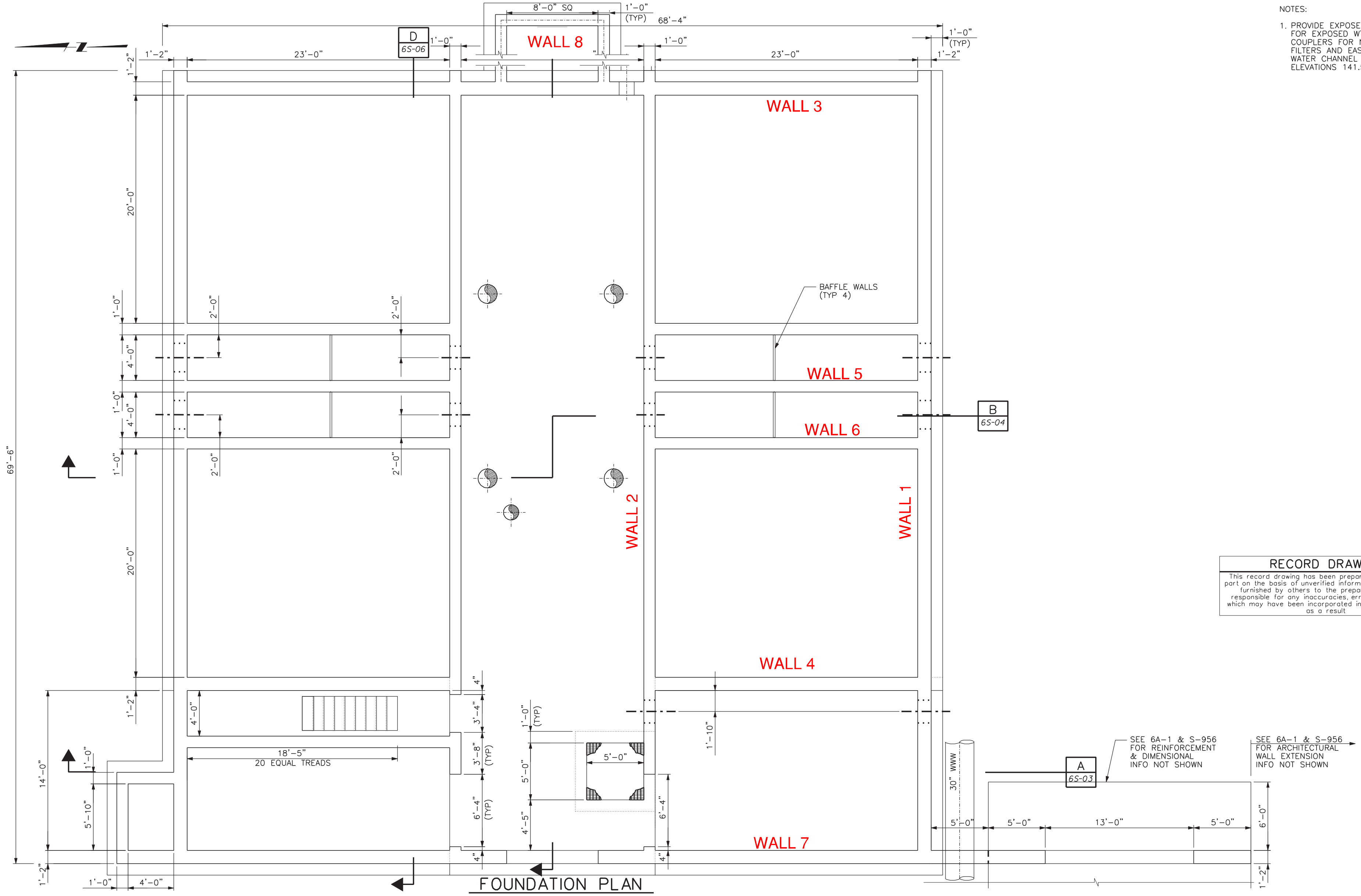


Area 6 - Filters Concrete Structure
ACI 350 Evaluation

WALL IDENTIFICATION

Job No: 1076081 File: P:\Wilsonville, City Of\Willamette WTP D-B\FILE-TRANSFER\cad_drawings\str\w06s01.dwg Plot Date: 01/24/2003 01:19:51 PM



FOUNDATION PLAN

NOTES:

1. PROVIDE EXPOSED WTSP, PROTECTION FOR EXPOSED WTSP AND REBAR COUPLERS FOR NORTH WALL OF FILTERS AND EAST END OF SETTLED WATER CHANNEL BETWEEN ELEVATIONS 141.50 AND 149.00

RECORD DRAWING

This record drawing has been prepared, entirely or in part on the basis of unverified information compiled and furnished by others to the preparer who is not responsible for any inaccuracies, errors or omissions which may have been incorporated into the document as a result

REV	DATE	BY	DESCRIPTION
R	12-02-03	BAR	RECORD DRAWING

SCALE 1/4"=1'-0"

WARNING 0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

DESIGNED B. CROOK
DRAWN B. CROOK
CHECKED

SUBMITTED BY
LICENSE NO. DATE
LICENSE NO. DATE

MWH
MONTGOMERY WATSON HARZA
Portland Oregon

City of WILSONVILLE in OREGON

CITY OF WILSONVILLE
WILLAMETTE RIVER WATER TREATMENT PLANT
FILTERS
STRUCTURAL
FOUNDATION PLAN

SHEET 6S-01

Engineers...Working Wonders With Water ™

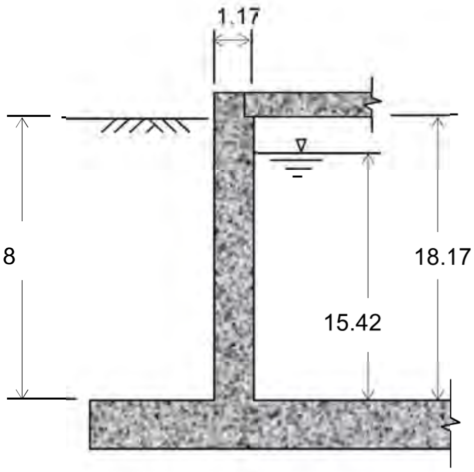
BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 10721A.10
DESIGN TASK: Wall 1 thru 6 - Pressures

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **23** ft
tank wall thickness, t_w = **14** inch
wall height to underside of roof, H_w = **18.17** ft

liquid height, H_L = **15.42** ft
liquid specific gravity = **1**
liquid density, γ_L = (sp.gr.)*γ_w = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION
(wall fixity = pinned at roof & fixed at floor)

Soil Data

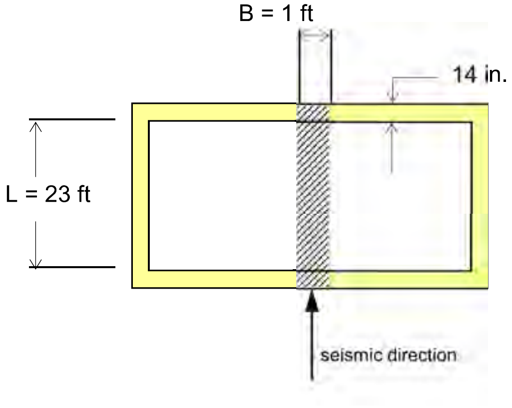
The site has no groundwater.

soil height above top of foundation base = **8** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf
0
concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.37**
Response modification factor, R_{wc} = **1.11**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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DESIGN TASK:			Wall 1 thru 6 - Pressures		

SHEET:

Weights:

unit 1-ft width wall mass, W_w = (14/12) * (18.17) * 0.15 = 3.18 kip

wall c.g. relative to base, h_w = 18.17 / 2 = 9.085 ft

unit width liquid mass, W_L = (23) * (1) * (15.42) * 32.17 = 22.13 kip

Seismic:

1). structure stiffness and dynamic property:

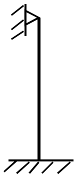
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(\ t_w / 12\ )*\rho_c$ = 0.09884 $k\text{-}sec^2/ft^2$

liquid mass, $m_i = (\ W_i / W_L\ )*(\ L/2\ )*H_L*\rho_L$ = 0.22895 $k\text{-}sec^2/ft^2$

centroidal distance of masses, $h = (\ h_w*m_w + h_i*m_i\ ) / (\ m_w + m_i\ )$ = 6.779 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 1856.35 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} =$$ (1856.35 / (0.0988 + 0.2289))^½ = 75.2544 rad/sec

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 75.2544 = 0.0835 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} =$$ (3.16*32.2*tanh(3.16*(0.6704)))^½ = 9.9379

$$\omega_c = \frac{\lambda}{\sqrt{L}} =$$ 9.9379 / (23)^½ = 2.0722 rad/sec,

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 2.0722 = 3.0321 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.325 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ ,\quad \text{but } \le\ 1.0\ =$$ 0.7700

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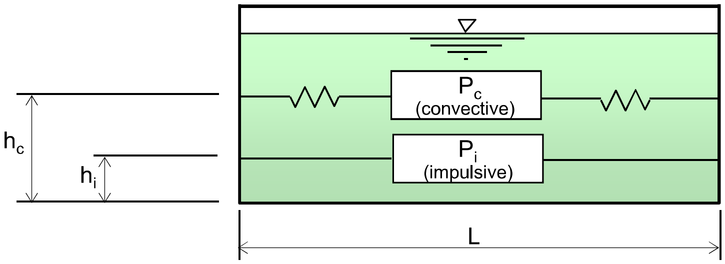
DESIGN TASK:					Wall 1 thru 6 - Pressures		



Dynamic Model

$L =$ 23 ft
$B =$ 1 ft
$H_L =$ 15.42 ft
$W_L =$ 22.13 kip

$L / H_L =$ 1.49157
$H_L / L =$ 0.67043

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) =$$ 22.13*(tanh(0.866*(1.4916)) / 0.866*(1.4916)) = 14.73 kip

hi (EBP) = HL * 0.375 = 15.42 * 0.375 = 5.783 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 9.659 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_{wi}}\right)W_i =$$ (0.611 * 1.25 / 2.37)*14.73 = 4.7 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) =$$ 22.13*(0.264*(1.4916)*tanh(3.16*(0.6704))) = 8.47 kip

$$h_{c\ (EBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 9.704 ft

$$h_{c\ (IBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 11.497 ft

$$\text{convective force}, P_c = \left(\frac{S_{ac}\ I}{R_{wc}}\right)W_c =$$ (0.3245 * 1.25 / 1.11)*8.47 = 3.1 kip

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DESIGN TASK: Wall 1 thru 6 - Pressures

5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 3.18 kip
wall c.g. relative to base, h_w = 9.085 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (0.611*1.25*0.77/2.37)*3.18 = 0.79 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (23/2)*(0.3245/1.4*1.25) = 3.33 \text{ ft}$$

Wave height is greater than the freeboard of 2.75-ft. Check possible effects on the roof.

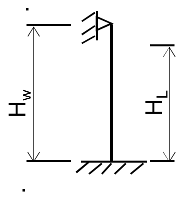
7). vertical acceleration:

design horizontal accereration, S_{DS} = 0.611 *g
vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4*S_{DS}$ = 0.2444 g

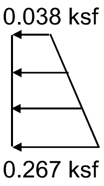
per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444*1*1/1 = 0.2444 \text{ g}$$

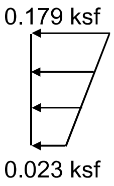
8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



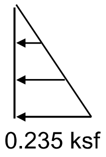
H_w = 18.17
H_L = 15.42



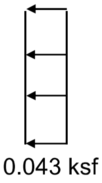
impulsive



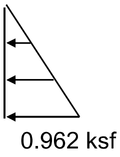
convective



vertical acceleration



wall inertia



hydrostatic

impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 4.70 kip
h_i = 5.783 ft
at $y = H_L$, p_{iy} = 0.038 ksf
at base $y = 0$, p_{iy} = 0.267 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 3.10 kip
h_c = 9.704 ft
at $y = H_L$, p_{cy} = 0.179 ksf
at base $y = 0$, p_{cy} = 0.023 ksf

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DESIGN TASK: Wall 1 thru 6 - Pressures

vertical acceleration:

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

$\ddot{u} =$ 0.2444
at $y = H_L$, $p_{vy} =$ 0.000 ksf
at base $y = 0$, $p_{vy} =$ 0.235 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ I\ \varepsilon\ \gamma_c\ (t_w/12)}{R_{wi}} =$$

$p_{wy} =$ 0.2481 $* \gamma_c * (t_w/12)$
at $y = H_w$, $p_{wy} =$ 0.043 ksf
at base $y = 0$, $p_{wy} =$ 0.043 ksf

hydrostatic:

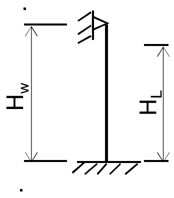
$q_{hy} = \gamma_L\,(H_L - y) =$

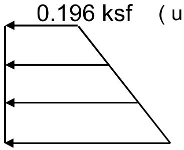
at $y = H_L$, $q_{hy} =$ 0.000 ksf
at base $y = 0$, $q_{hy} =$ 0.962 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at $y = H_w$, $p_y =$ 0.196 ksf
at base $y = 0$, $p_y =$ 0.390 ksf





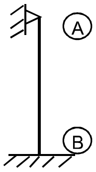
0.196 ksf (unfactored = 0.196 / 1.4 = 0.14 ksf)

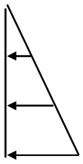
0.390 ksf (unfactored = 0.39 / 1.4 = 0.278 ksf)

resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

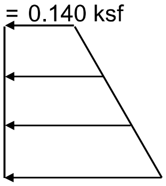
wall height, H_w = 18.17 ft
liquid height, H_L = 15.42 ft





0.962 ksf
hydrostatic

unfactored load = 0.140 ksf



unfactored load = 0.278 ksf
resultant dynamic pressures

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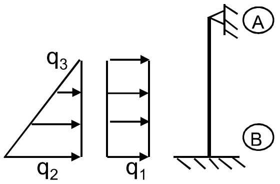
DESIGN TASK:					Wall 1 thru 6 - Pressures		

10). wall design pressures for external soil loading:

static soil:

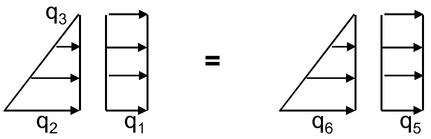


The site has no groundwater.

wall height = 18.17 ft
soil height above top of base = 8 ft
groundwater ht. above base = 0 ft
dry soil lateral pressure = 0.055 k/ft^3
sat. soil lateral pressure = 0.000 k/ft^3
live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:

LL lateral surcharge, q1 = 0.1000 ksf
unfactored soil, q2 = 0.4400 ksf
unfactored soil, q3 = 0.0000 ksf



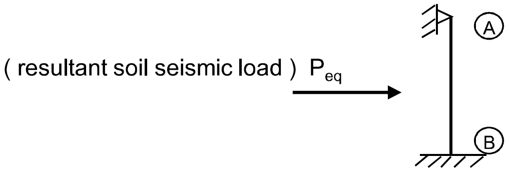
equivalent soil loadings:
unfactored q5 = 0.1000 ksf
unfactored q6 = 0.4400 ksf

soil seismic:

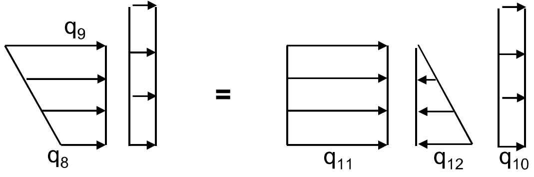
resultant factored soil seismic load per foot of wall width, $P_{u\ (eq)}$ = **1.088** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **5.33** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0003 ksf
equivalent soil seismic, q9 = 0.2717 ksf
wall seismic (see wall page 5), q10 = 0.0434 ksf
equivalent soil seismic, q11 = q9 = 0.2717 ksf
equivalent soil seismic, q12 = q8 - q9 = -0.2713 ksf

unfactored equivalent soil seismic, q8 =0.0003 / 1.4 = 0.0002 ksf
unfactored equivalent soil seismic, q9 =0.2717 / 1.4 = 0.1940 ksf
unfactored wall seismic , q10 = 0.0434 / 1.4 = 0.0310 ksf
unfactored equivalent soil seismic, q11 =0.2717 / 1.4 = 0.1940 ksf
unfactored equivalent soil seismic, q12 =-0.2713 / 1.4 = -0.1938 ksf

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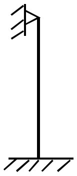
CHKD:		**DESCRIPTION:**		Area 6 - Filters	**JOB NO:**	10721A.10
DESIGN TASK:				Wall 1 thru 6 - Pressures		

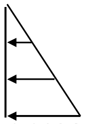
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



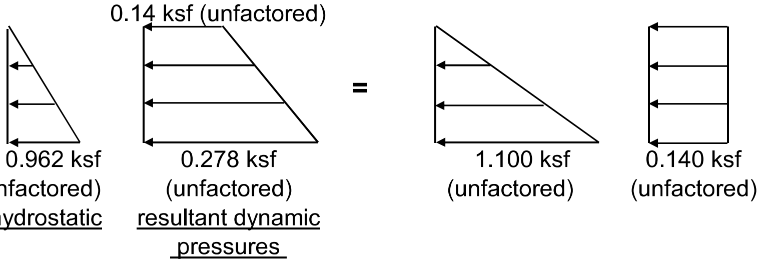
Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

wall height = 18.17 ft
water depth = 15.42 ft



b). load case 2: hydrostatic + dynamic:



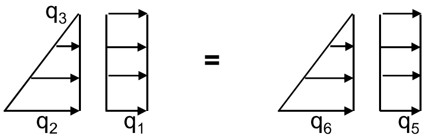
wall height = 18.17 ft
water depth = 15.42 ft

c). load case 3: static soil + LL surcharge:

wall height = 18.17 ft
soil height on wall = 8 ft

equivalent static soil & surcharge loadings...

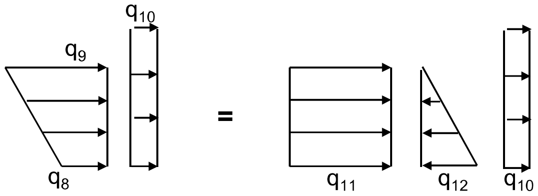
LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.440 ksf
unfactored soil, q3 = 0.000 ksf



equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.440 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 18.17 ft
soil height on wall = 8 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.194 ksf
unfactored equivalent soil seismic, q10 = 0.031 ksf
unfactored equivalent soil seismic, q11 = 0.194 ksf
unfactored equivalent soil seismic, q12 = -0.194 ksf

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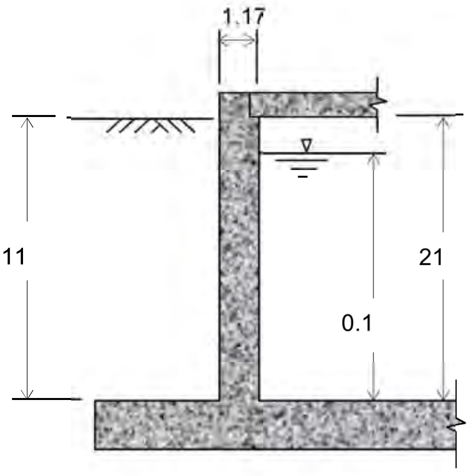
DESIGN TASK:					Wall 7 - Pressures		

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **14** ft
tank wall thickness, t_w = **14** inch
wall height to underside of roof, H_w = **21** ft

liquid height, H_L = **0.1** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION

(wall fixity = pinned at roof & fixed at floor)

Soil Data

The site has no groundwater.

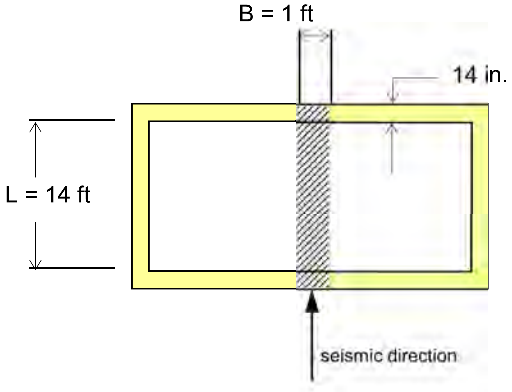
soil height above top of foundation base = **11** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf
0

concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.5**
Response modification factor, R_{wc} = **1**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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DESIGN TASK:					Wall 7 - Pressures		

Weights:

unit 1-ft width wall mass, W_w = (14/12) * (21) * 0.15 = 3.68 kip

wall c.g. relative to base, h_w = 21 / 2 = 10.500 ft

unit width liquid mass, W_L = (14) * (1) * (0.1) * 32.17 = 0.09 kip

Seismic:

1). structure stiffness and dynamic property:

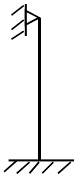
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.11424 k-sec^2/ft^2

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.00000 k-sec^2/ft^2

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 10.5 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 813.83 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} =$$ (813.83 / (0.1142 + 0))^½ = 84.4039 rad/sec

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 84.4039 = 0.0744 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} =$$ (3.16*32.2*tanh(3.16*(0.0071)))^½ = 1.5146

$$\omega_c = \frac{\lambda}{\sqrt{L}} =$$ 1.5146 / (14)^½ = 0.4048 rad/sec,

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 0.4048 = 15.5214 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.063 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ ,\quad \text{but} \le 1.0 =$$ 1.0000

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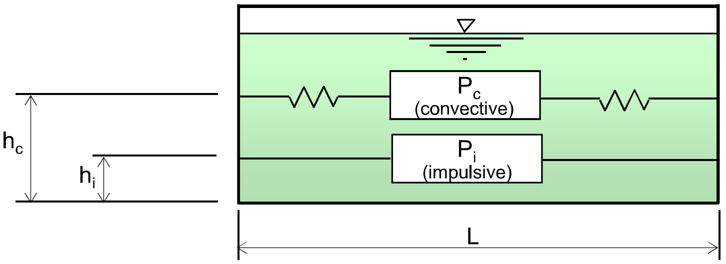
DESIGN TASK:					Wall 7 - Pressures		



Dynamic Model

L =	14	ft
B =	1	ft
H_L =	0.1	ft
W_L =	0.09	kip
L / H_L =	########	
H_L / L =	0.00714	

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L \left(\frac{\tanh\left(0.866 \frac{L}{H_L}\right)}{0.866 \frac{L}{H_L}} \right) =$$

0.09*(tanh(0.866*(140)) / 0.866*(140)) = 0 kip

hi (EBP) = HL * 0.375 = 0.1 * 0.375 = 0.038 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 6.05 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_{wi}} \right) W_i =$$

(0.611 * 1.25 / 2.5)*0 = 0.0 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L \left(0.264 \left(\frac{L}{H_L} \right) \tanh\left(3.16 \left(\frac{H_L}{L} \right) \right) \right) =$$

0.09*(0.264*(140)*tanh(3.16*(0.0071))) = 0.08 kip

$$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = 0.05 \text{ ft}$$

$$h_{c\ (IBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = 198.279 \text{ ft}$$

$$\text{convective force, } P_c = \left(\frac{S_{ac}\ I}{R_{wc}} \right) W_c =$$

(0.0634 * 1.25 / 1)*0.08 = 0.0 kip

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DESIGN TASK:					Wall 7 - Pressures		

5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 3.68 kip

wall c.g. relative to base, h_w = 10.500 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (0.611*1.25*1/2.5)*3.68 = 1.12 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (14/2)*(0.0634/1.4*1.25) = 0.40 \text{ ft}$$

7). vertical acceleration:

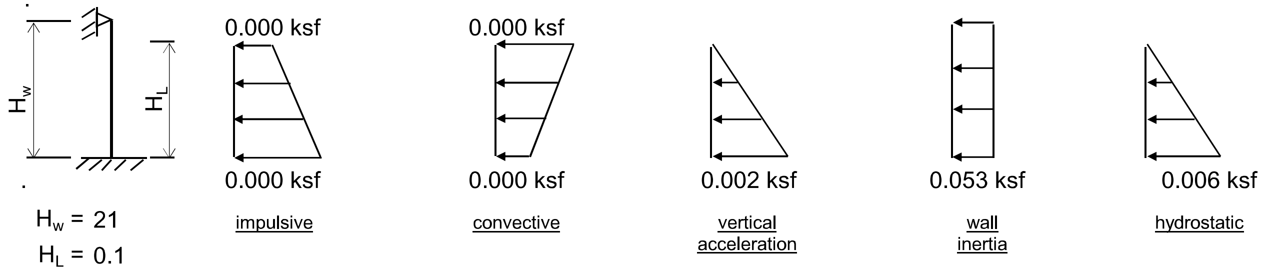
design horizontal accereration, S_{DS} = 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4*S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444*1*1/1 = 0.2444 \text{ g}$$

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



H_w = 21

H_L = 0.1

impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 0.00 kip

h_i = 0.038 ft

at $y = H_L$, p_{iy} = 0.000 ksf

at base $y = 0$, p_{iy} = 0.000 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 0.00 kip

h_c = 0.05 ft

at $y = H_L$, p_{cy} = 0.000 ksf

at base $y = 0$, p_{cy} = 0.000 ksf

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DESIGN TASK: Wall 7 - Pressures

vertical acceleration:

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

$\ddot{u}$ = 0.2444
at y = H_L, p_{vy} = 0.000 ksf
at base y = 0, p_{vy} = 0.002 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\;I\;\varepsilon\,\gamma_c\,(t_w/12)}{R_{wi}} =$$

p_{wy} = 0.3055 * γ_c * (t_w/12)
at y = H_w, p_{wy} = 0.053 ksf
at base y = 0, p_{wy} = 0.053 ksf

hydrostatic:

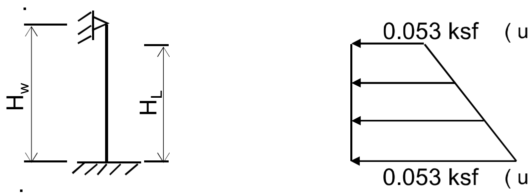
$q_{hy} = \gamma_L\,(H_L - y) =$

at y = H_L, q_{hy} = 0.000 ksf
at base y = 0, q_{hy} = 0.006 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y = 0.053 ksf
at base y = 0, p_y = 0.053 ksf



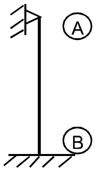
(unfactored = 0.053 / 1.4 = 0.038 ksf)

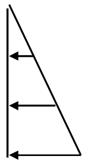
(unfactored = 0.053 / 1.4 = 0.038 ksf)

resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

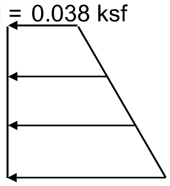
wall height, H_w = 21 ft
liquid height, H_L = 0.1 ft





0.006 ksf
hydrostatic

unfactored load = 0.038 ksf



unfactored load = 0.038 ksf
resultant dynamic pressures

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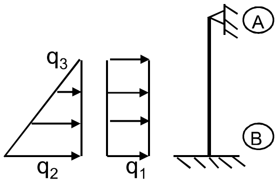
DESIGN TASK:	Wall 7 - Pressures				

10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 21 ft

soil height above top of base = 11 ft

groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

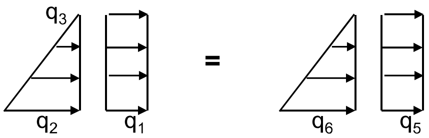
live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:

LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.6050 ksf

unfactored soil, q3 = 0.0000 ksf



equivalent soil loadings:

unfactored q5 = 0.1000 ksf

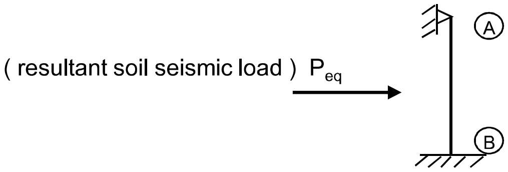
unfactored q6 = 0.6050 ksf

soil seismic:

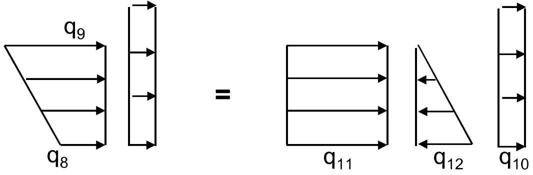
resultant factored soil seismic load per foot of wall width, $P_{u\,(eq)}$ = **2.057** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **7.33** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0003 ksf

equivalent soil seismic, q9 = 0.3737 ksf

wall seismic (see wall page 5), q10 = 0.0535 ksf

equivalent soil seismic, q11 = q9 = 0.3737 ksf

equivalent soil seismic, q12 = q8 - q9 = -0.3733 ksf

unfactored equivalent soil seismic, q8 =0.0003 / 1.4 = 0.0002 ksf

unfactored equivalent soil seismic, q9 =0.3737 / 1.4 = 0.2669 ksf

unfactored wall seismic , q10 = 0.0535 / 1.4 = 0.0382 ksf

unfactored equivalent soil seismic, q11 =0.3737 / 1.4 = 0.2669 ksf

unfactored equivalent soil seismic, q12 =-0.3733 / 1.4 = -0.2667 ksf

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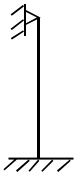
DESIGN TASK:	Wall 7 - Pressures				

11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:

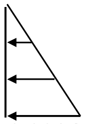


Load Cases:

case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

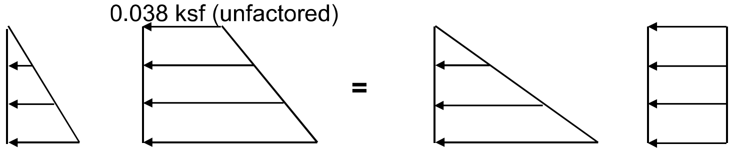
wall height = 21 ft
water depth = 0.1 ft



(unfactored) 0.006 ksf

b). load case 2: hydrostatic + dynamic:

0.038 ksf (unfactored)



0.006 ksf (unfactored) hydrostatic

0.038 ksf (unfactored) resultant dynamic pressures

0.006 ksf (unfactored)

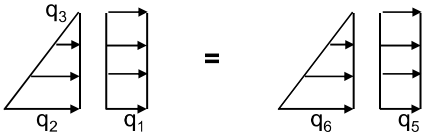
0.038 ksf (unfactored)

wall height = 21 ft
water depth = 0.1 ft

c). load case 3: static soil + LL surcharge:

wall height = 21 ft
soil height on wall = 11 ft

equivalent static soil & surcharge loadings...



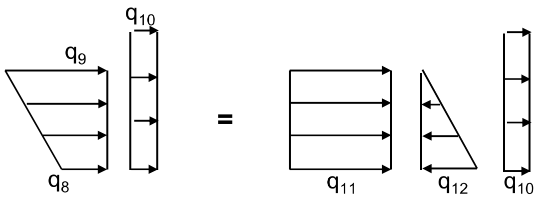
LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.605 ksf
unfactored soil, q3 = 0.000 ksf

equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.605 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)

equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 21 ft
soil height on wall = 11 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.267 ksf
unfactored equivalent soil seismic, q10 = 0.038 ksf
unfactored equivalent soil seismic, q11 = 0.267 ksf
unfactored equivalent soil seismic, q12 = -0.267 ksf

Area 6 - Filters
Wall 1 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	9.93	15.99	30.50	***0.52***	35	126	***0.27***	***<- OK***
1.2F+1.4E	1.00	13.60	13.60	30.50	***0.45***	45	126	***0.36***	***<- OK***
1.6(H+L)	1.41	4.45	6.27	30.50	***0.21***	18	126	***0.15***	***<- OK***
1.6H+1.4E	1.00	5.71	5.71	30.50	***0.19***	22	126	***0.17***	***<- OK***

Vertical Span

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	14.60	23.51	43.50	***0.54***	45	126	***0.35***	***<- OK***
1.2F+1.4E	1.00	19.20	19.20	43.50	***0.44***	57	126	***0.45***	***<- OK***
1.6(H+L)	1.41	5.73	8.08	43.50	***0.19***	26	126	***0.21***	***<- OK***
1.6H+1.4E	1.00	6.52	6.52	43.50	***0.15***	28	126	***0.22***	***<- OK***

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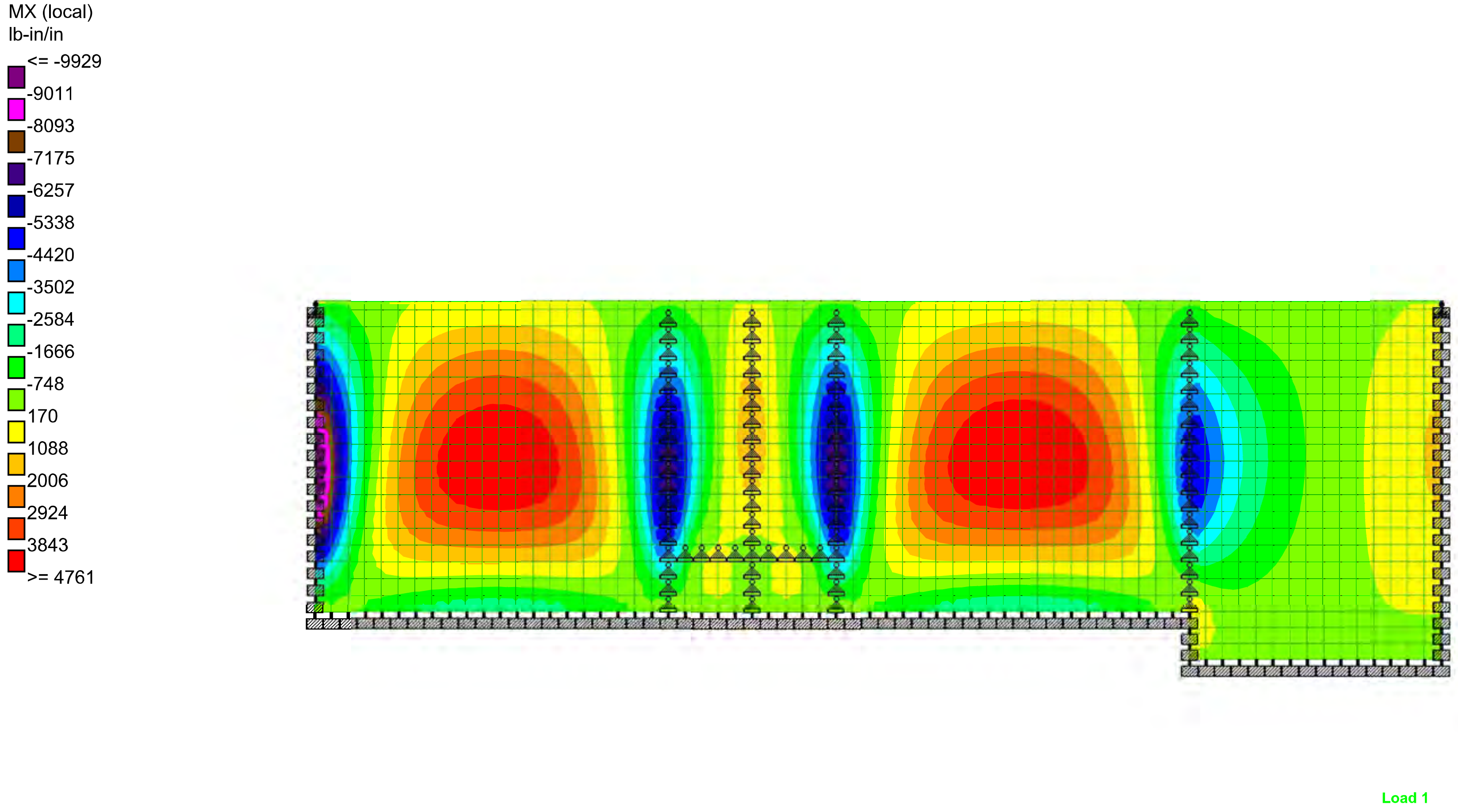
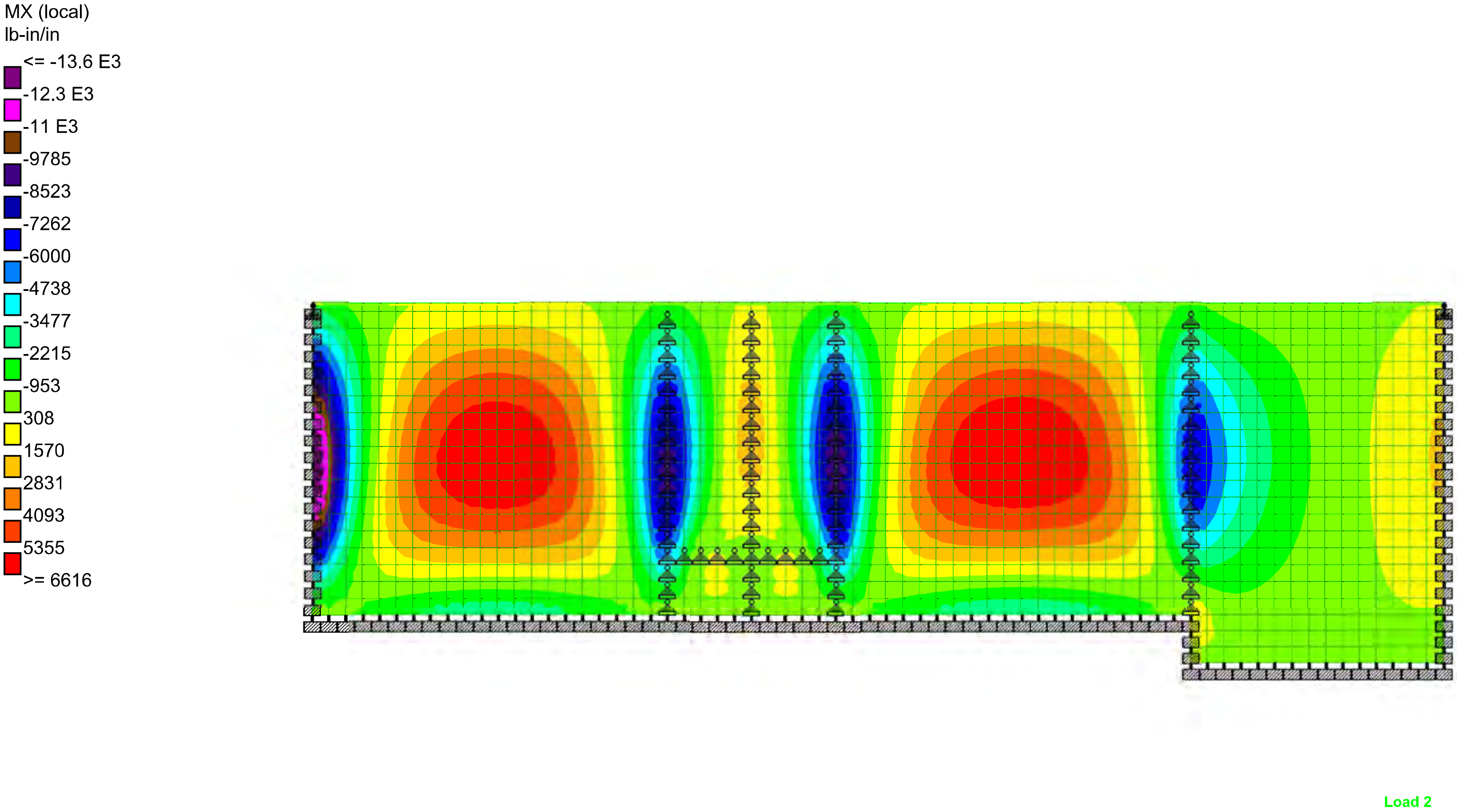
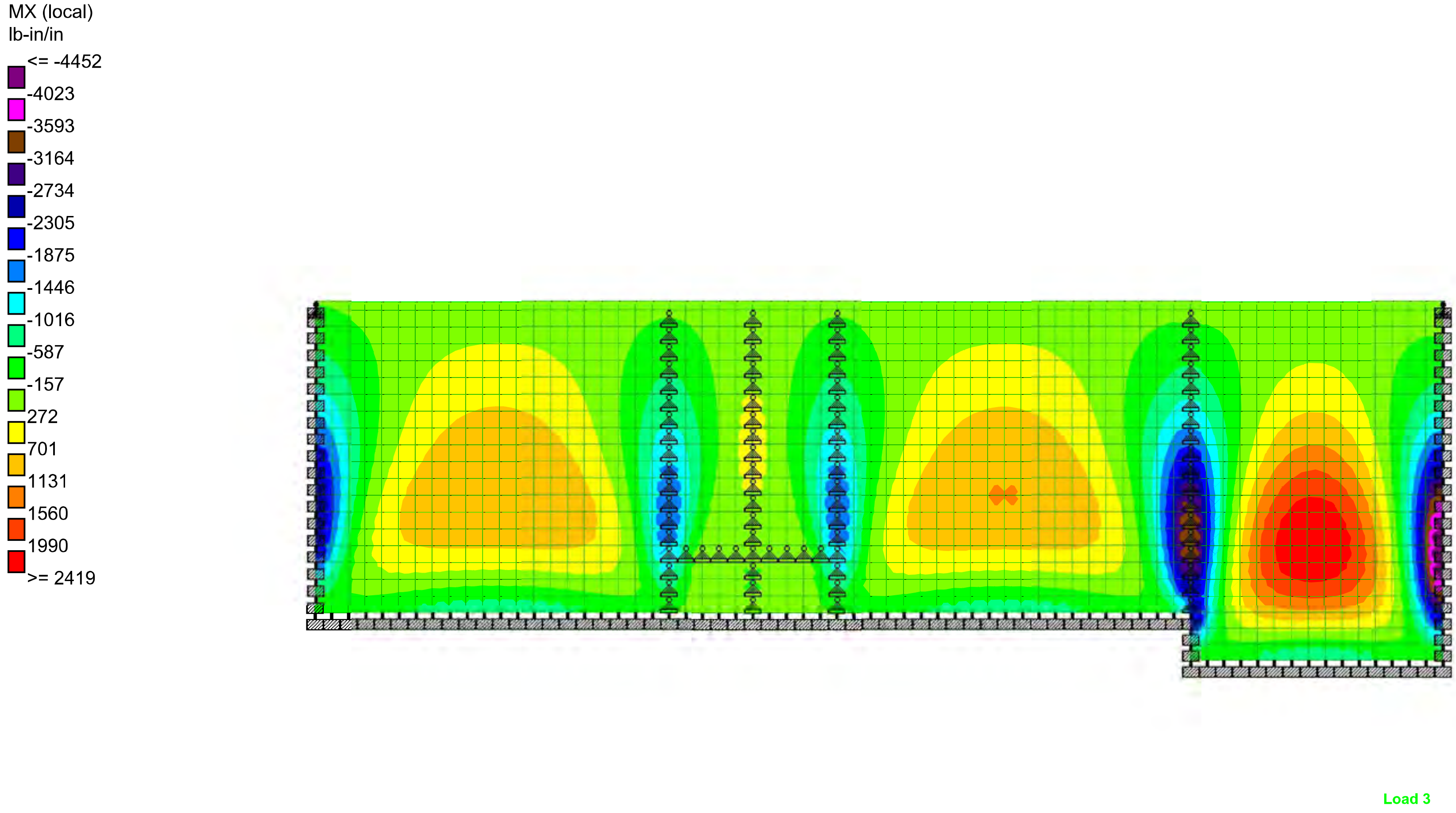
Job Title	Area 6 - Filters Load Case: 1.4F	Job No	10721A.10	Sheet No	1
		Part	Wall 1	Rev	
		Ref			
		By	CC	Date 05-Aug-17	Chd
Client	Willamette River WTP	File	Wall 1.std	Date/Time	10-Aug-2017 13:44



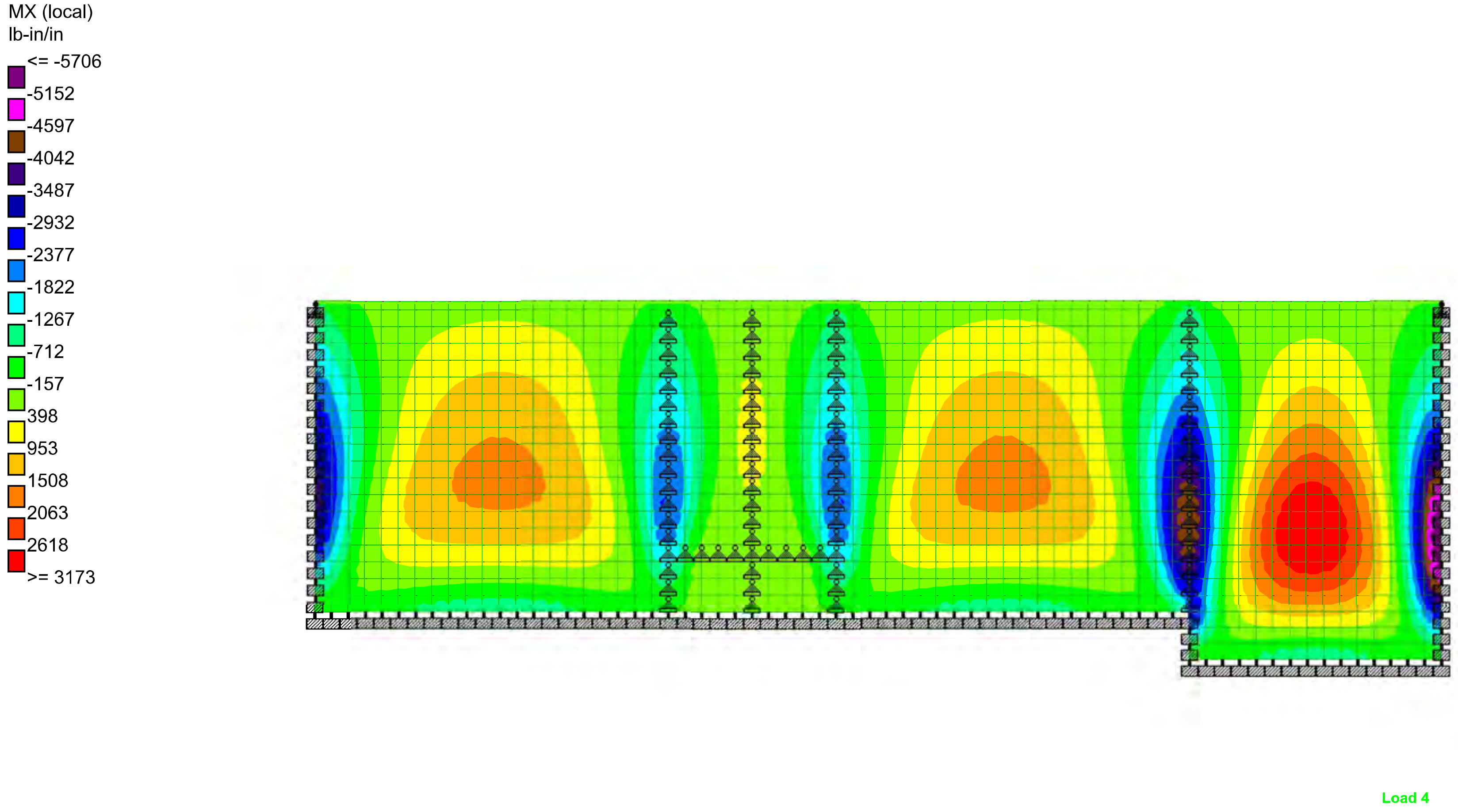
Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
Job Title Area 6 - Filters	Ref		
Load Case: 1.2F+1.4E	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



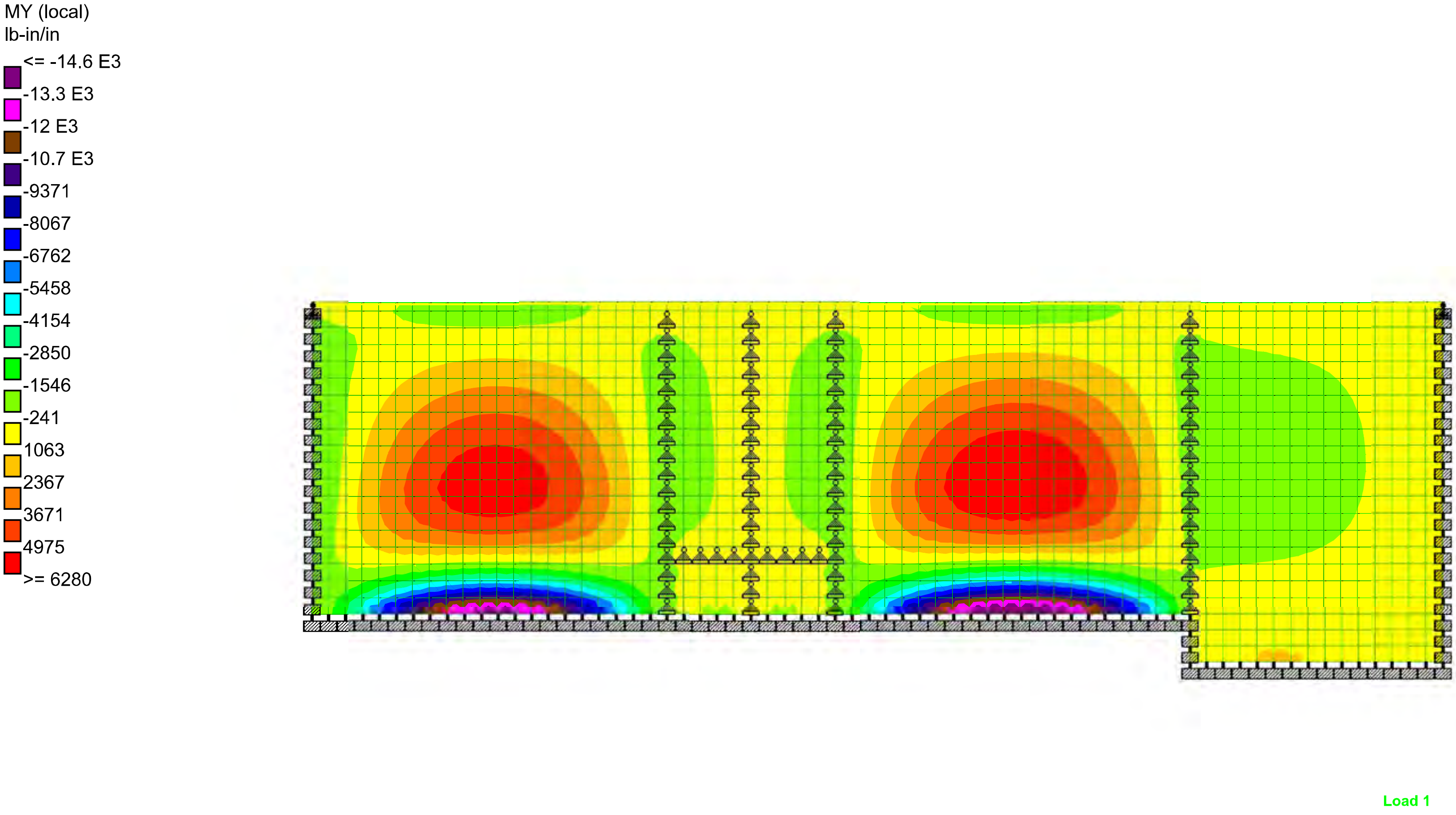
Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 1			
Job Title Area 6 - Filters	Ref			
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44		



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
Job Title Area 6 - Filters	Ref		
Load Case: 1.6H+1.4E	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 1		
Job Title Area 6 - Filters	Ref		
Load Case: 1.4F	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



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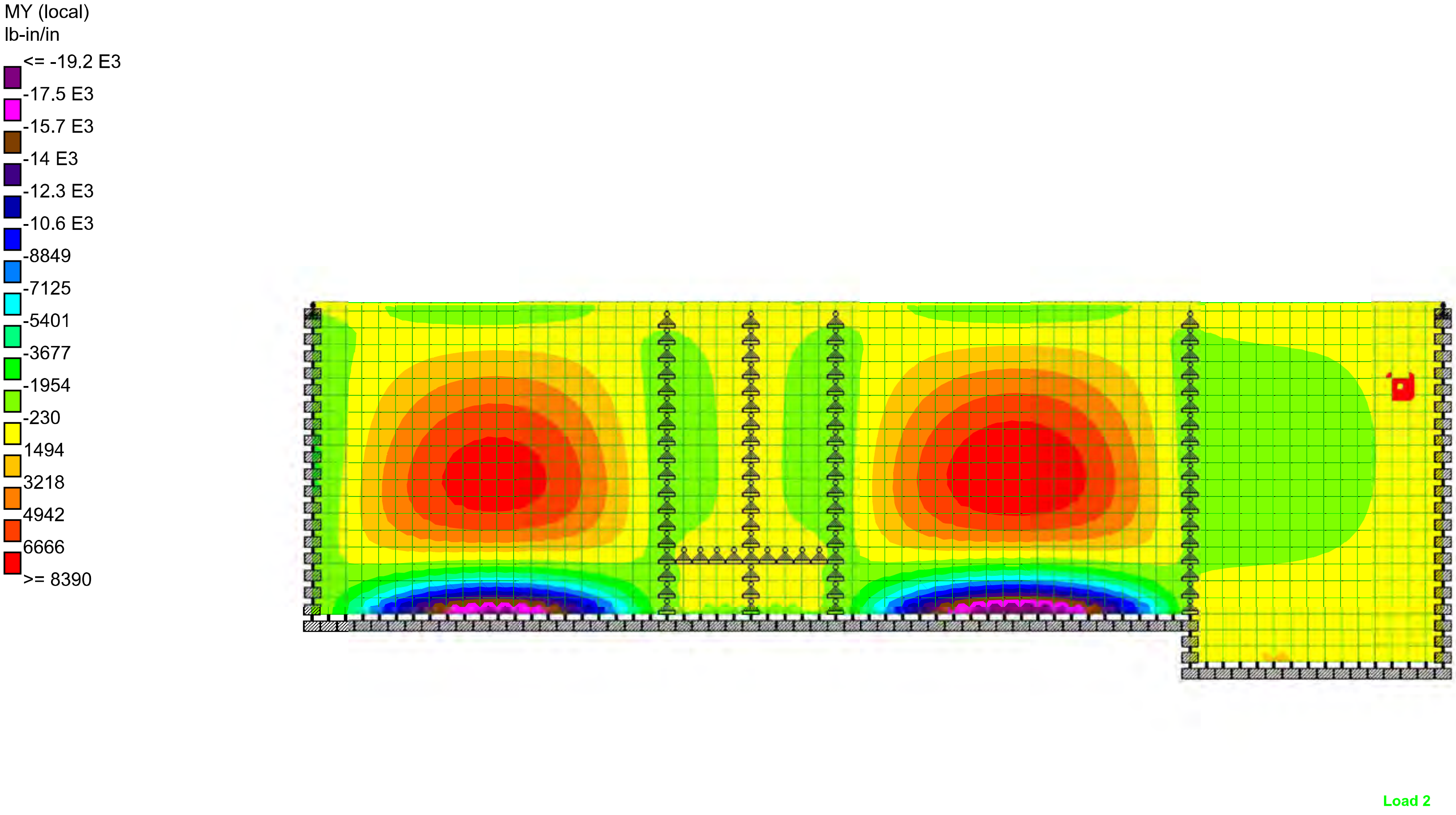
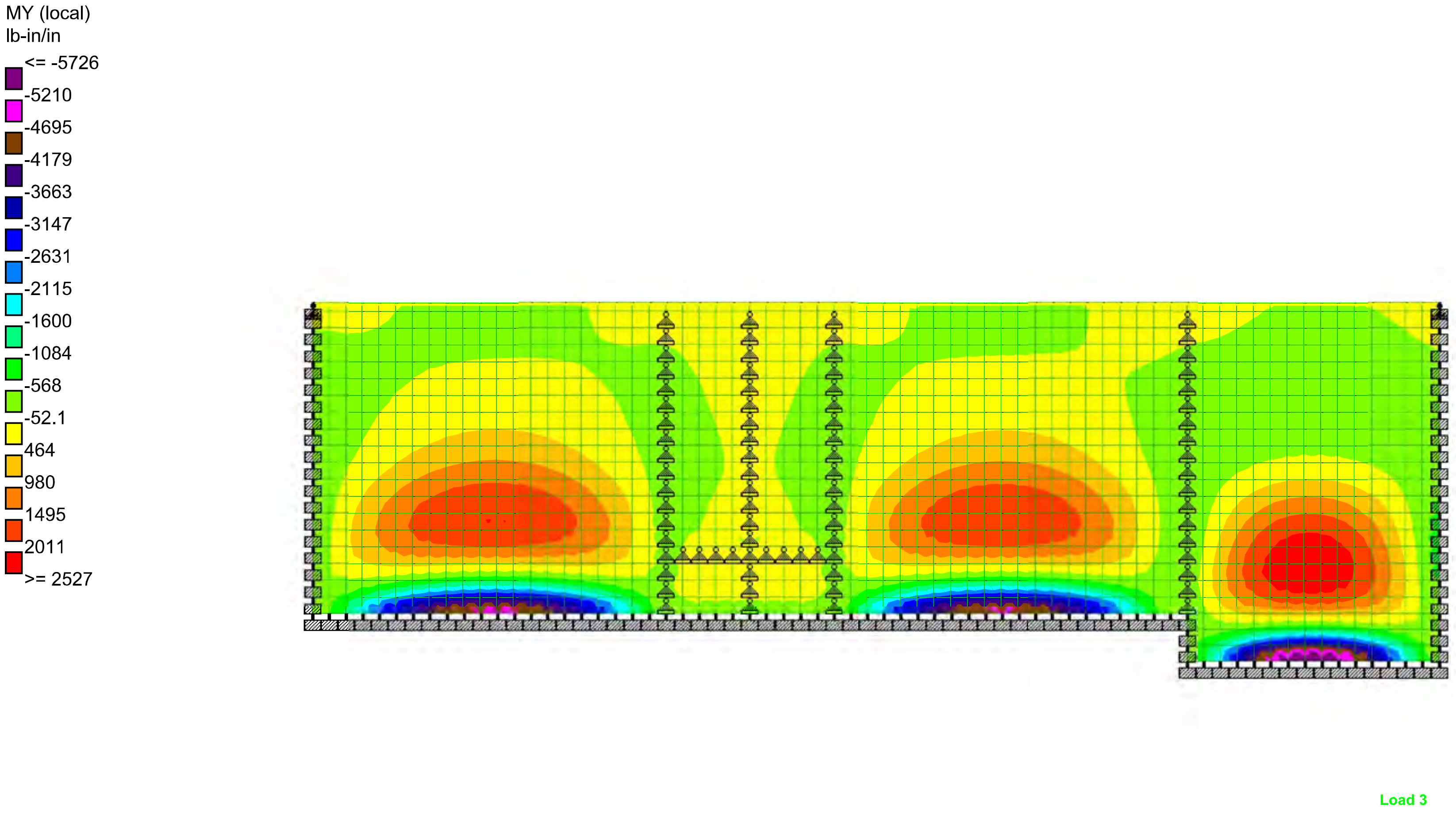
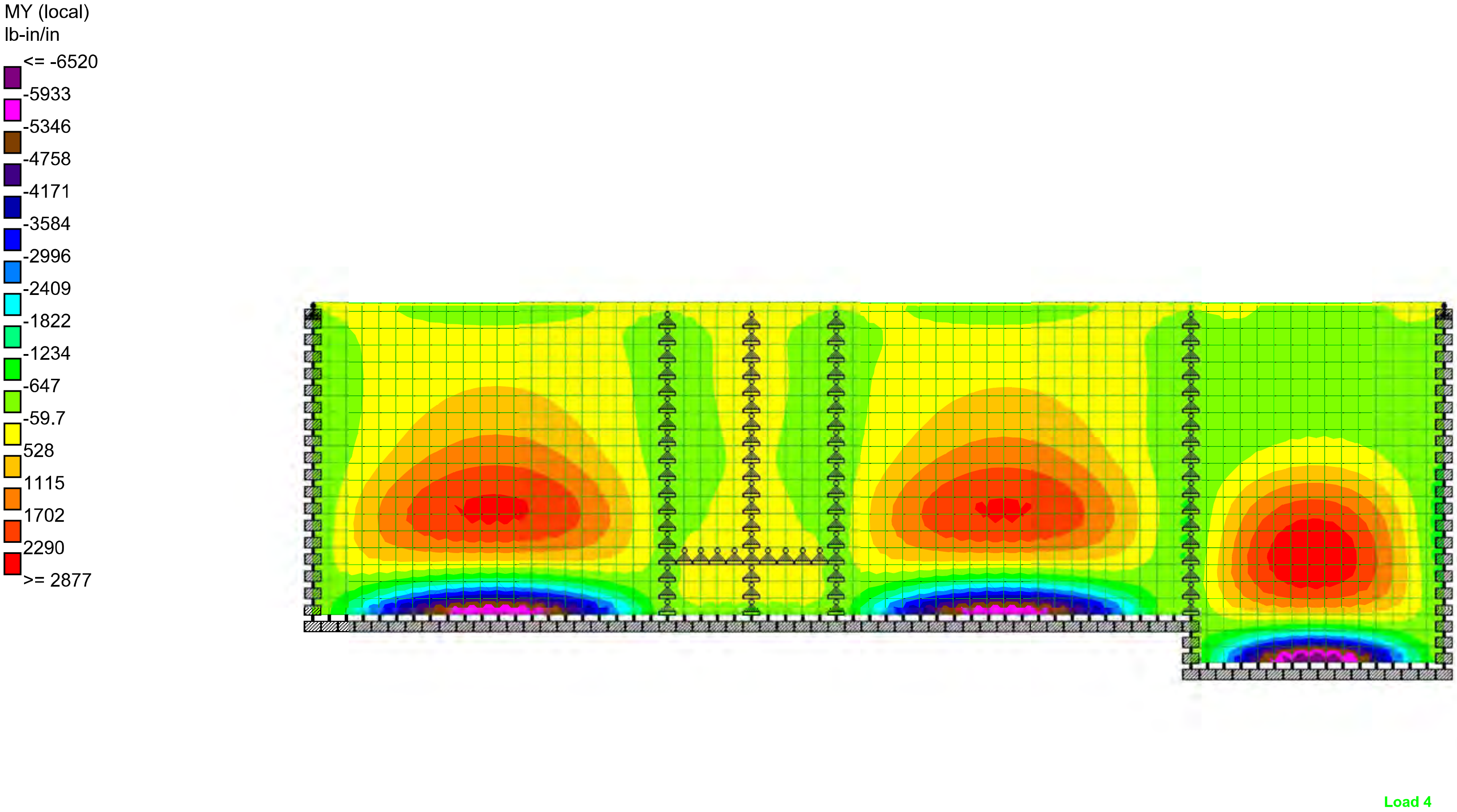
Job Title Area 6 - Filters Load Case: 1.2F+1.4E	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 1			
	Ref			
	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 1.std		Date/Time 10-Aug-2017 13:44	



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
Job Title Area 6 - Filters	Part Wall 1		
	Ref		
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
Job Title Area 6 - Filters Load Case: 1.6H+1.4E	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



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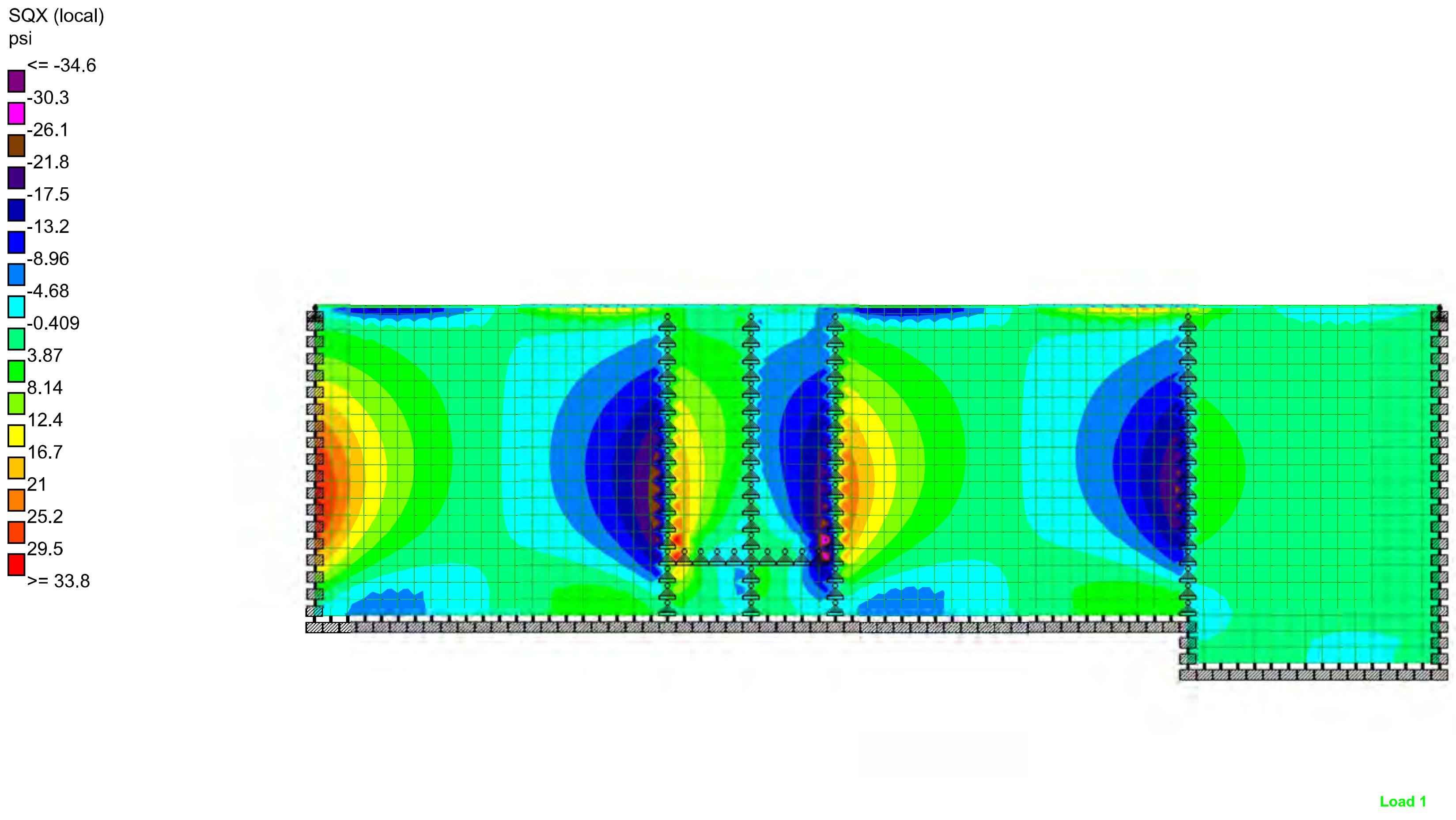
Job Title Area 6 - Filters Load Case: 1.4F	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 1			
	Ref			
	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44		



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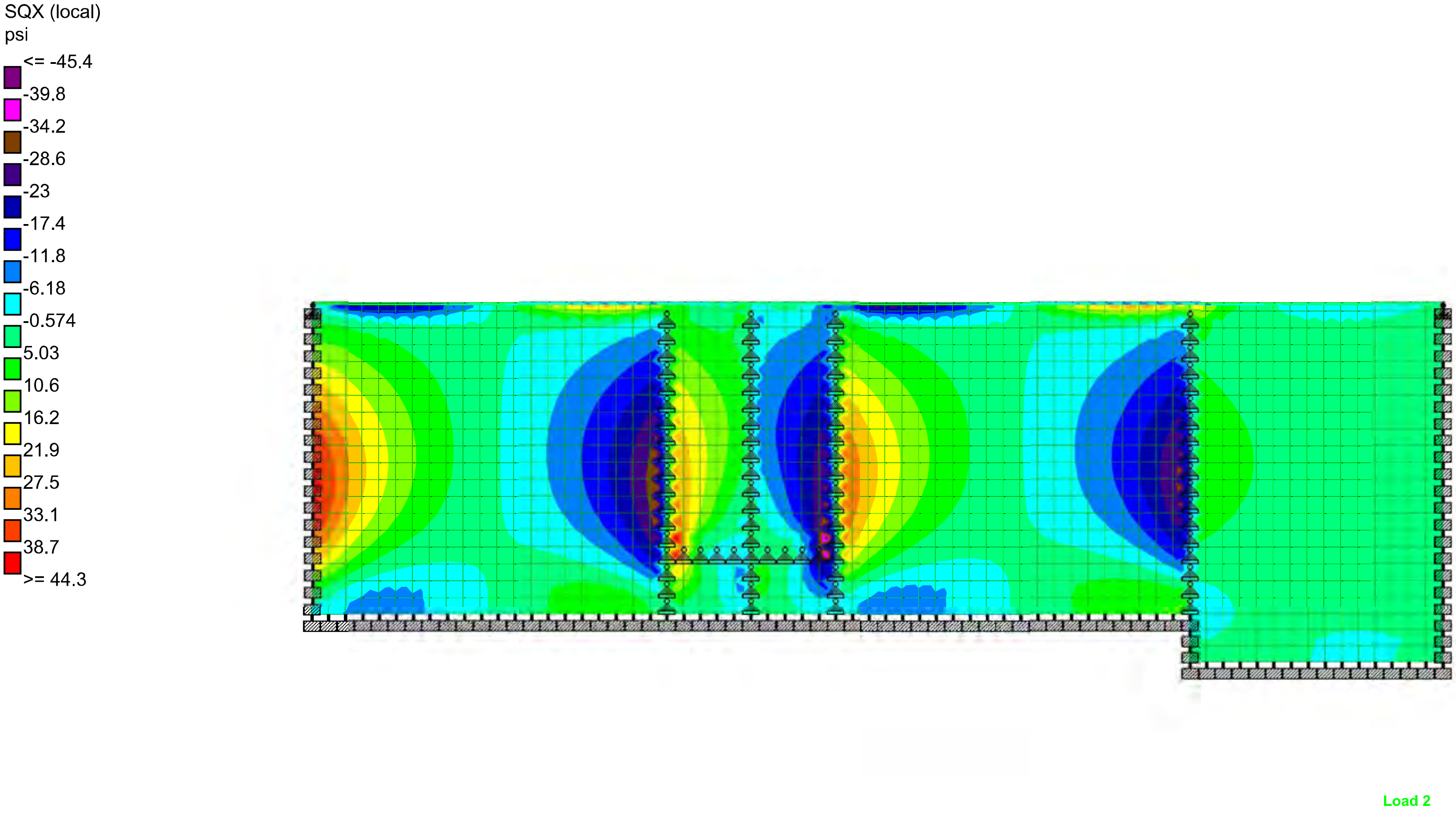
	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 1		
Job Title Area 6 - Filters	Ref		
Load Case: 1.2F+1.4E	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



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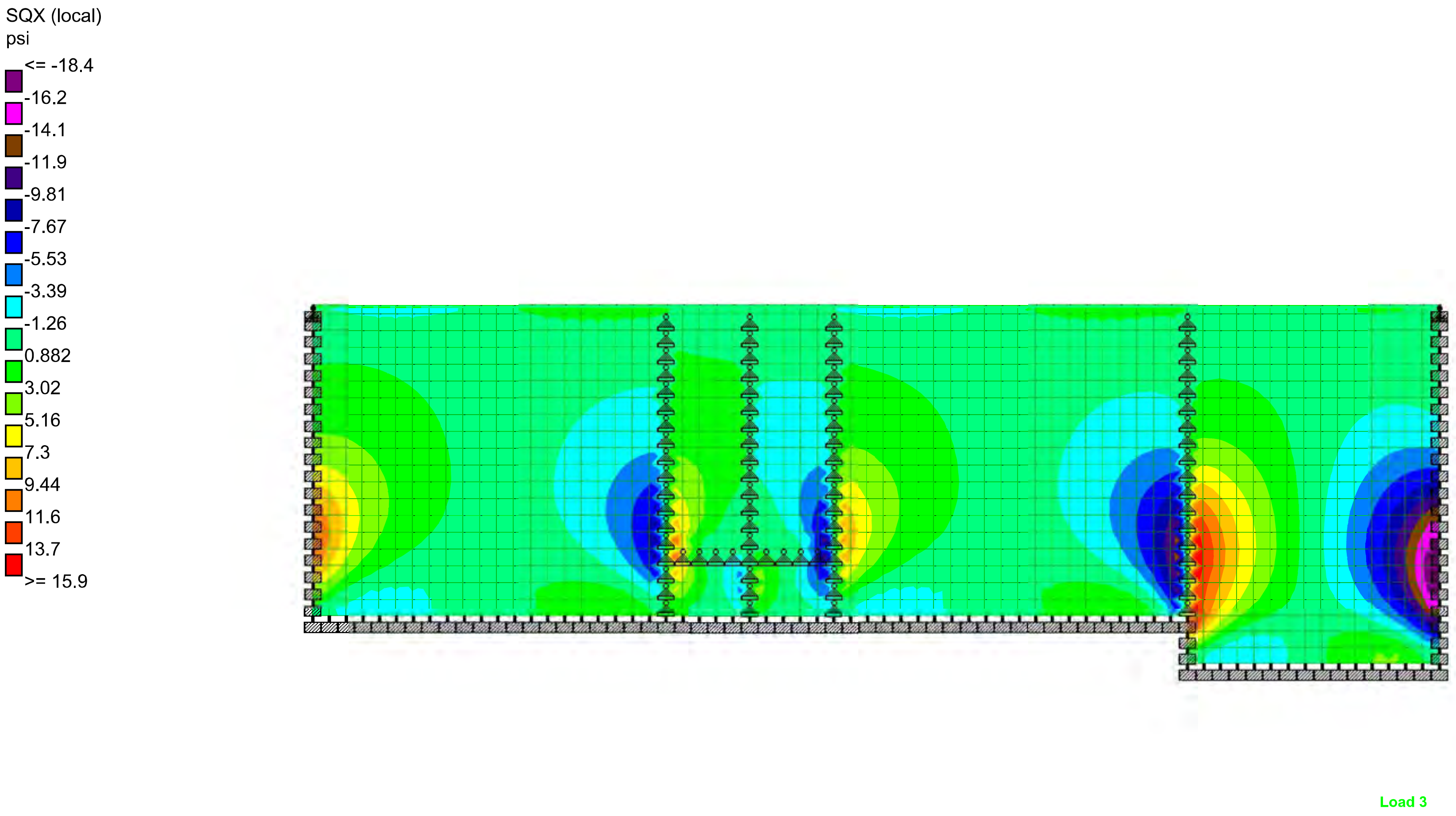
	Part Wall 1		
Job Title Area 6 - Filters	Ref		
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



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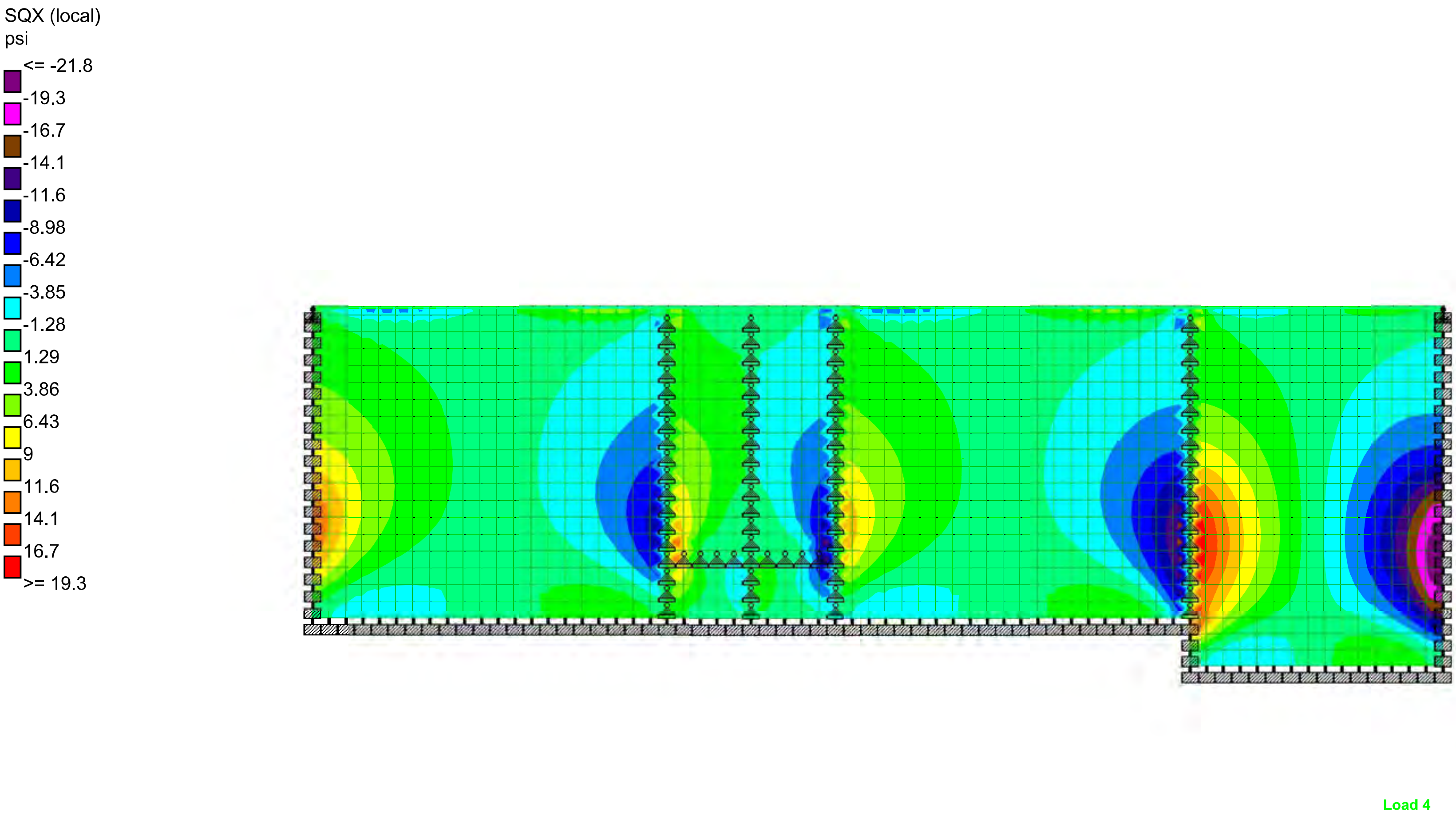
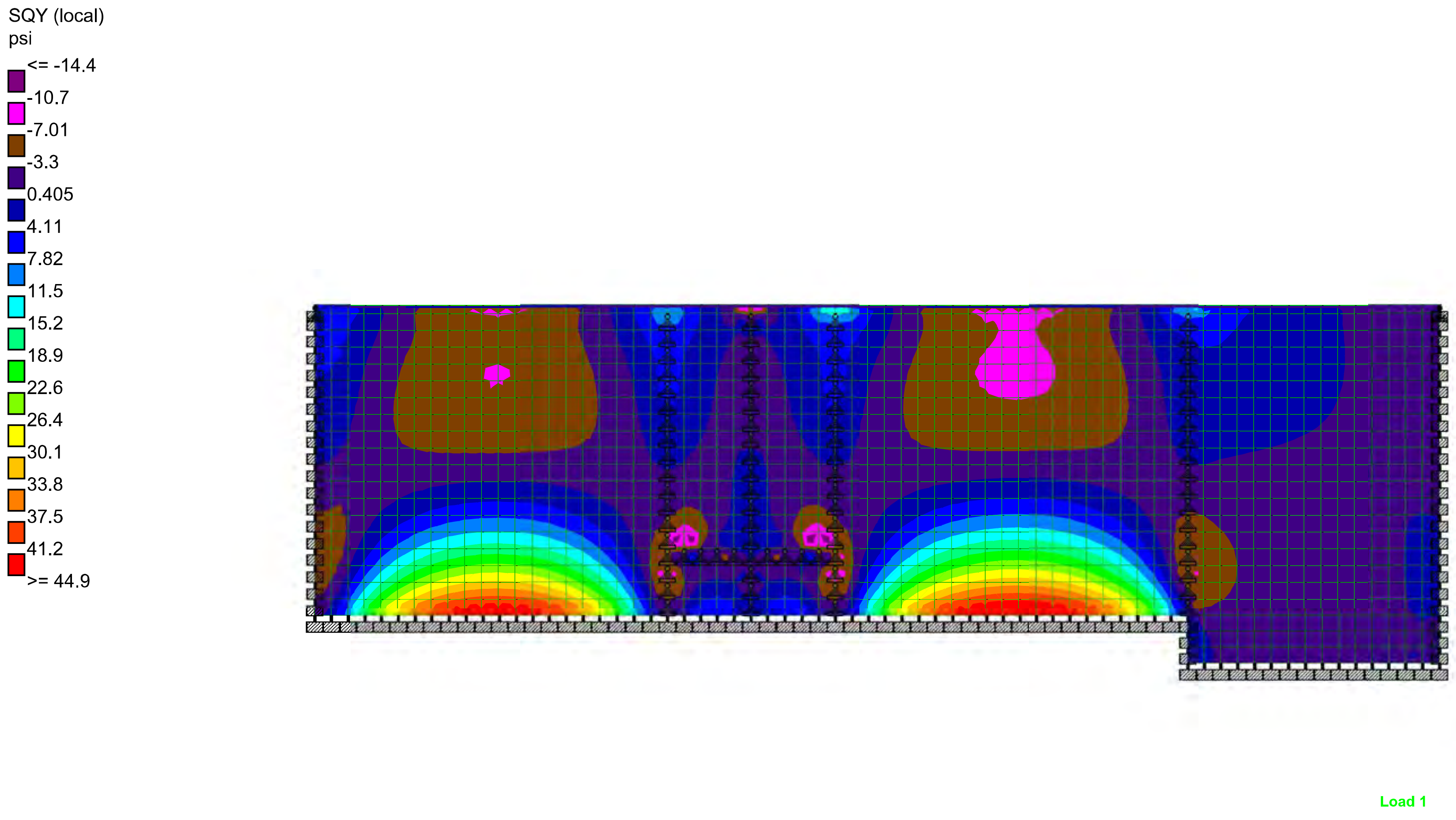
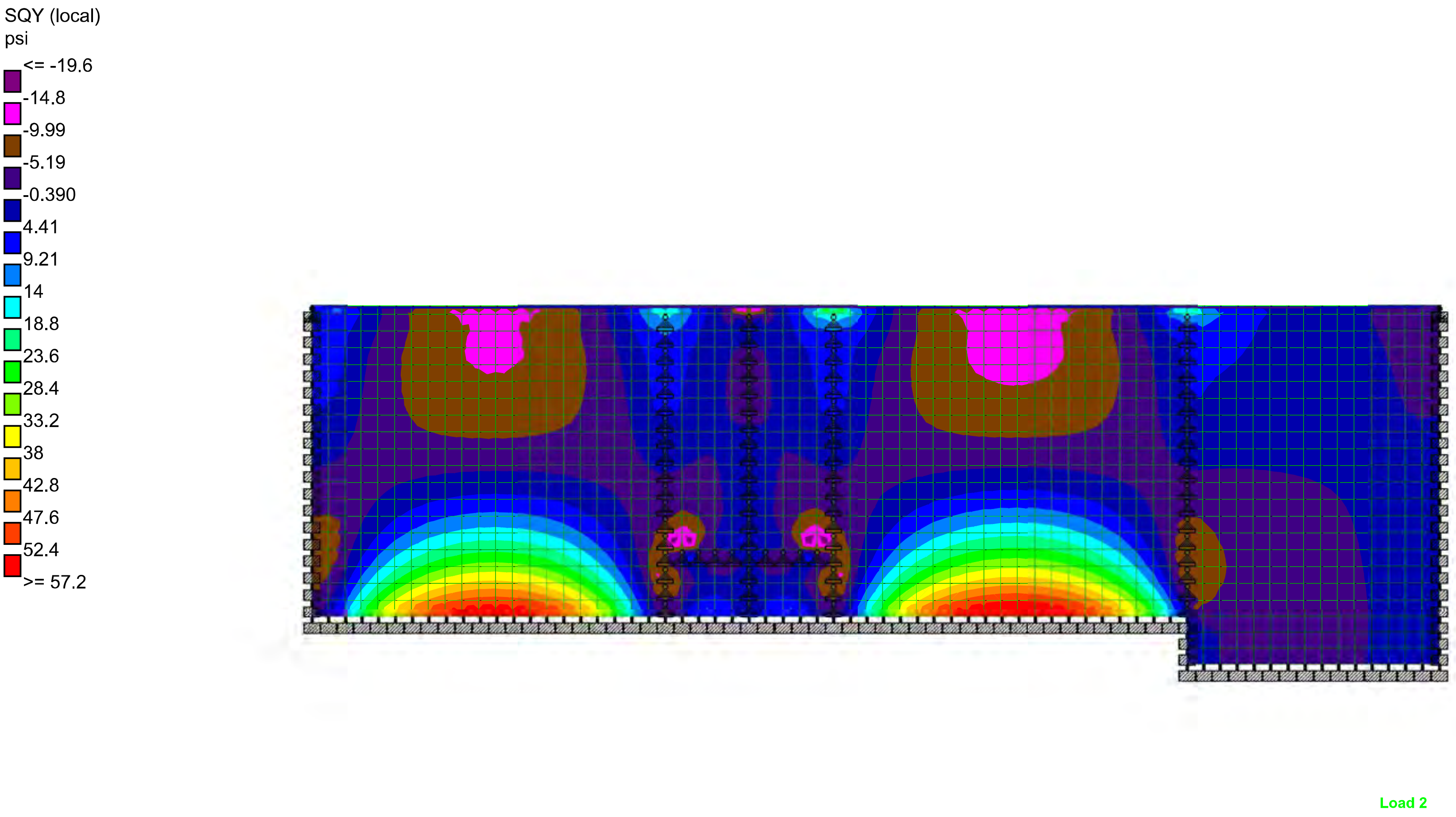
Job Title Area 6 - Filters Load Case: 1.6H+1.4E	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
Job Title Area 6 - Filters	Ref		
Load Case: 1.4F	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 1		
Job Title Area 6 - Filters	Ref		
Load Case: 1.2F+1.4E	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



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	Part Wall 1		
Job Title Area 6 - Filters	Ref		
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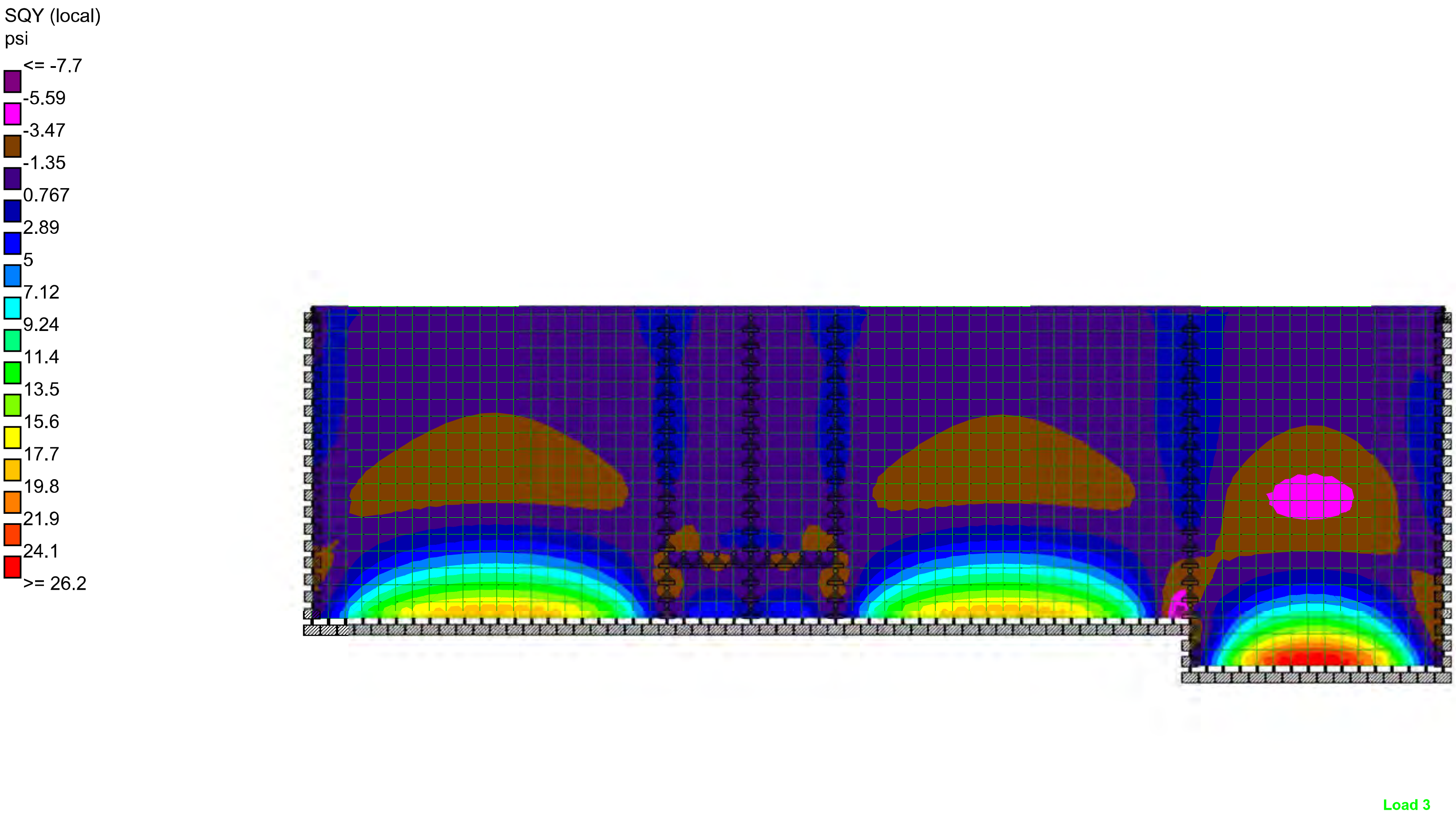
Client Willamette River WTP	File Wall 1.std	Date/Time 10-Aug-2017 13:44	



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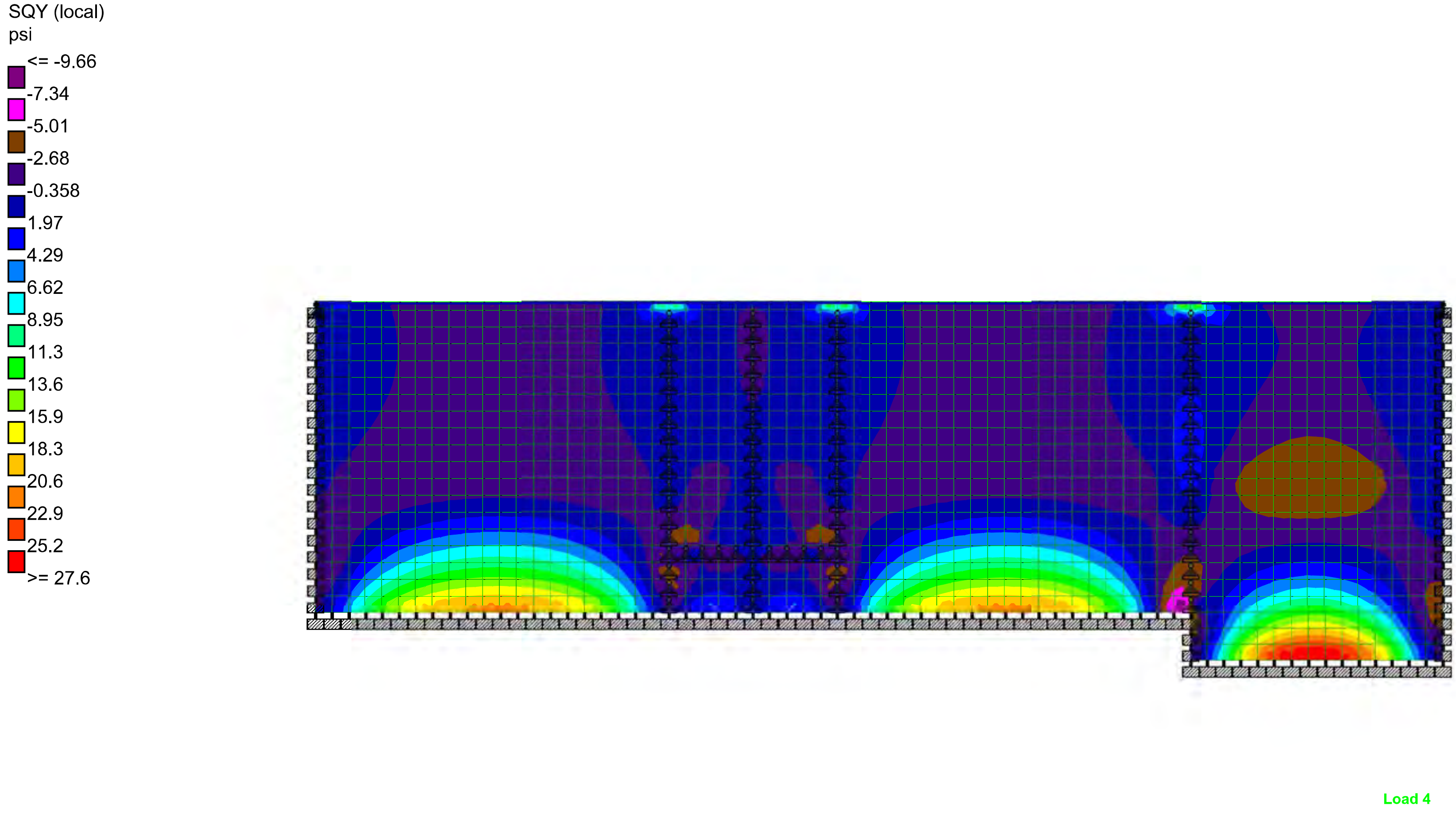
Job Title Area 6 - Filters Load Case: 1.6H+1.4E	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 1			
	Ref			
	By CC	Date 05-Aug-17		Chd
Client Willamette River WTP	File Wall 1.std		Date/Time 10-Aug-2017 13:44	



Area 6 - Filters
Wall 2 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	4.78	7.70	18.50	***0.42***	28	126	***0.22***	***<- OK***
1.2F+1.4E	1.00	5.99	5.99	18.50	***0.32***	35	126	***0.28***	***<- OK***

Vertical Span (Mid-Height) - Dry Side

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	4.94	7.95	14.50	***0.55***	0	126	***0.00***	***<- OK***
1.2F+1.4E	1.00	6.20	6.20	14.50	***0.43***	0	126	***0.00***	***<- OK***

Vertical Span (Bottom) - Wet Side

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	8.10	13.04	27.50	***0.47***	40	126	***0.31***	***<- OK***
1.2F+1.4E	1.00	10.00	10.00	27.50	***0.36***	49	126	***0.39***	***<- OK***

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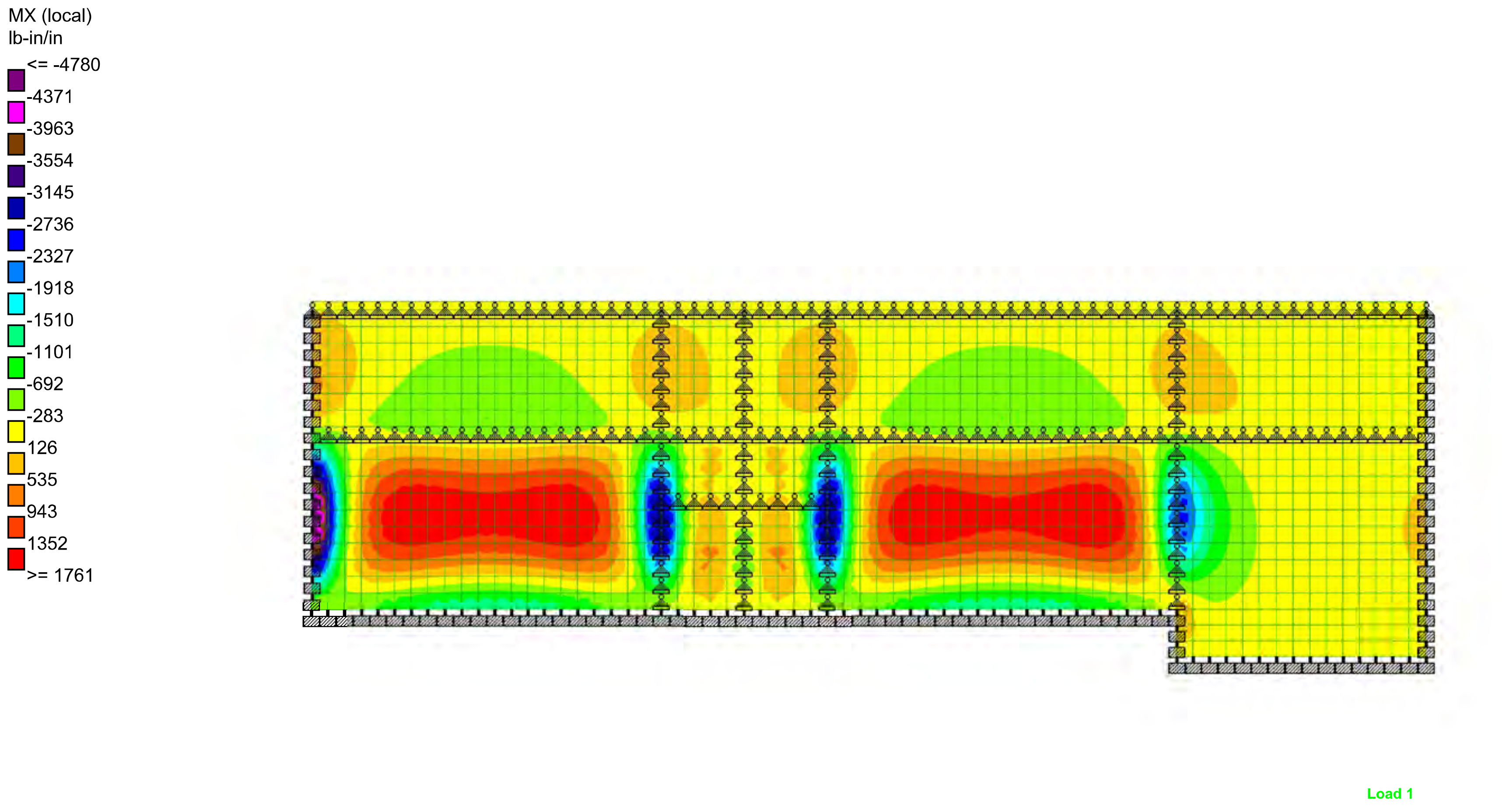
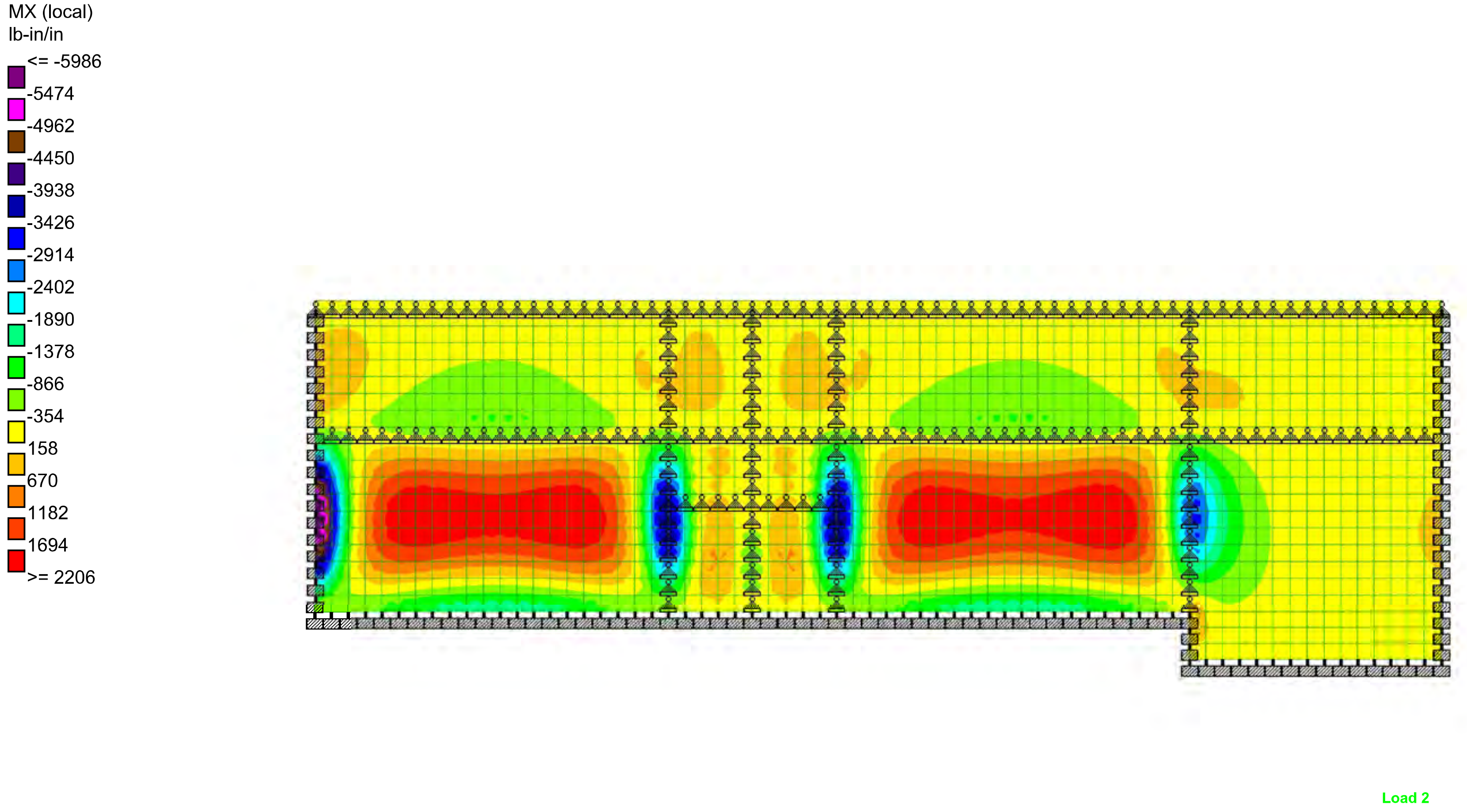
Job Title Area 6 - Filters Load Case: 1.4F	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 2			
	Ref			
	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31		



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 2		
Job Title Area 6 - Filters Load Case: 1.2F+1.4E	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31	



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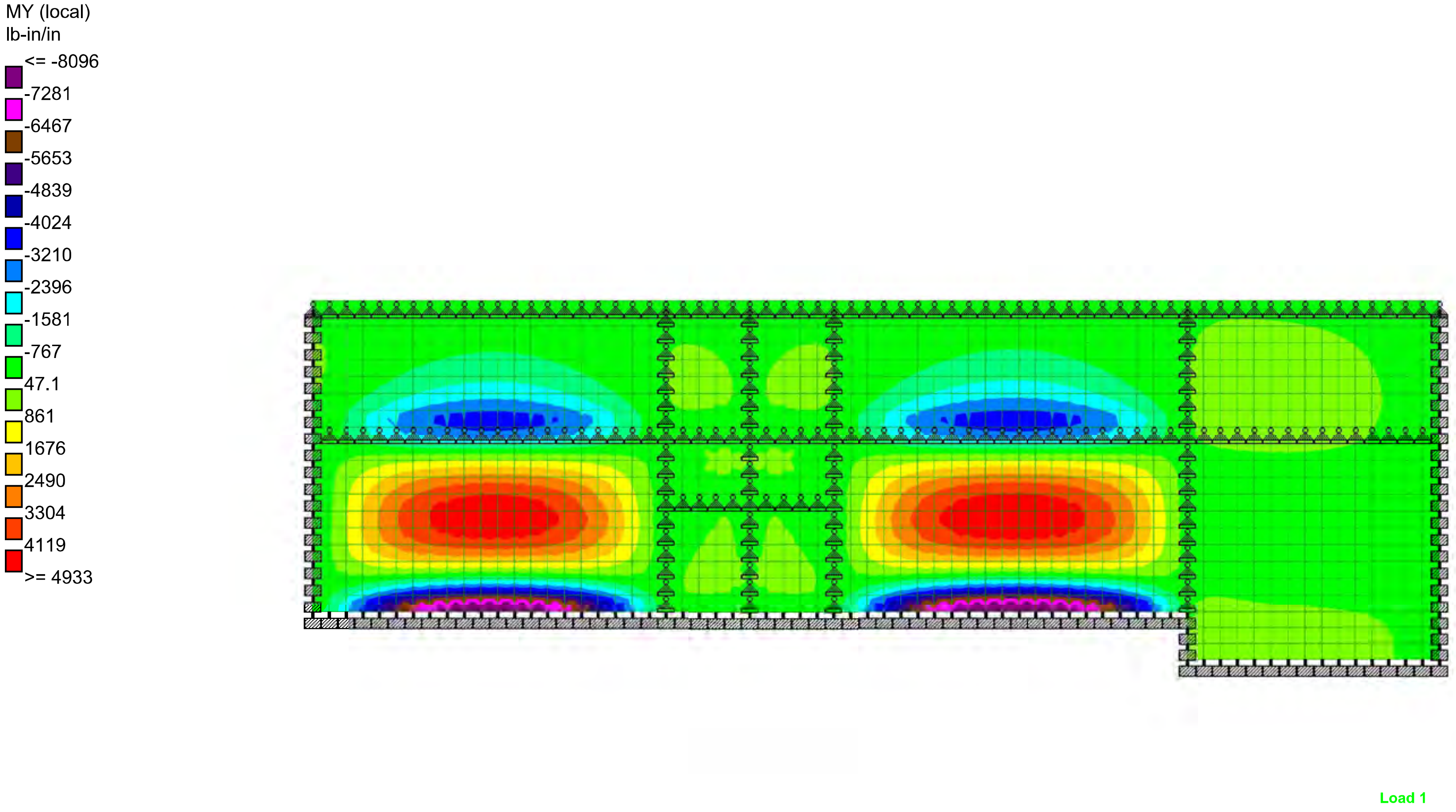
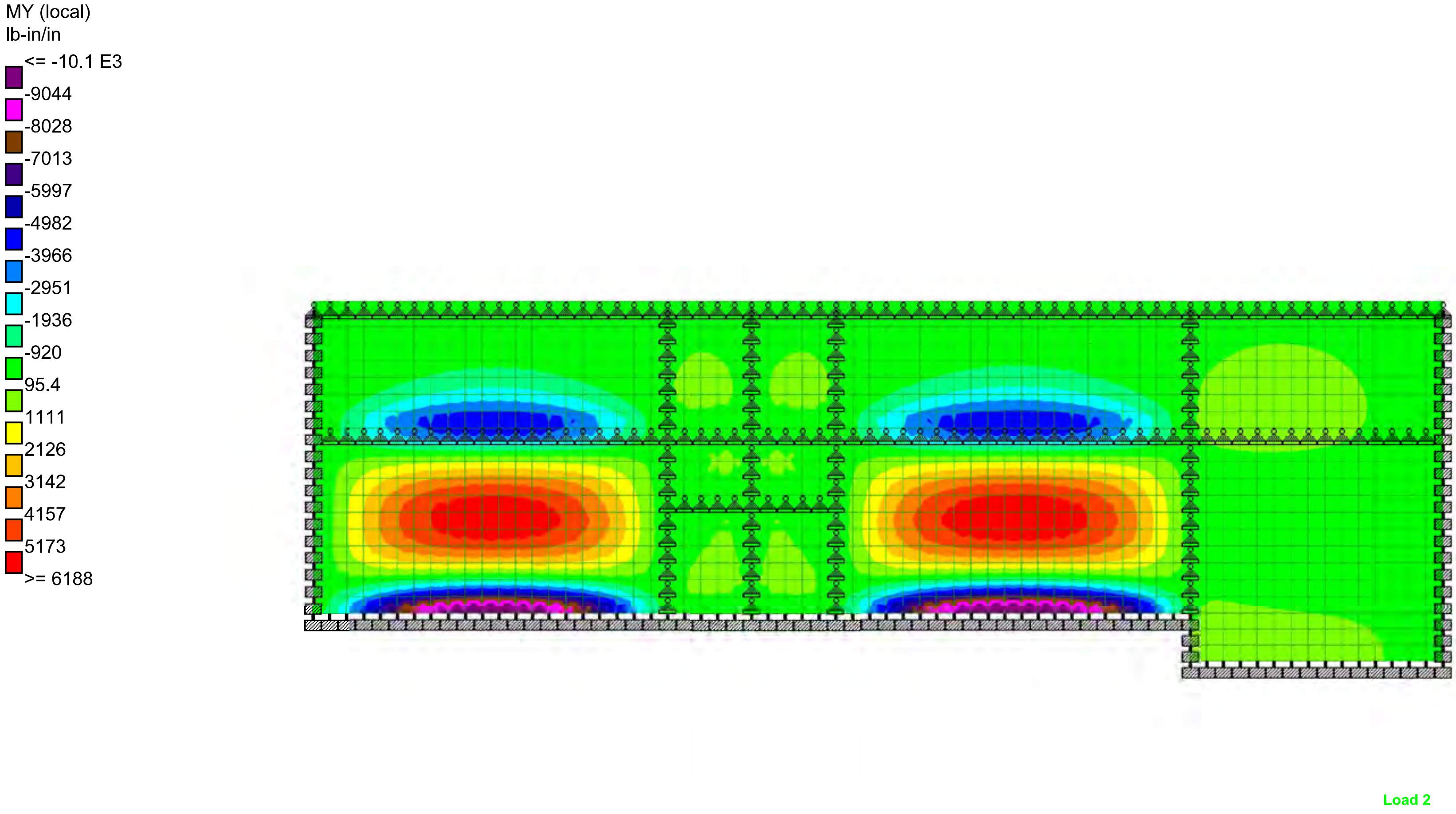
Job Title	Area 6 - Filters Load Case: 1.4F	Job No 10721A.10	Sheet No 1	Rev
		Part Wall 2		
		Ref		
		By CC	Date 05-Aug-17	Chd
Client	Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31	

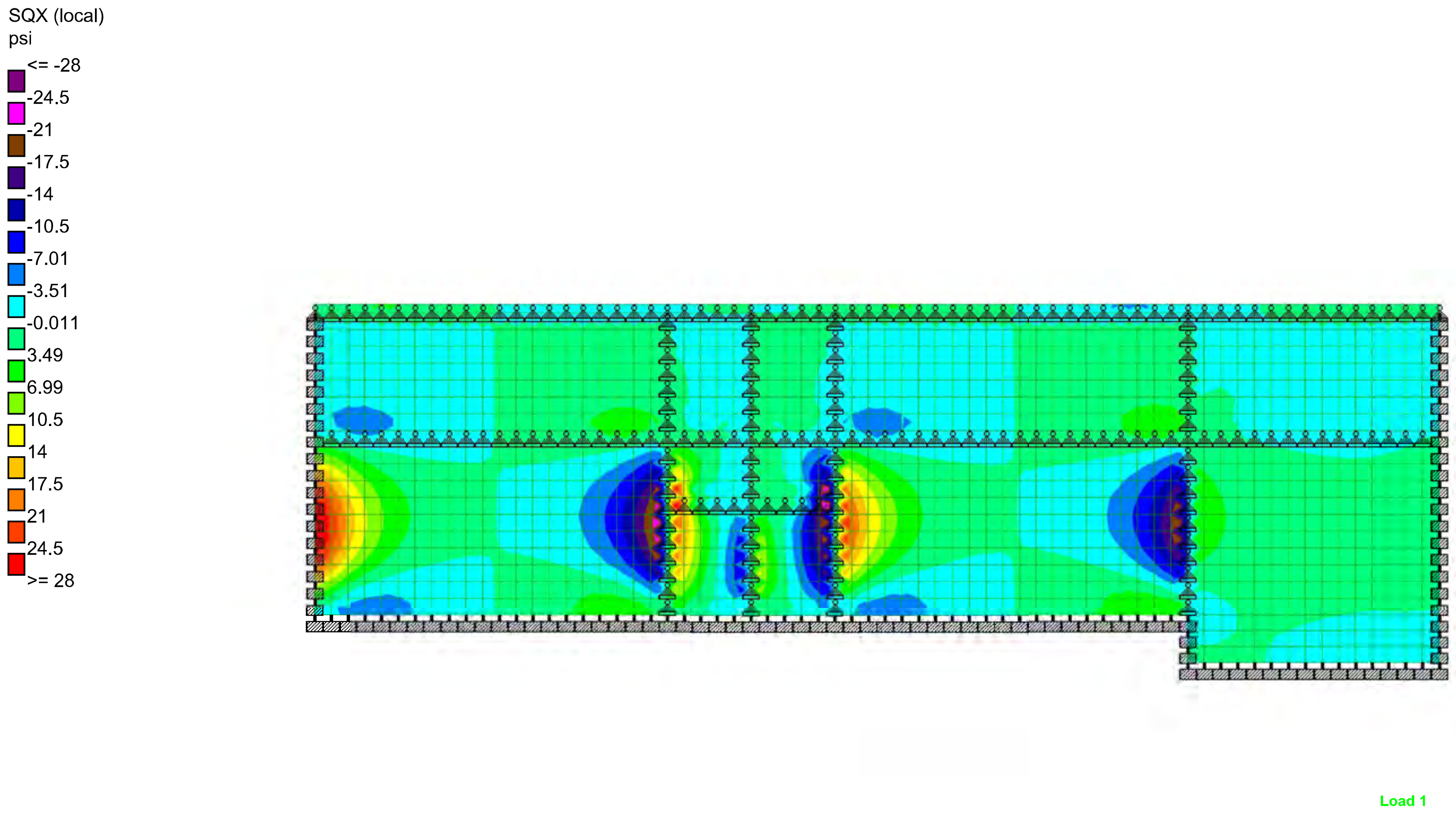


Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 2		
Job Title Area 6 - Filters	Ref		
Load Case: 1.2F+1.4E	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31	



Software licensed to Carollo Engineers

Job Title Area 6 - Filters **Load Case: 1.4F**	Job No **10721A.10**	Sheet No **1**		Rev
	Part Wall 2			
	Ref			
	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31		



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 2		
Job Title Area 6 - Filters	Ref		
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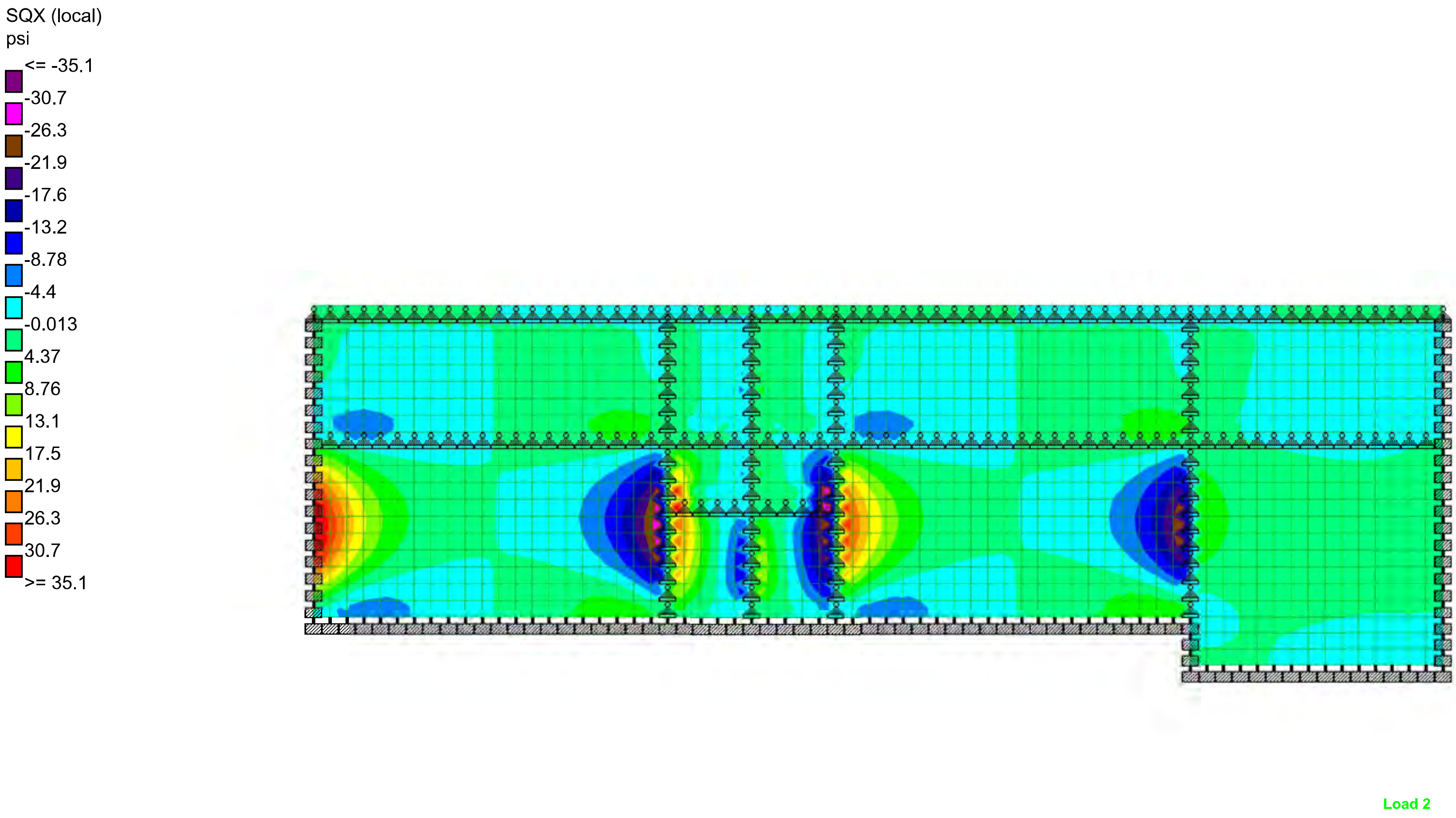
Client Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31	



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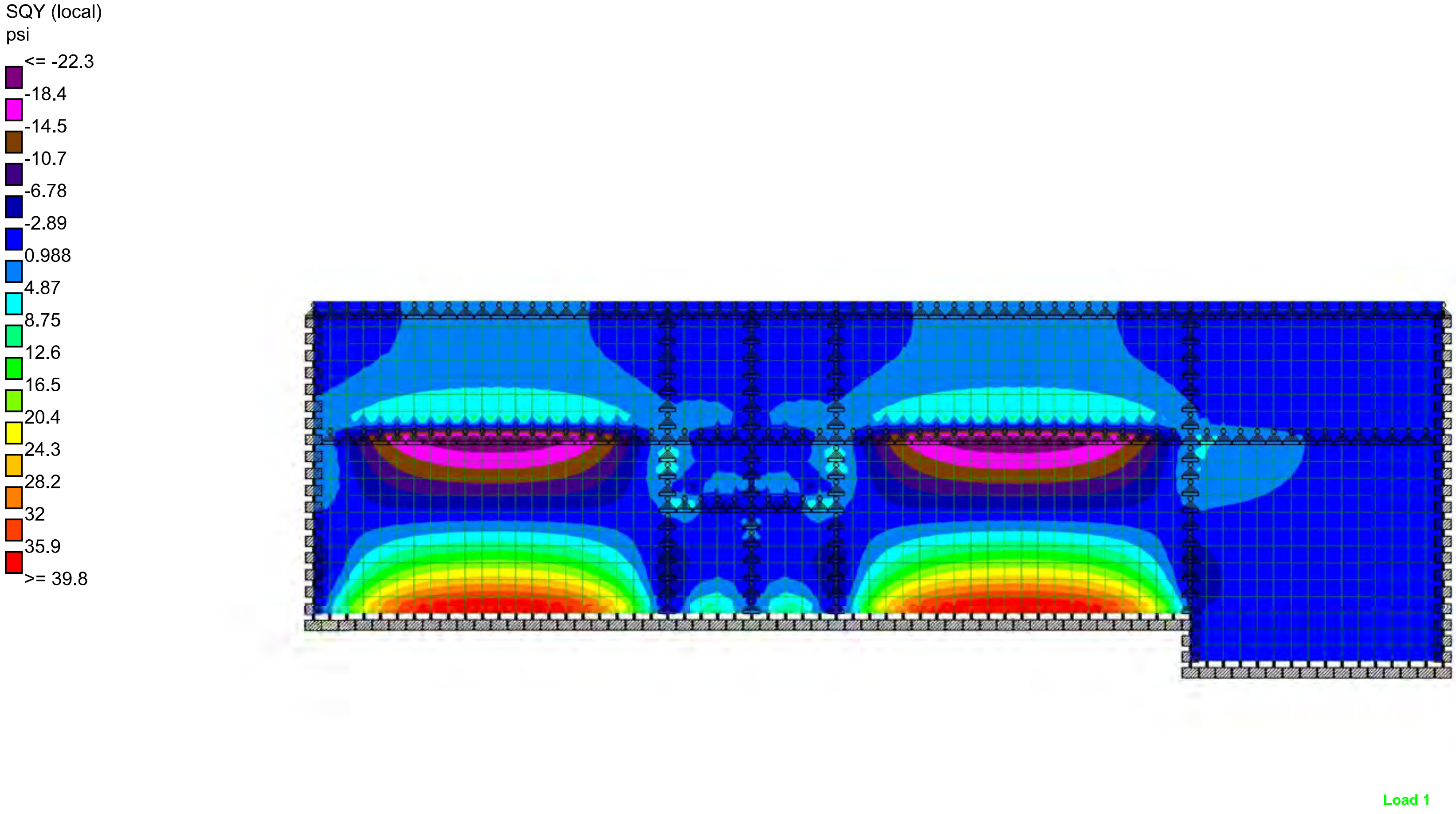
	Part Wall 2			
Job Title Area 6 - Filters	Ref			
Load Case: 1.4F	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31		



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 2		
Job Title Area 6 - Filters	Ref		
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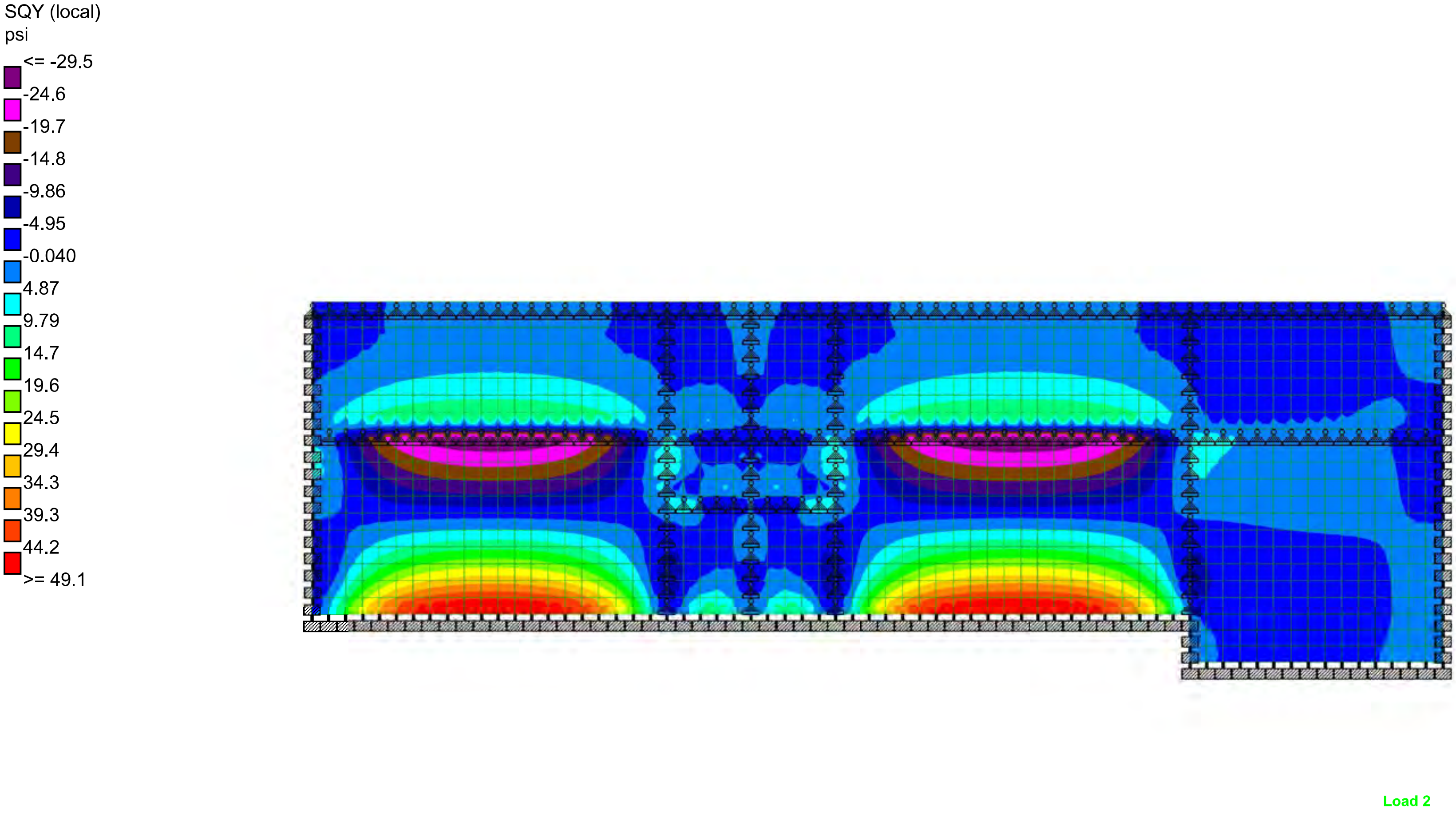
Client Willamette River WTP	File Wall 2.std	Date/Time 10-Aug-2017 14:31	



Area 6 - Filters
Wall 3 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	9.14	14.72	30.50	***0.48***	29	126	***0.23***	***<- OK***
1.2F+1.4E	1.00	12.50	12.50	30.50	***0.41***	38	126	***0.30***	***<- OK***
1.6(H+L)	1.41	2.40	3.38	30.50	***0.11***	10	126	***0.08***	***<- OK***
1.6H+1.4E	1.00	3.32	3.32	30.50	***0.11***	12	126	***0.10***	***<- OK***

Vertical Span

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	14.40	23.18	43.50	***0.53***	45	126	***0.35***	***<- OK***
1.2F+1.4E	1.00	19.00	19.00	43.50	***0.44***	57	126	***0.45***	***<- OK***
1.6(H+L)	1.41	5.00	7.05	43.50	***0.16***	20	126	***0.15***	***<- OK***
1.6H+1.4E	1.00	6.18	6.18	43.50	***0.14***	21	126	***0.17***	***<- OK***

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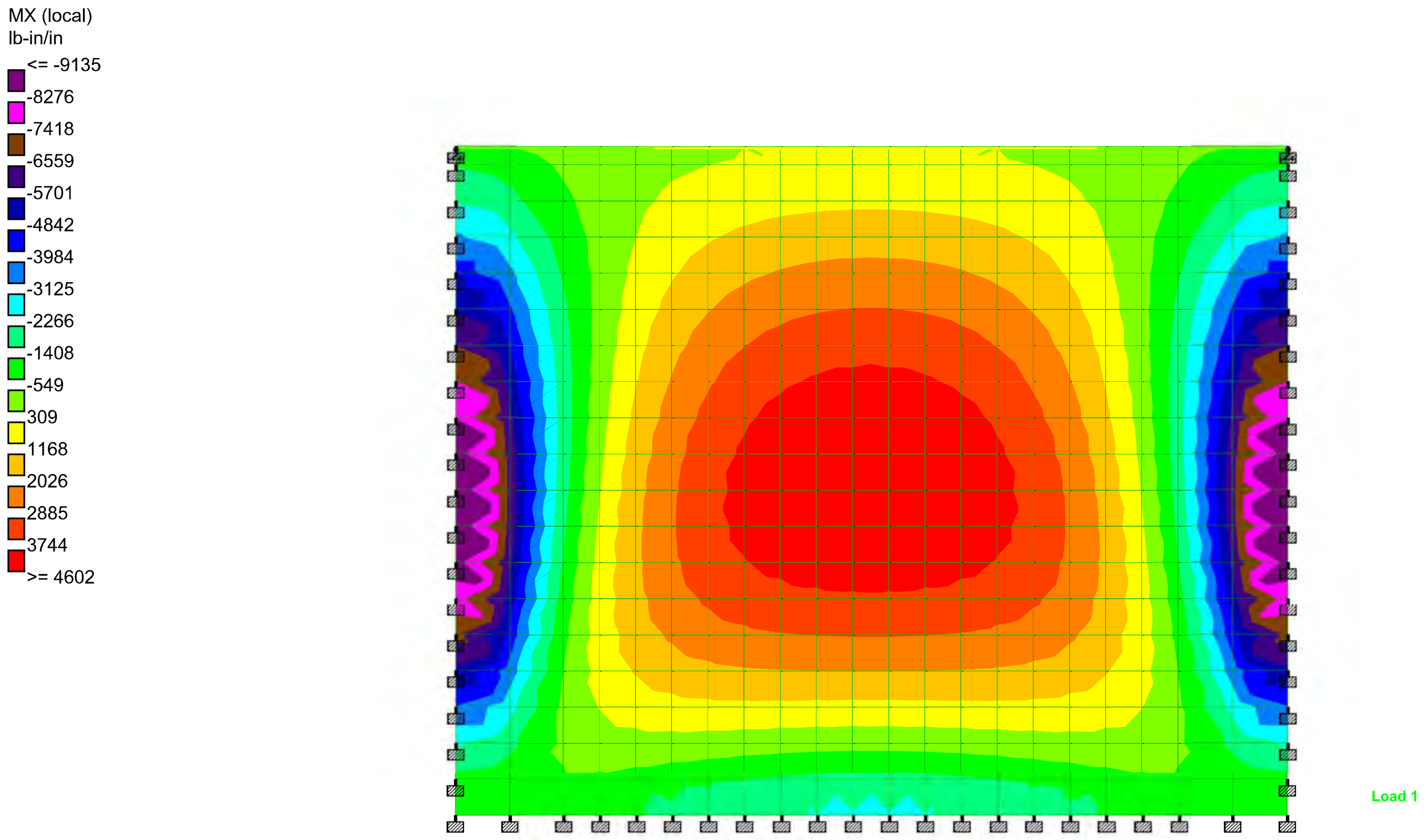
Job Title	Area 6 - Filters	Job No 10721A.10	Sheet No 1	Rev
		Part Wall 3		
		Ref		
	Load Case: 1.4F	By CC	Date 05-Aug-17	Chd
Client	Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



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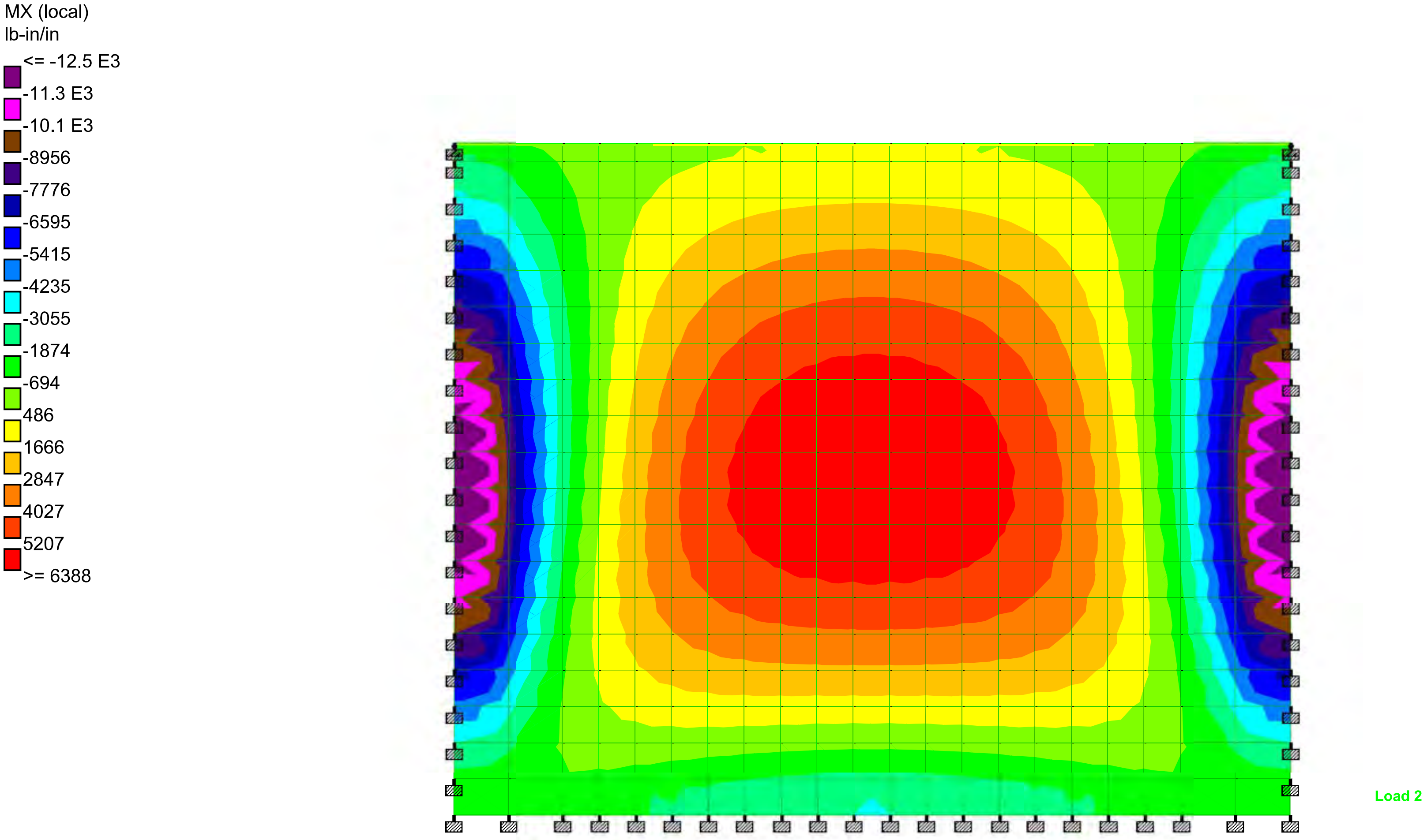
Job Title Area 6 - Filters Load Case: 1.2F+1.4E	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 3		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



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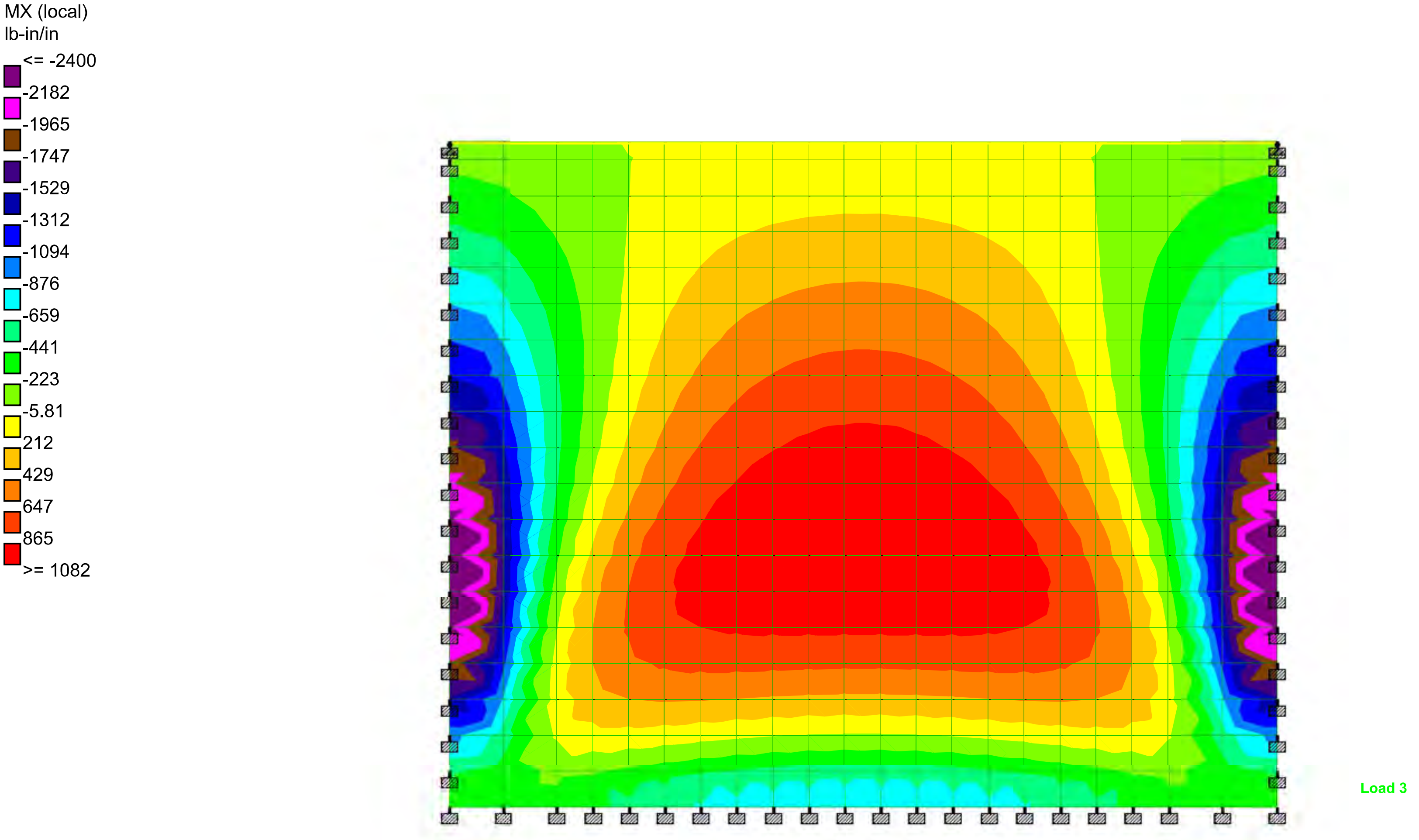
Job Title Area 6 - Filters	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 3			
	Ref			
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38		



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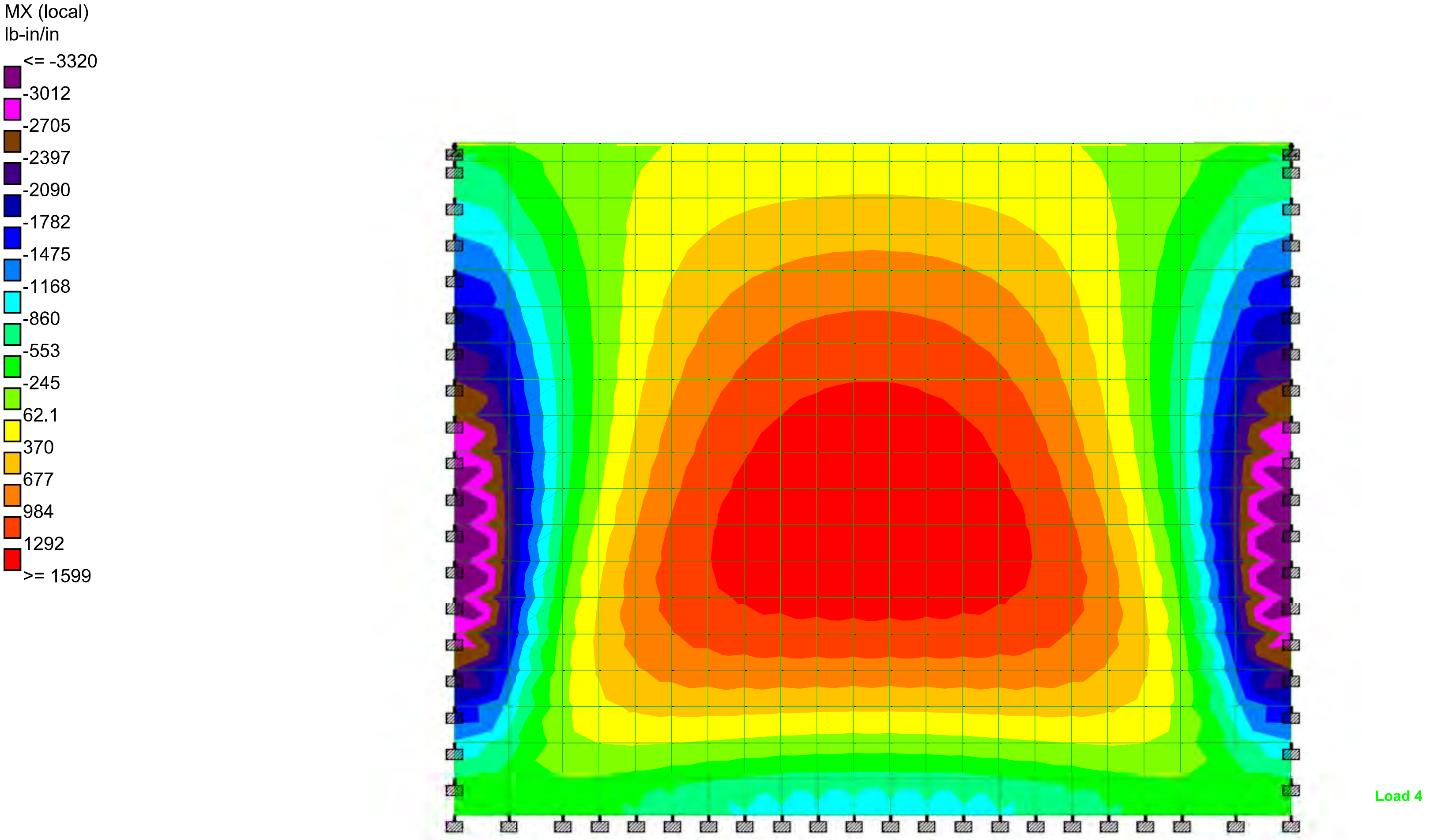
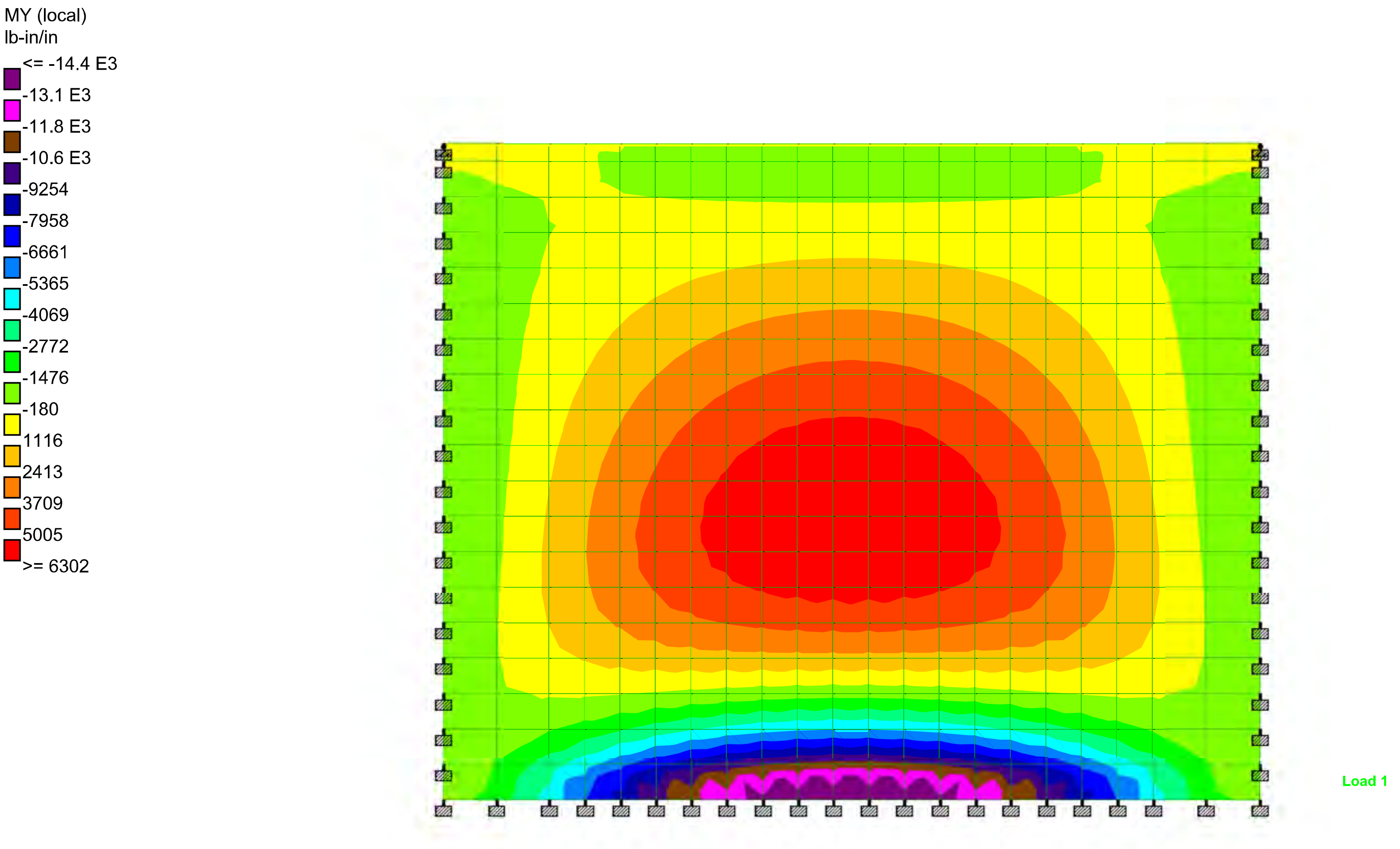
Job Title Area 6 - Filters	Job No **10721A.10**		Sheet No **1**	Rev
Load Case: 1.6H+1.4E	Part Wall 3			
	Ref			
	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 3.std		Date/Time 10-Aug-2017 15:38	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 3		
Job Title Area 6 - Filters Load Case: 1.4F	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



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Job Title Area 6 - Filters	Job No 10721A.10	Sheet No 1	Rev
Load Case: 1.2F+1.4E	Part Wall 3		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	

MY (local)
lb-in/in
<= -19 E3
🟪 -17.3 E3
🟪 -15.5 E3
🟫 -13.8 E3
🟪 -12.1 E3
🟦 -10.4 E3
🟦 -8705
🟦 -6995
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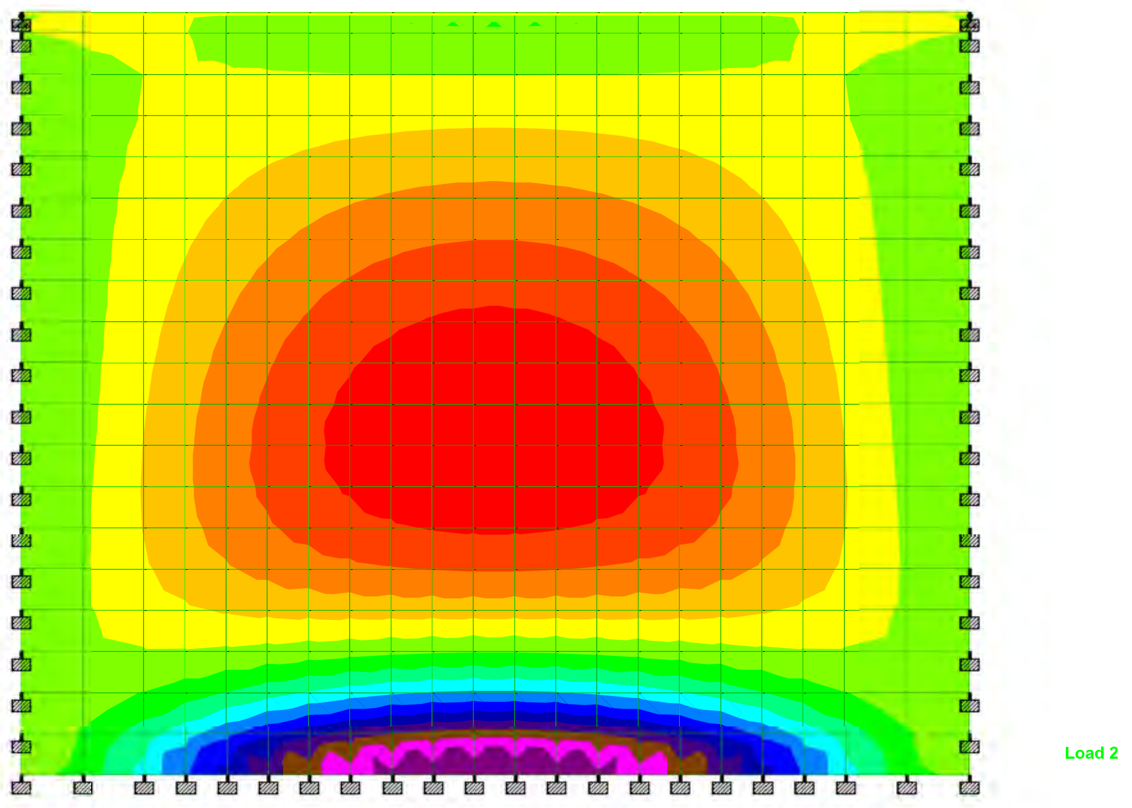
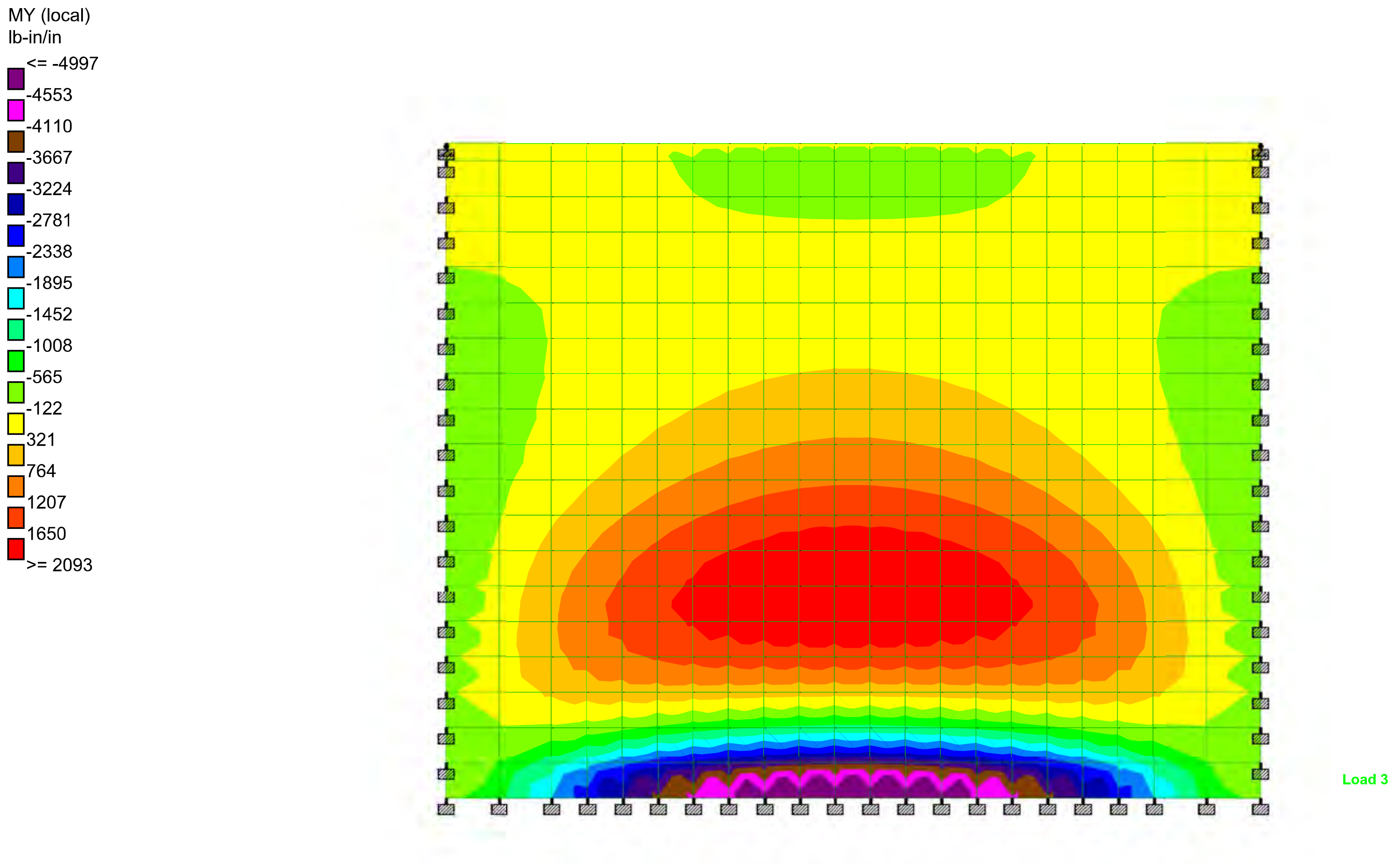


Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 3		
Job Title Area 6 - Filters	Ref		
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



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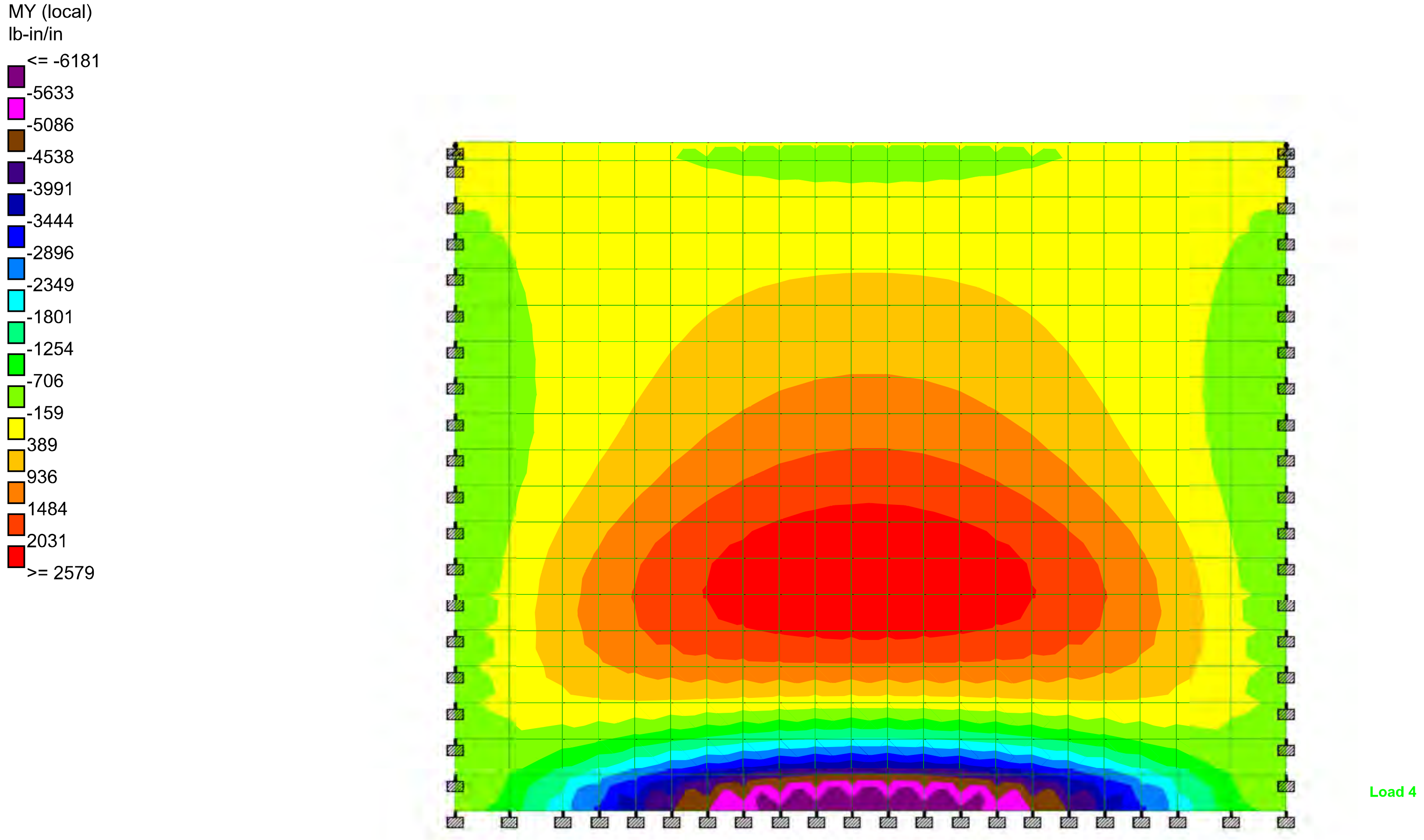
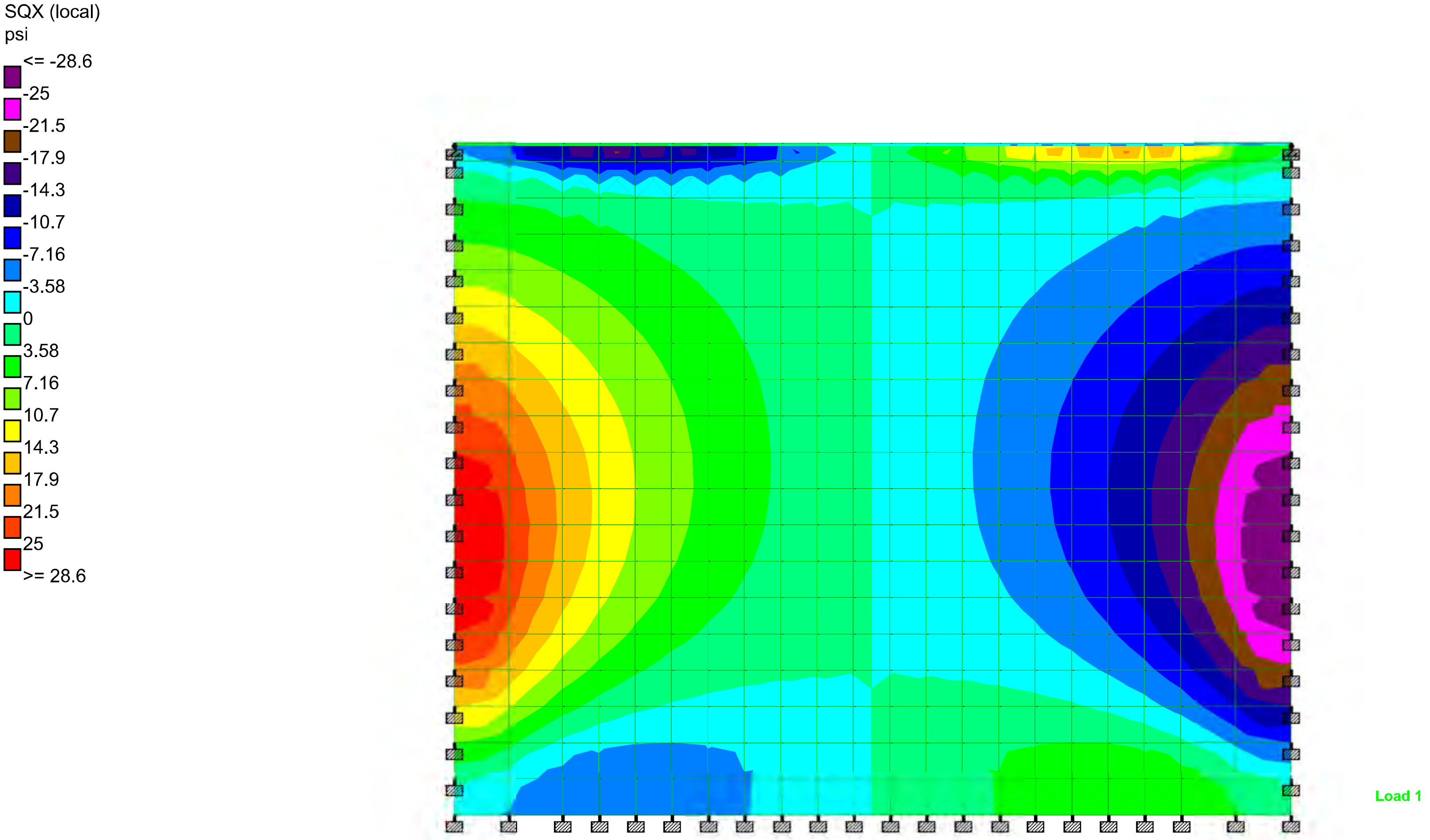
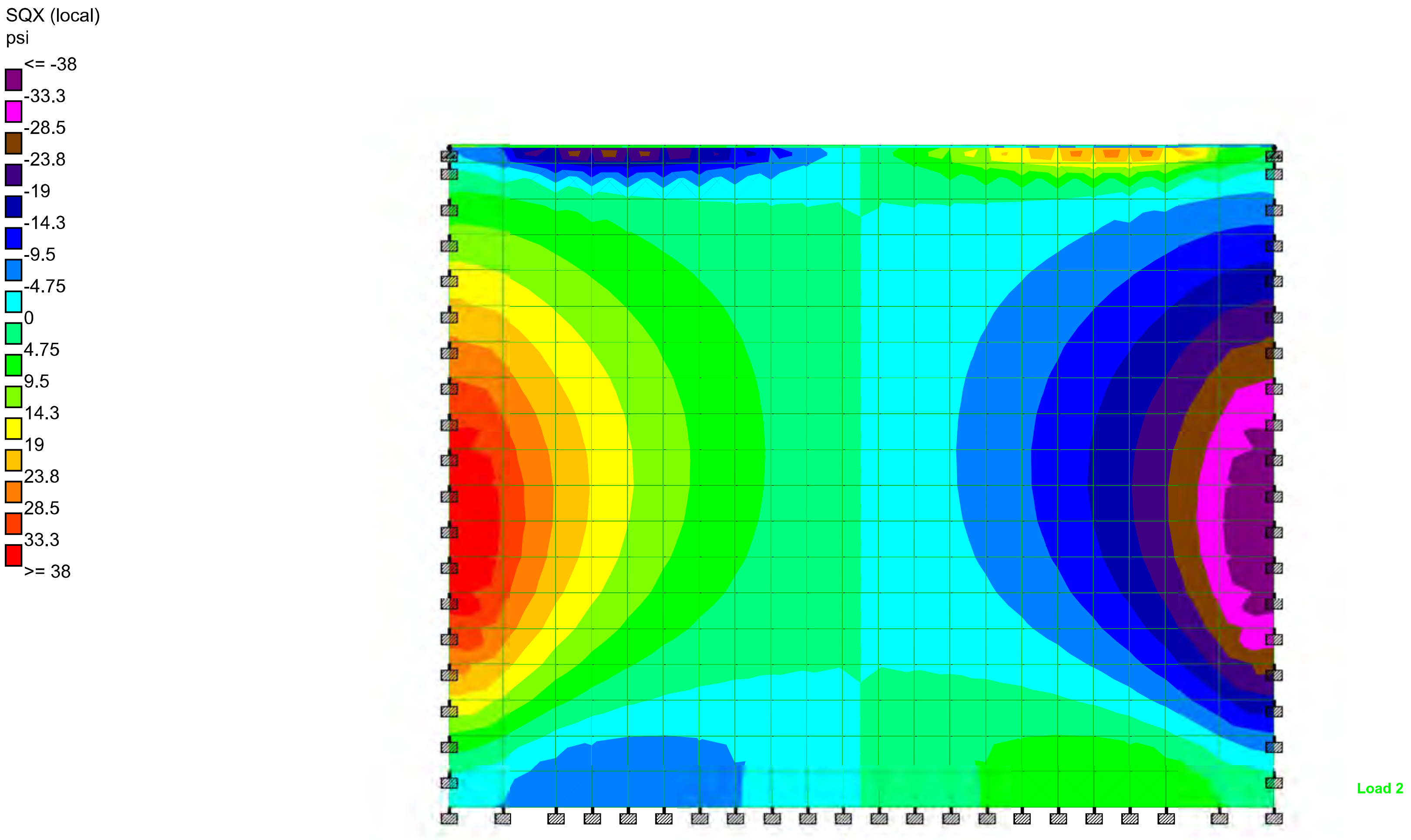
Job Title	Area 6 - Filters	Job No 10721A.10	Sheet No 1	Rev
		Part Wall 3		
	Load Case: 1.6H+1.4E	Ref		
		By CC	Date 05-Aug-17	Chd
Client	Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



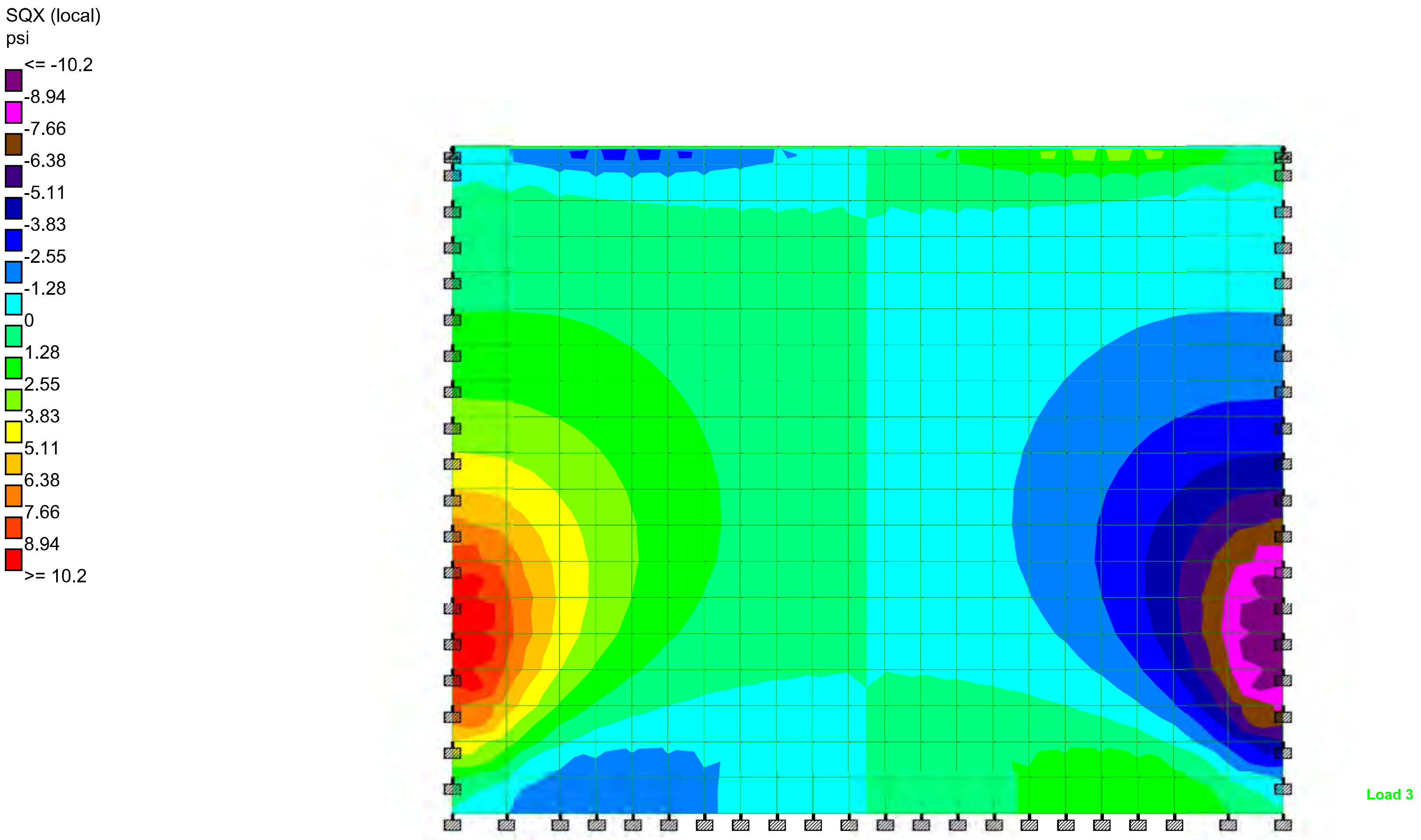
Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
Job Title Area 6 - Filters Load Case: 1.4F	Part Wall 3		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 3			
Job Title Area 6 - Filters	Ref			
Load Case: 1.2F+1.4E	By CC	Date 05-Aug-17		Chd
Client Willamette River WTP	File Wall 3.std		Date/Time 10-Aug-2017 15:38	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
Job Title Area 6 - Filters	Part Wall 3		
	Ref		
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



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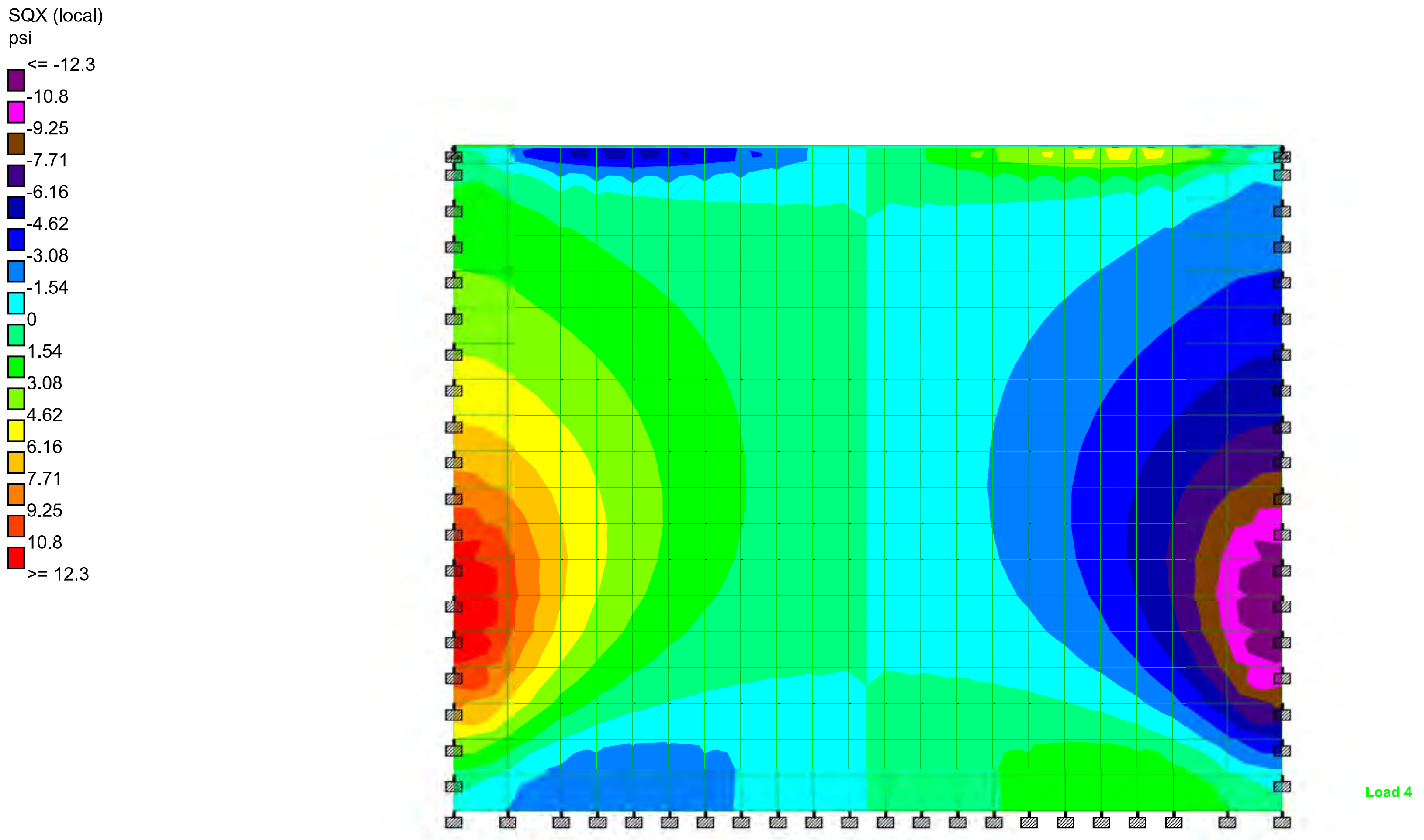
Job Title Area 6 - Filters	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 3		
	Ref		
Load Case: 1.6H+1.4E	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



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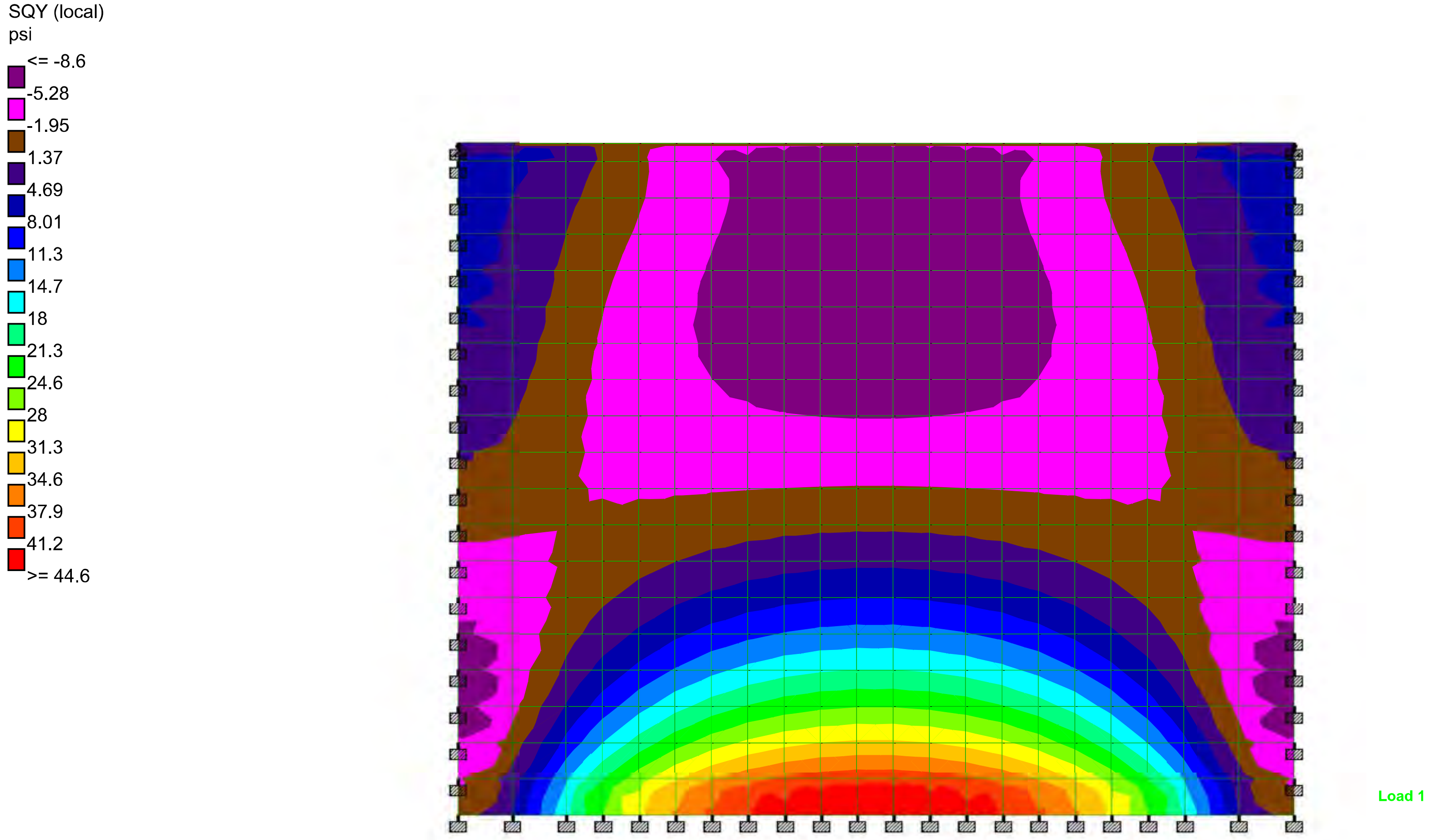
Job Title	Area 6 - Filters Load Case: 1.4F	Job No 10721A.10	Sheet No 1	Rev
		Part Wall 3		
		Ref		
		By CC	Date 05-Aug-17	Chd
Client	Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



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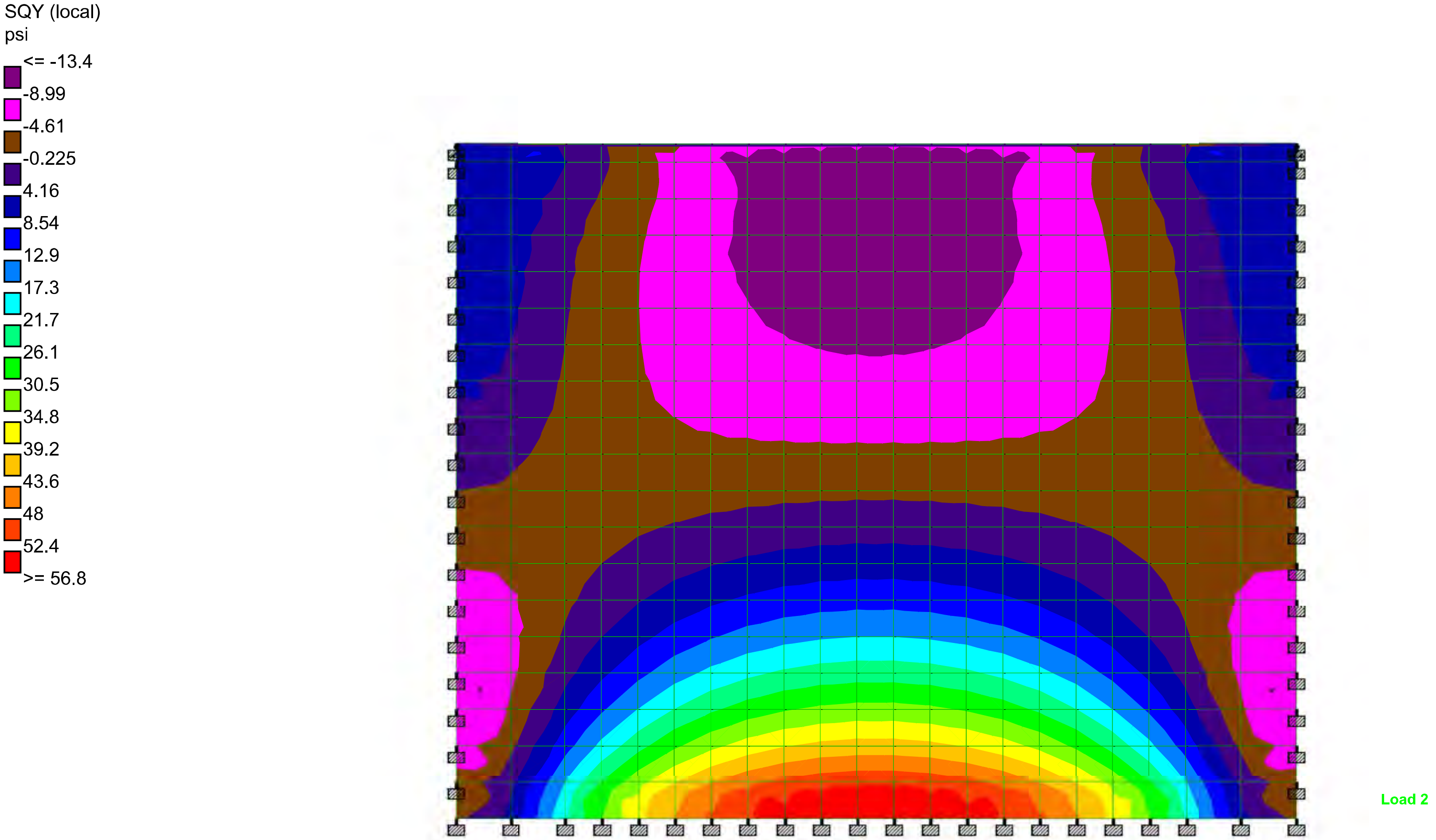
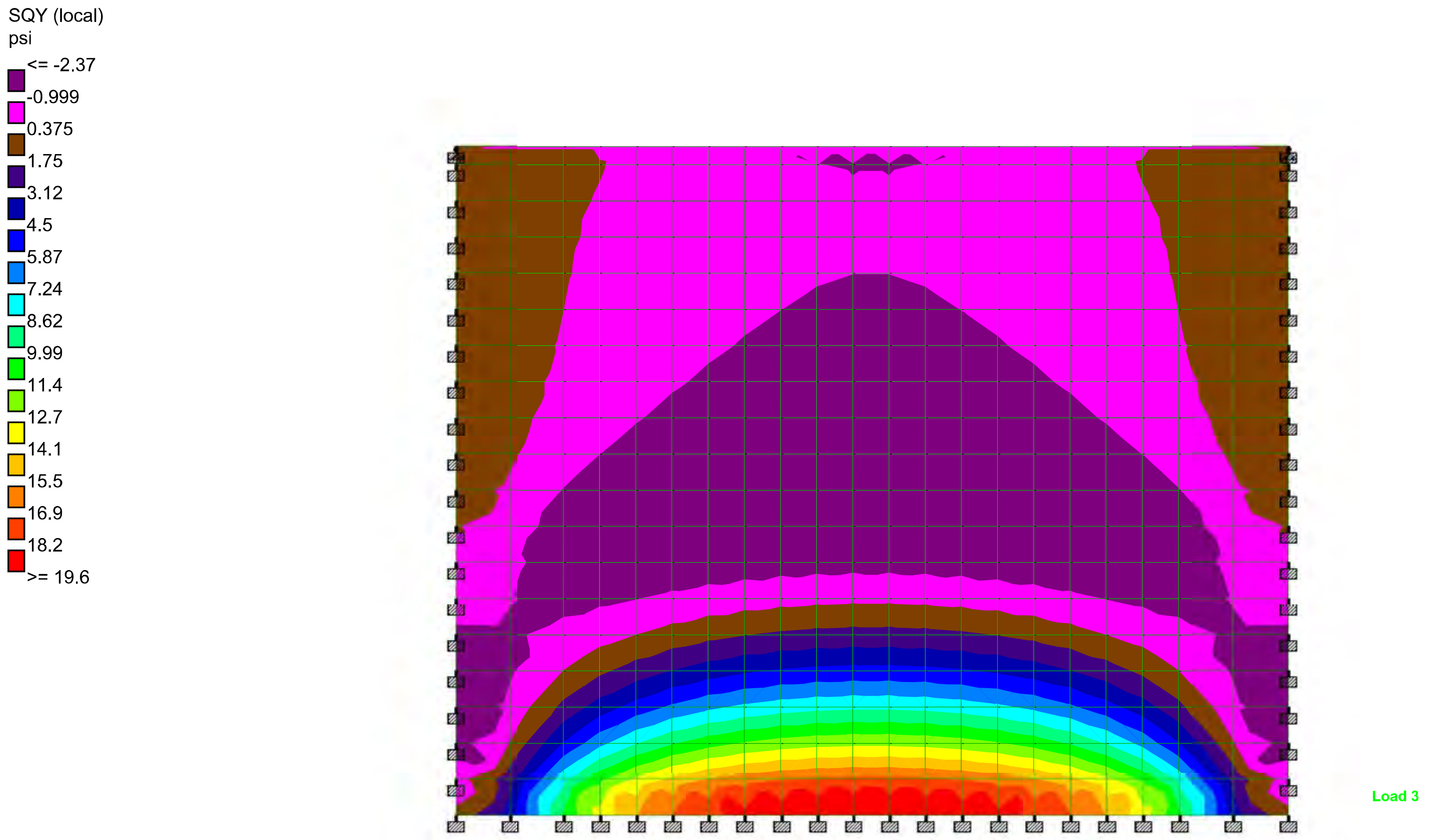
Job No 10721A.10	Sheet No 1		Rev
Job Title Area 6 - Filters	Part Wall 3		
Load Case: 1.2F+1.4E	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 3.std	Date/Time 10-Aug-2017 15:38	



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**		Rev
	Part Wall 3			
Job Title Area 6 - Filters	Ref			
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17		Chd
Client Willamette River WTP	File Wall 3.std		Date/Time 10-Aug-2017 15:38	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 3		
Job Title Area 6 - Filters	Ref		
Load Case: 1.6H+1.4E	By CC	Date 05-Aug-17	Chd
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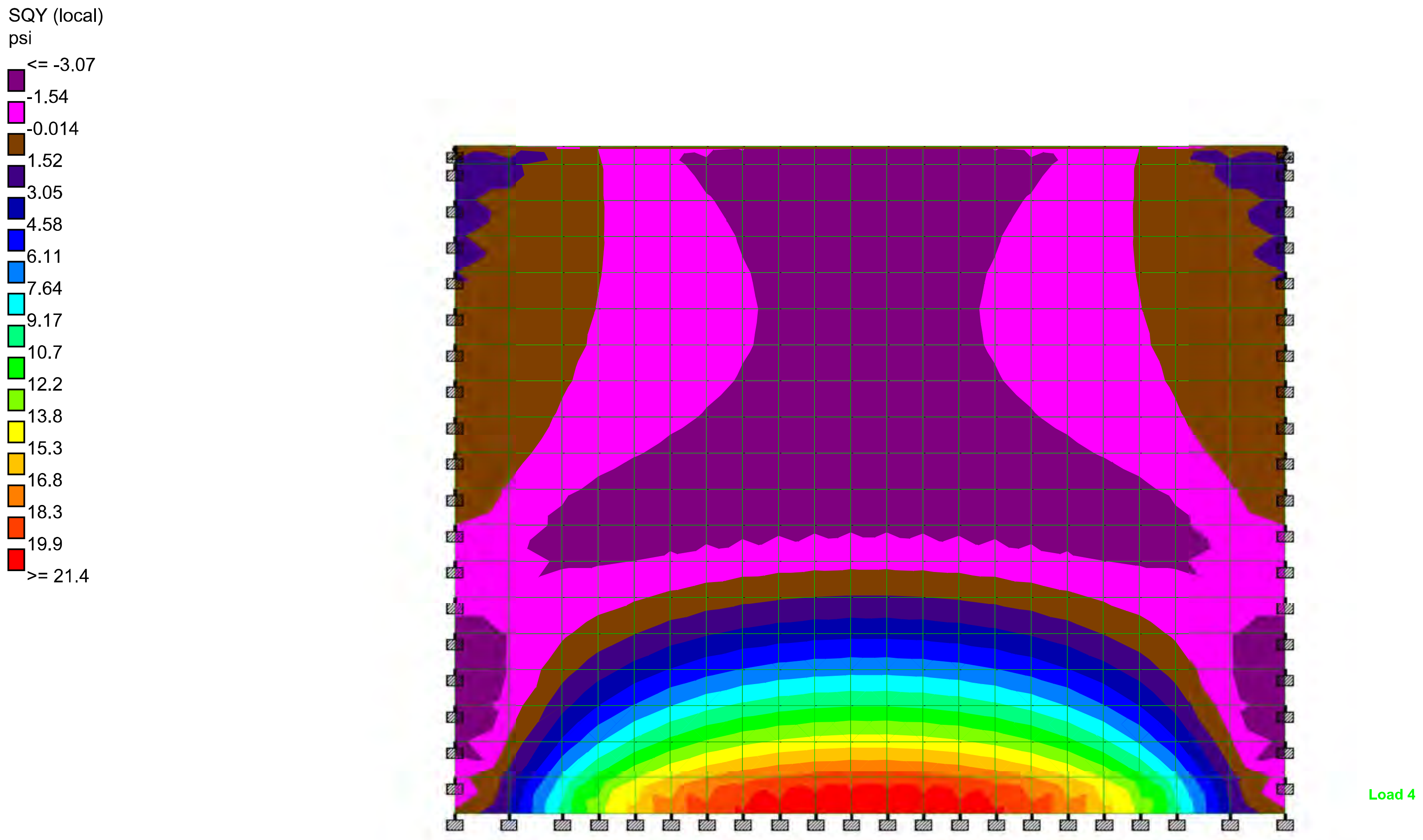

Area 6 - Filters
Wall 4 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	9.30	14.97	16.00	***0.94***	29	126	***0.23***	***<- OK***
1.2F+1.4E	1.00	12.80	12.80	16.00	***0.80***	38	126	***0.30***	***<- OK***

Vertical Span (Mid-Height)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	6.40	10.30	17.50	***0.59***	0	126	***0.00***	***<- OK***
1.2F+1.4E	1.00	8.56	8.56	17.50	***0.49***	0	126	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	14.60	23.51	43.00	***0.55***	45	126	***0.35***	***<- OK***
1.2F+1.4E	1.00	19.20	19.20	43.00	***0.45***	57	126	***0.45***	***<- OK***

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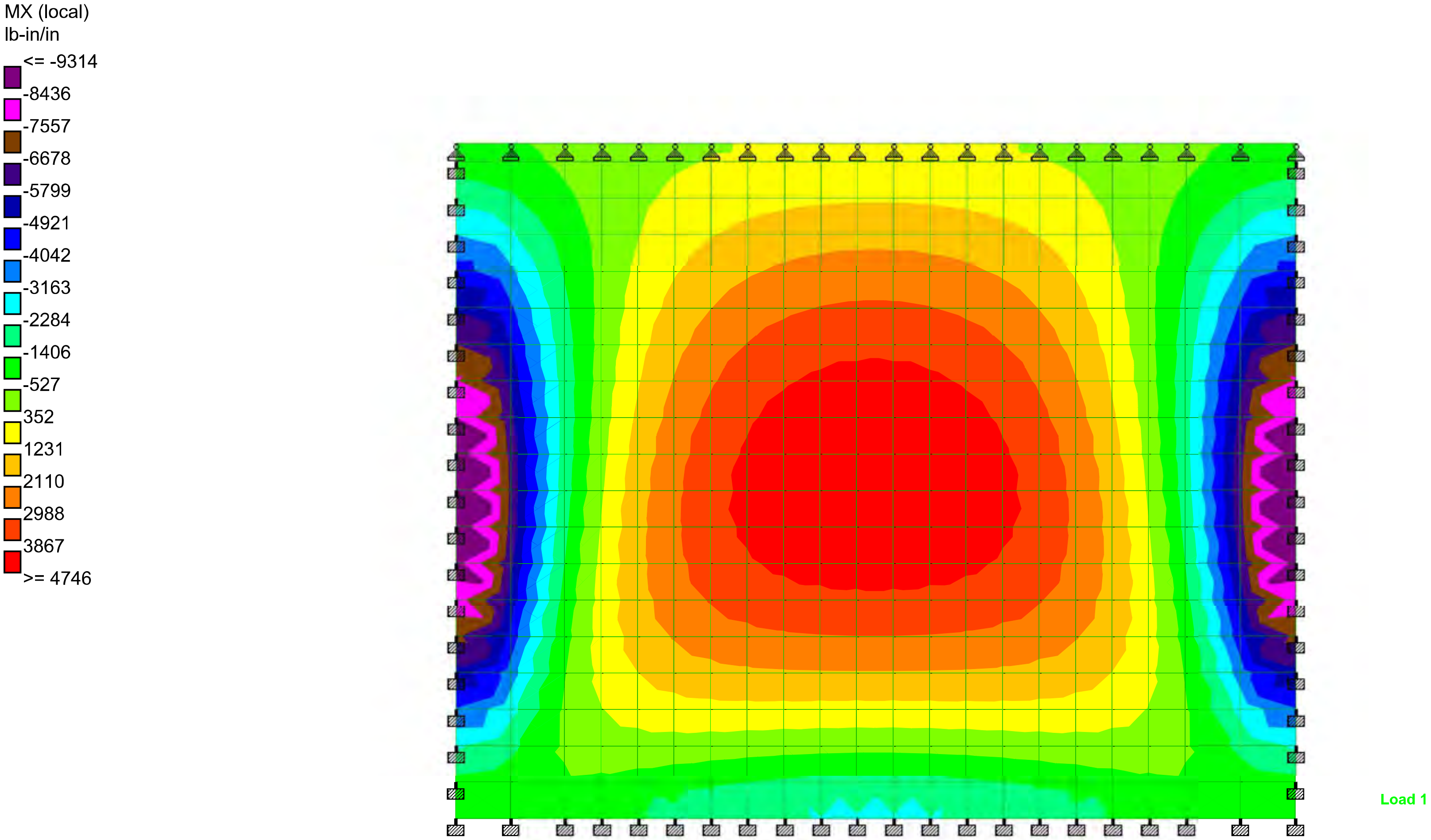
Job Title	Area 6 - Filters Load Case: 1.4F	Job No 10721A.10	Sheet No 1	Rev
		Part Wall 4		
		Ref		
		By CC	Date 05-Aug-17	Chd
Client	Willametter River WTP	File Wall 4.std	Date/Time 11-Aug-2017 10:43	



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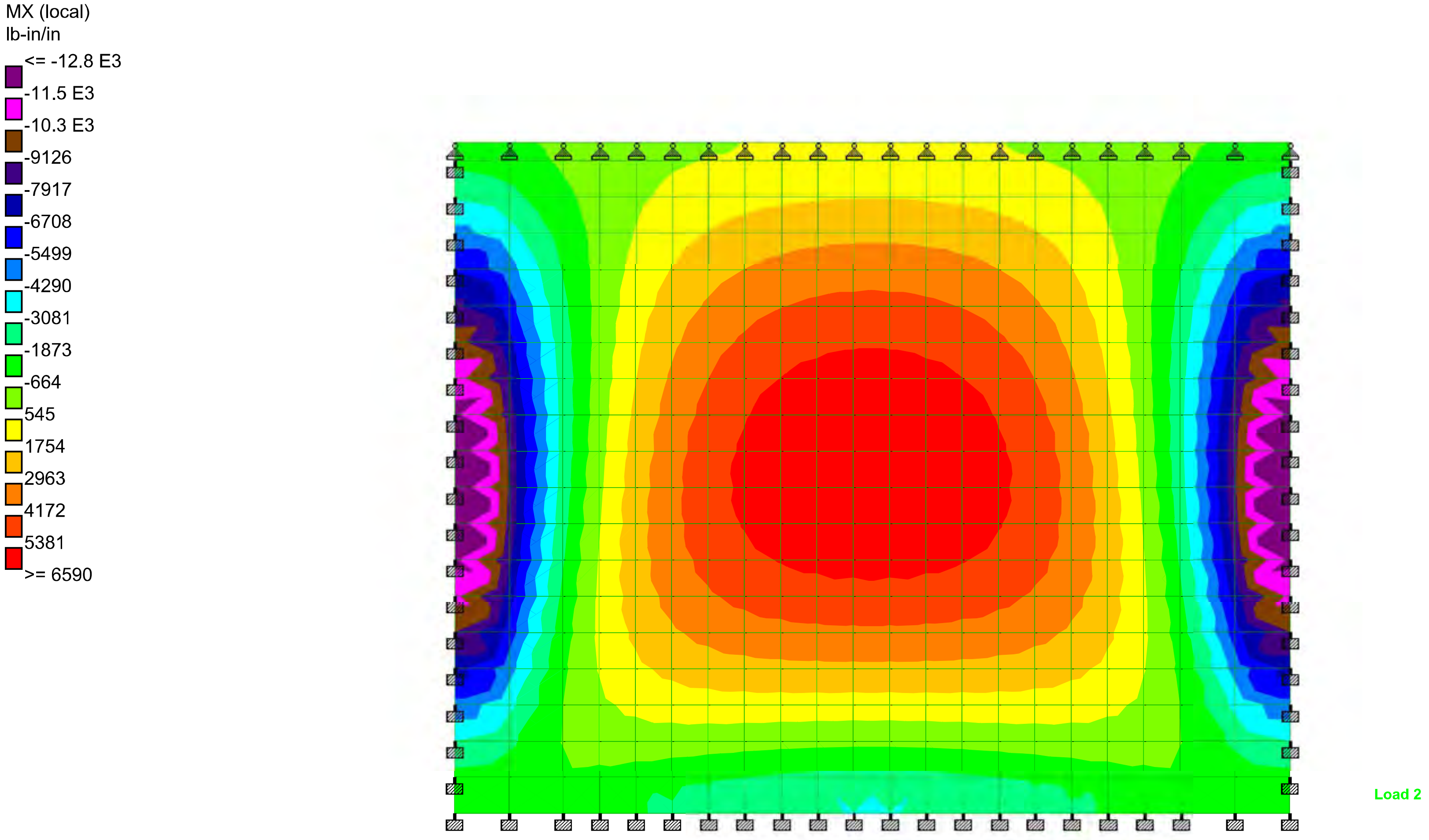
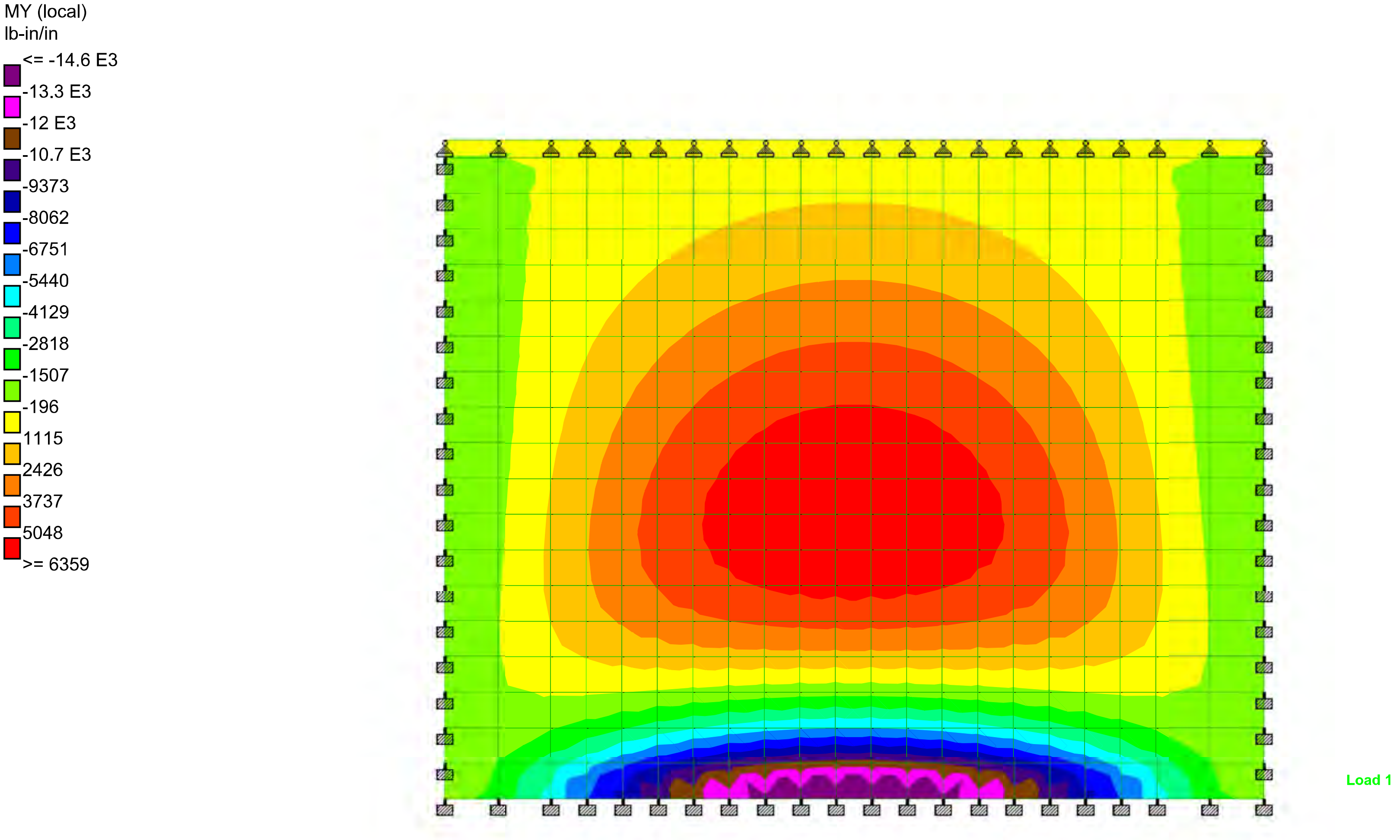
Job Title Area 6 - Filters	Job No 10721A.10	Sheet No 1	Rev
Load Case: 1.2F+1.4E	Part Wall 4		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 11-Aug-2017 10:43	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 4			
Job Title Area 6 - Filters	Ref			
Load Case: 1.4F	By CC	Date 05-Aug-17		Chd
Client Willamette River WTP	File Wall 4.std		Date/Time 11-Aug-2017 10:43	



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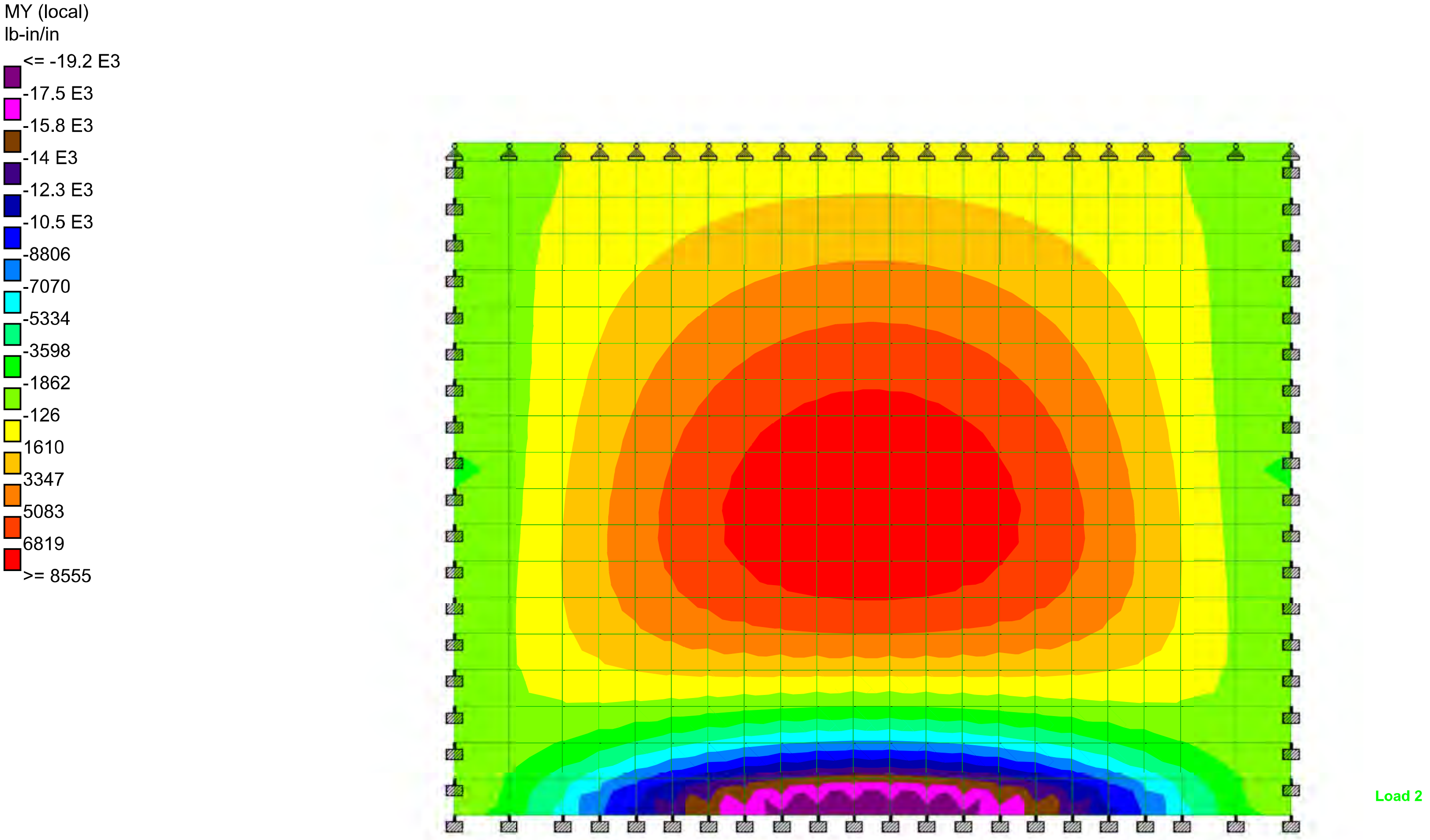
		Job No 10721A.10	Sheet No 1		Rev
		Part Wall 4			
Job Title	Area 6 - Filters Load Case: 1.2F+1.4E	Ref			
		By CC	Date 05-Aug-17		Chd
Client	Willamette River WTP	File Wall 4.std		Date/Time	11-Aug-2017 10:43



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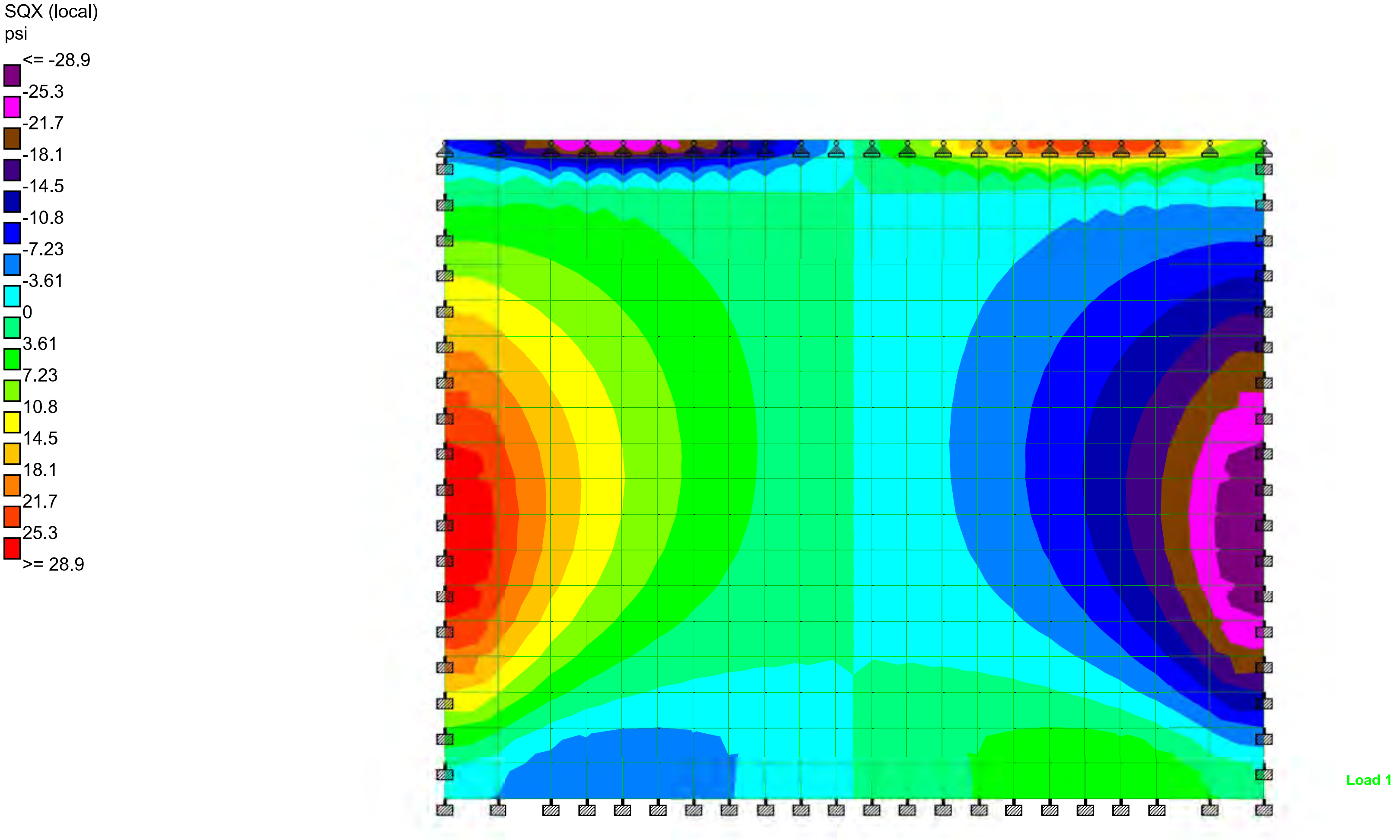
Job Title Area 6 - Filters Load Case: 1.4F	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 4		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 11-Aug-2017 10:43	



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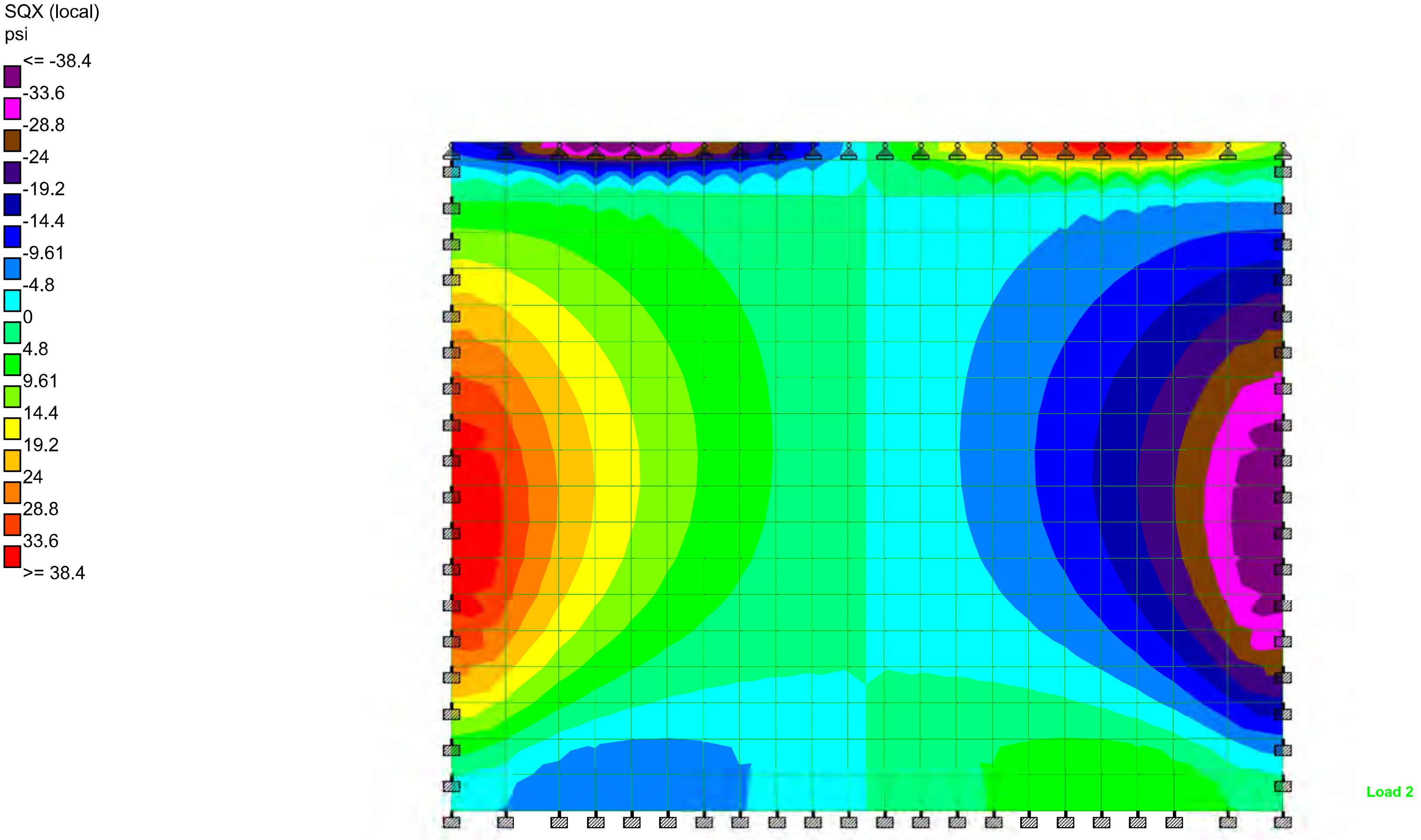
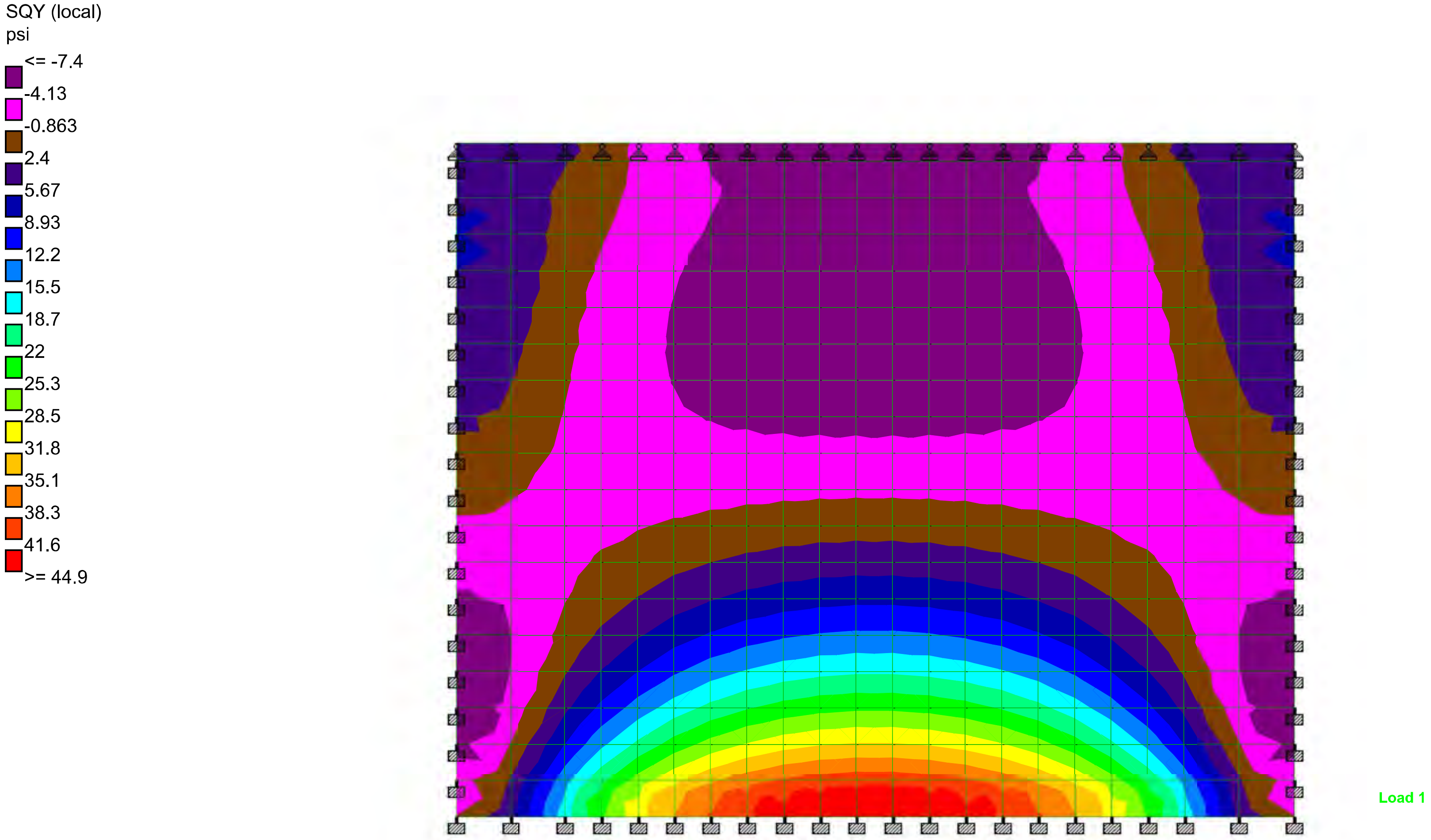
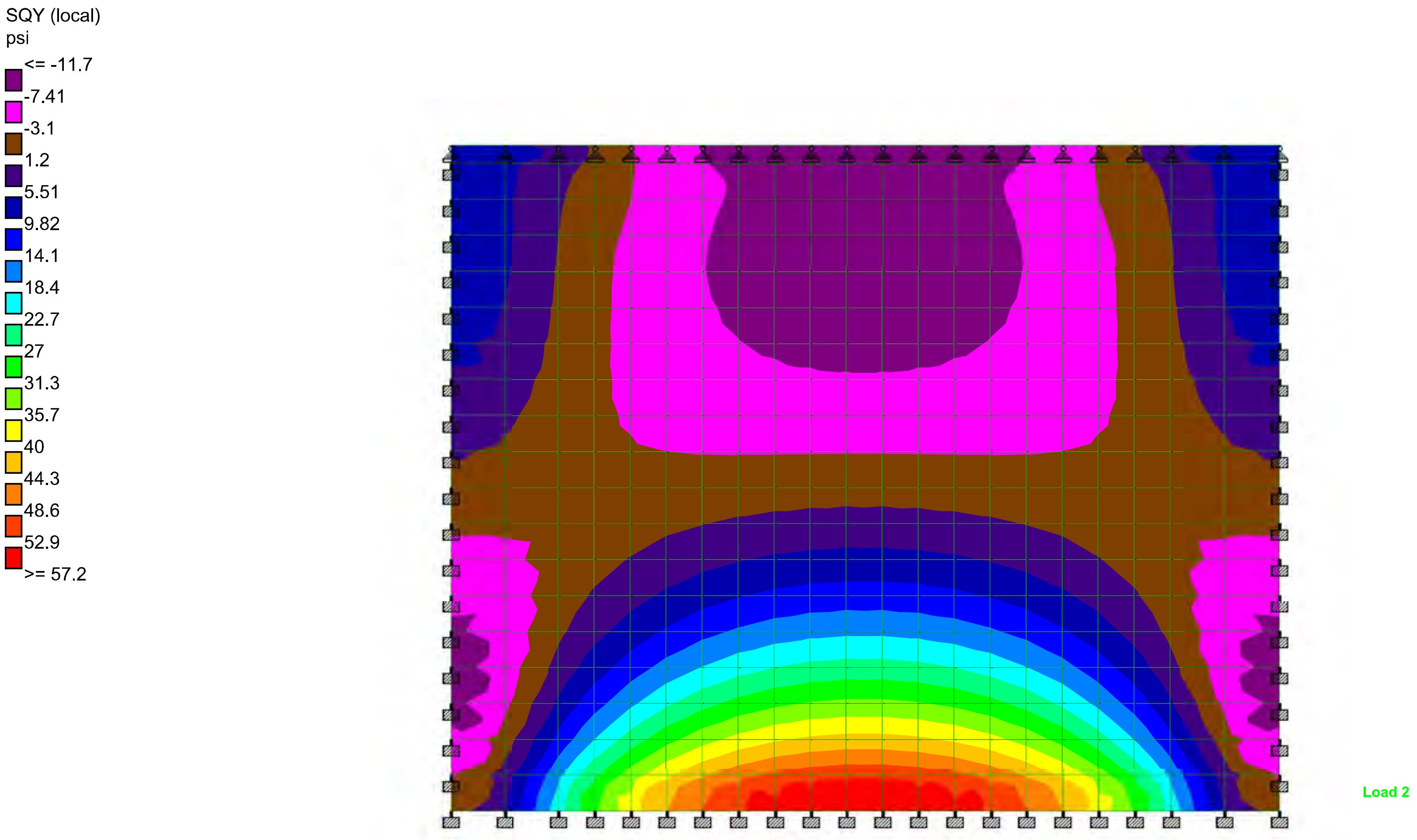
Job Title Area 6 - Filters Load Case: 1.2F+1.4E	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 4			
	Ref			
	By CC	Date 05-Aug-17	Chd	
Client Willametter River WTP	File Wall 4.std		Date/Time 11-Aug-2017 10:43	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 4		
Job Title Area 6 - Filters	Ref		
Load Case: 1.4F	By CC	Date 05-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 11-Aug-2017 10:43	



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 4		
Job Title Area 6 - Filters Load Case: 1.2F+1.4E	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 11-Aug-2017 10:43	



Area 6 - Filters
Wall 5 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	4.68	7.53	24.50	***0.31***	17	126	***0.13***	***<- OK***

Vertical Span

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	5.30	8.53	35.00	***0.24***	26	126	***0.21***	***<- OK***

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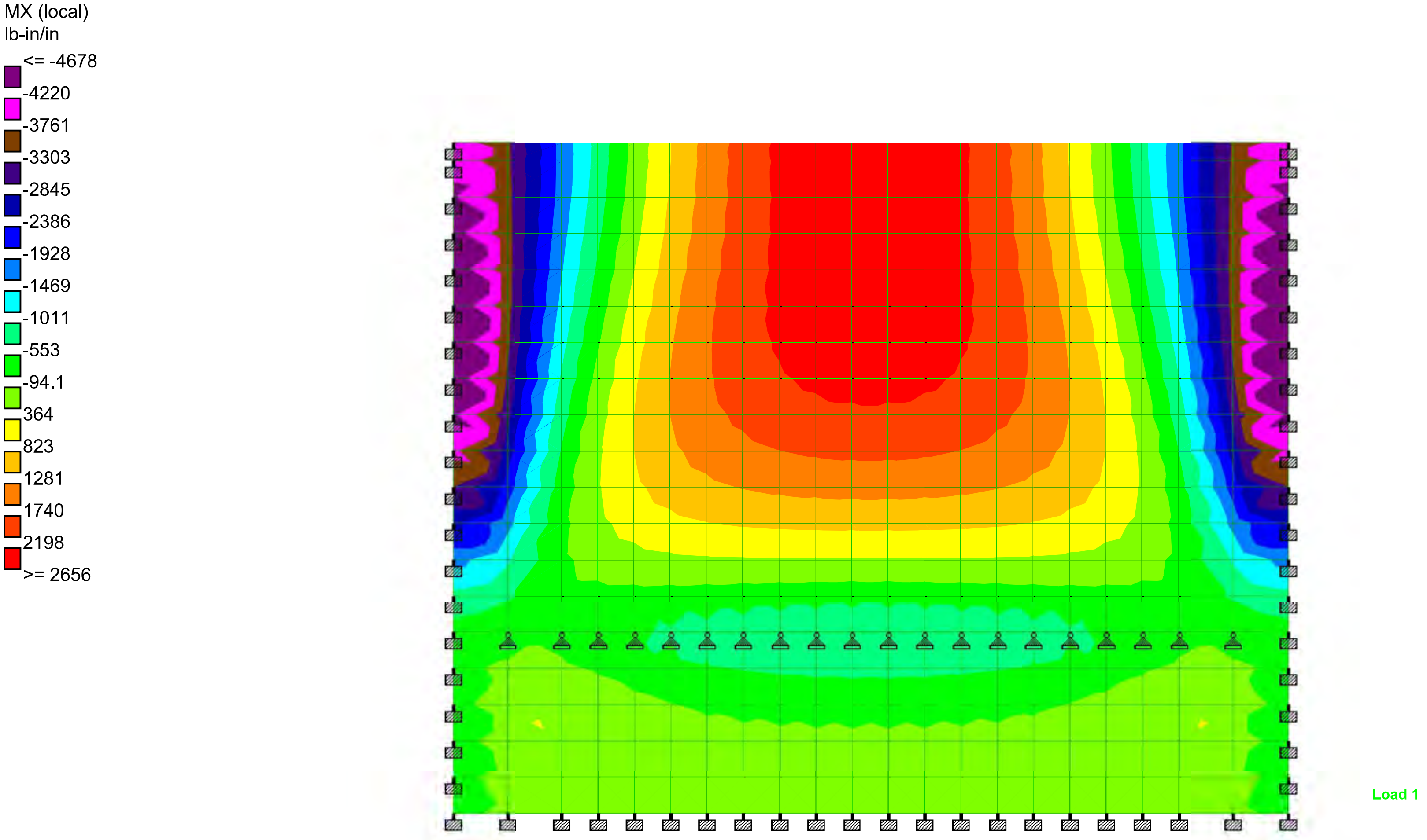
Job Title Area 6 - Filters	Job No 10721A.10	Sheet No 1	Rev
Load Case: 1.4F	Part Wall 5		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 5.std	Date/Time 11-Aug-2017 10:52	



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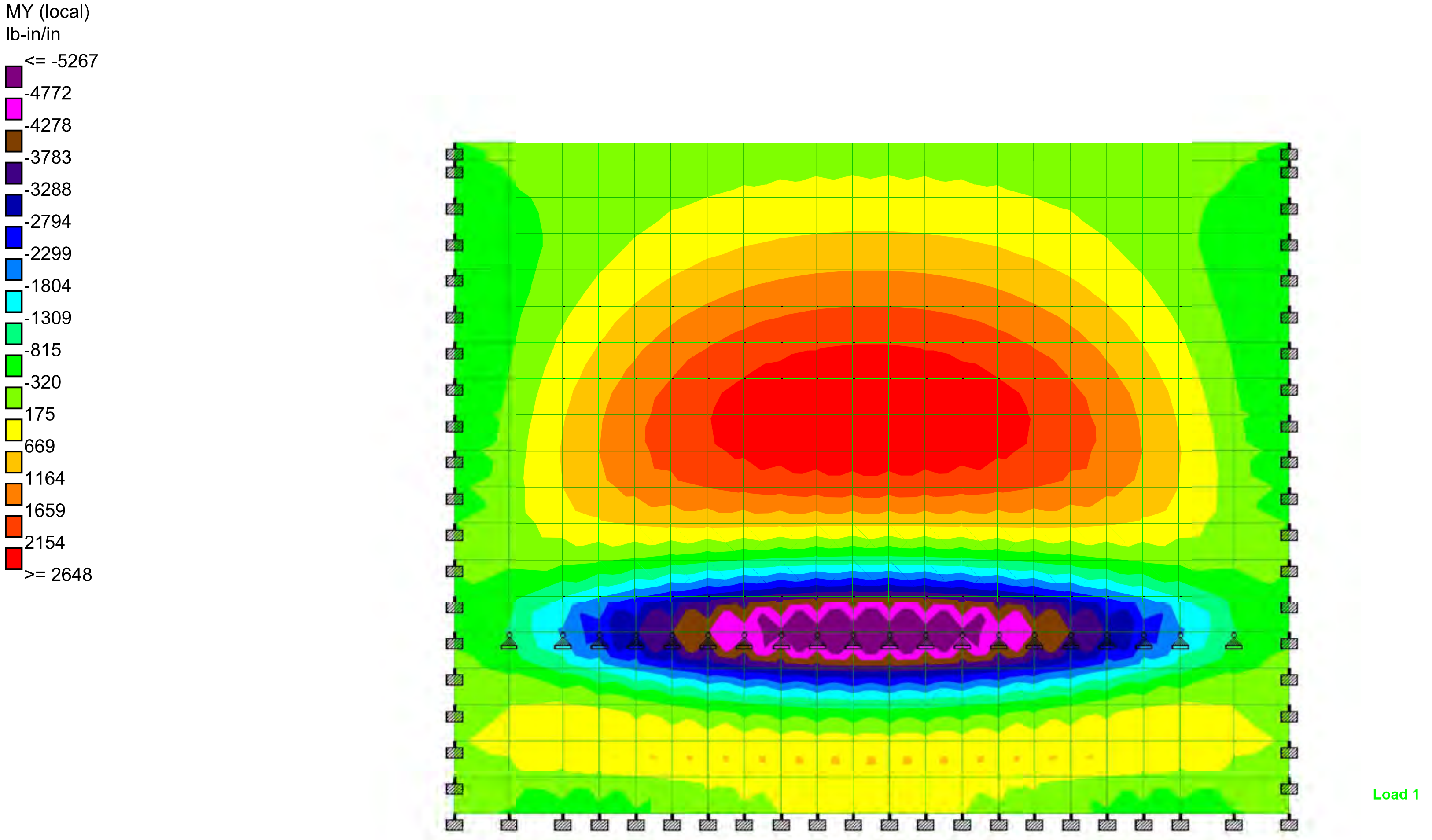
Job Title Area 6 - Filters	Job No **10721A.10**	Sheet No **1**		Rev
	Part Wall 5			
	Ref			
Load Case: 1.4F	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 5.std	Date/Time 11-Aug-2017 10:52		



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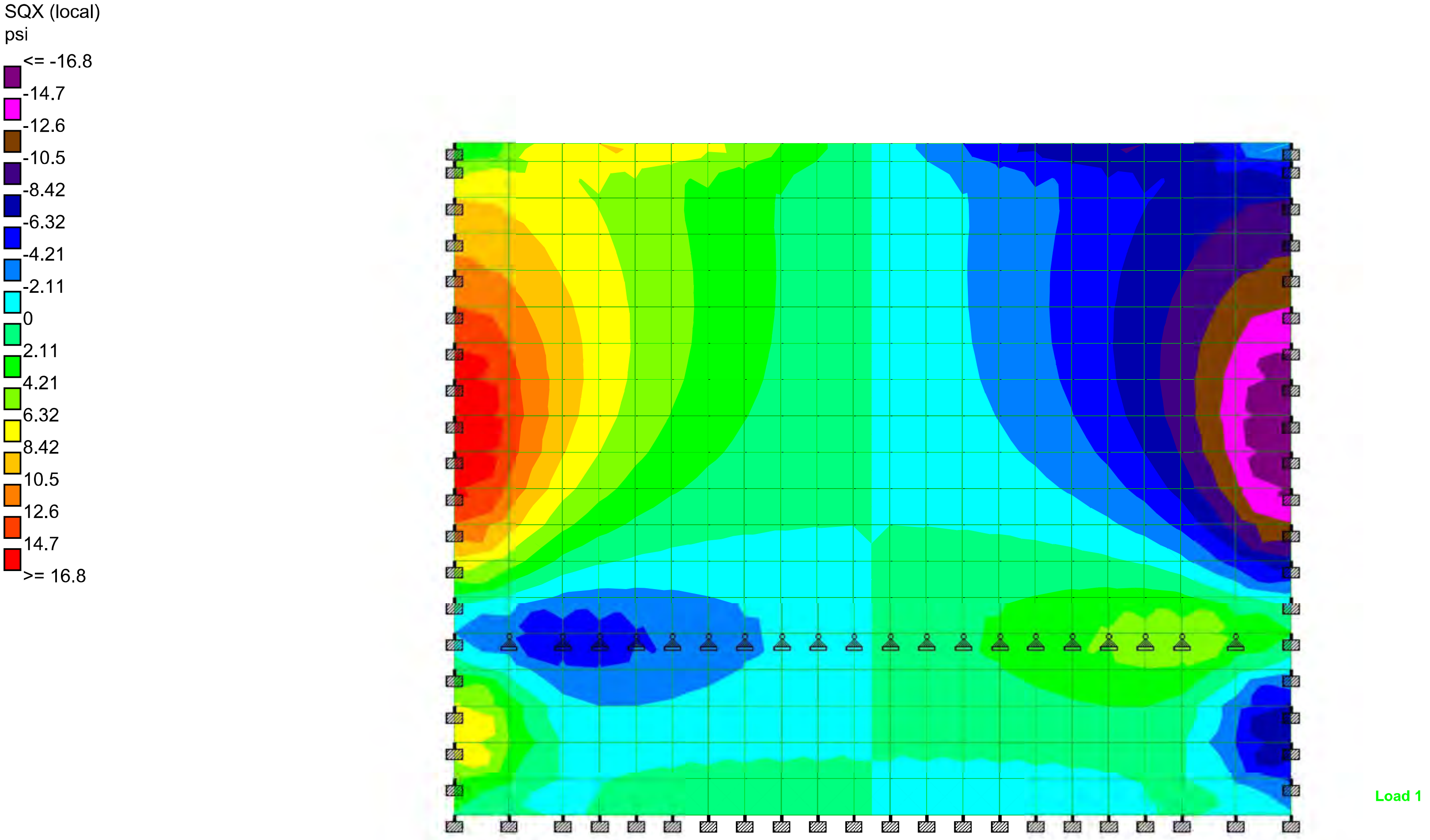
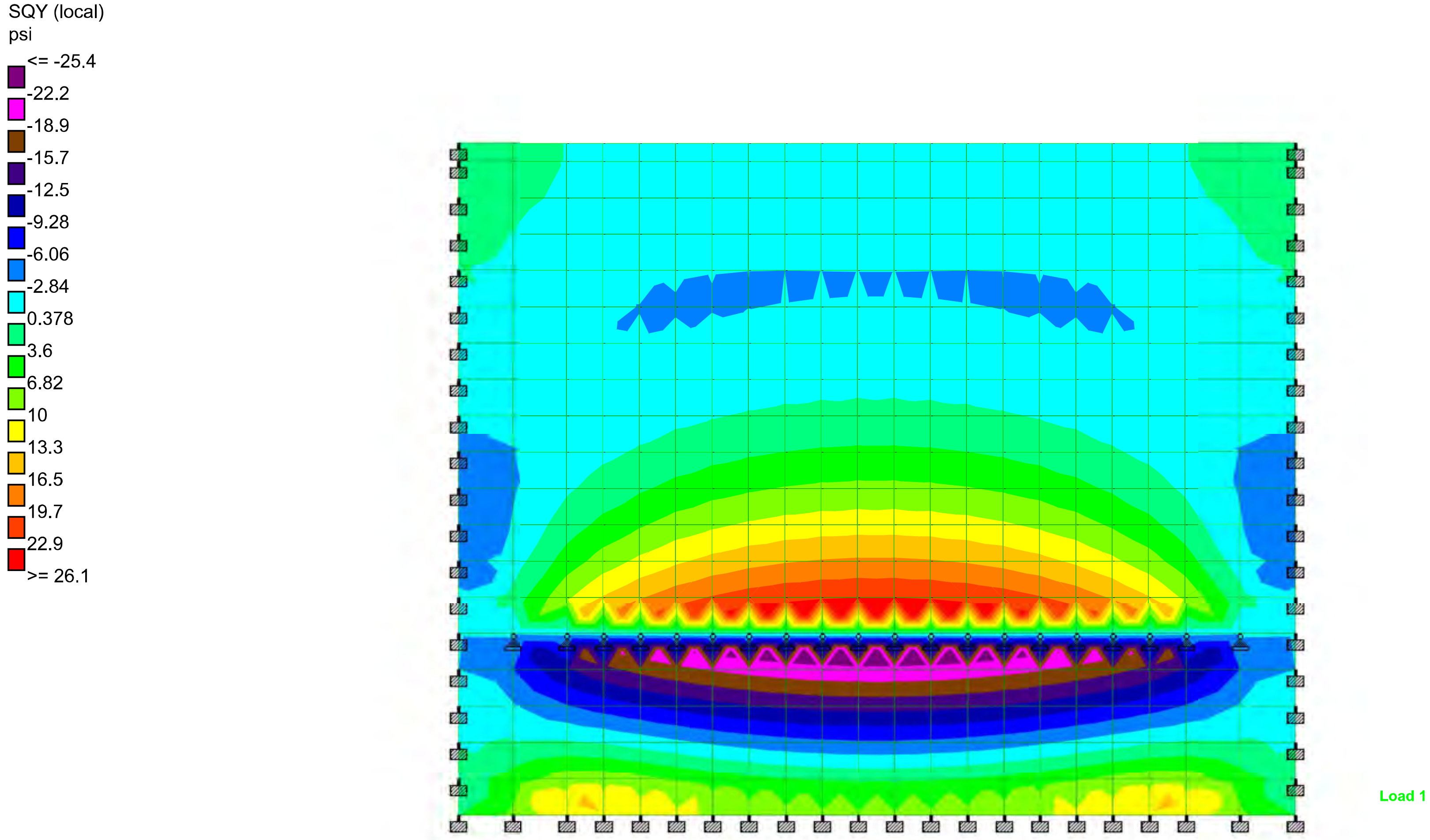
Job Title	Area 6 - Filters Load Case: 1.4F	Job No 10721A.10	Sheet No 1	Rev
		Part Wall 5		
		Ref		
		By CC	Date 05-Aug-17	Chd
Client	Willamette River WTP	File Wall 5.std	Date/Time 11-Aug-2017 10:52	



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
	Part Wall 5		
Job Title Area 6 - Filters	Ref		
Load Case: 1.4F	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 5.std	Date/Time 11-Aug-2017 10:52	



Area 6 - Filters
Wall 7 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.6(H+L)	1.41	4.74	6.68	16.00	***0.42***	19	126	***0.15***	***<- OK***
1.6H+1.4E	1.00	5.91	5.91	16.00	***0.37***	23	126	***0.18***	***<- OK***

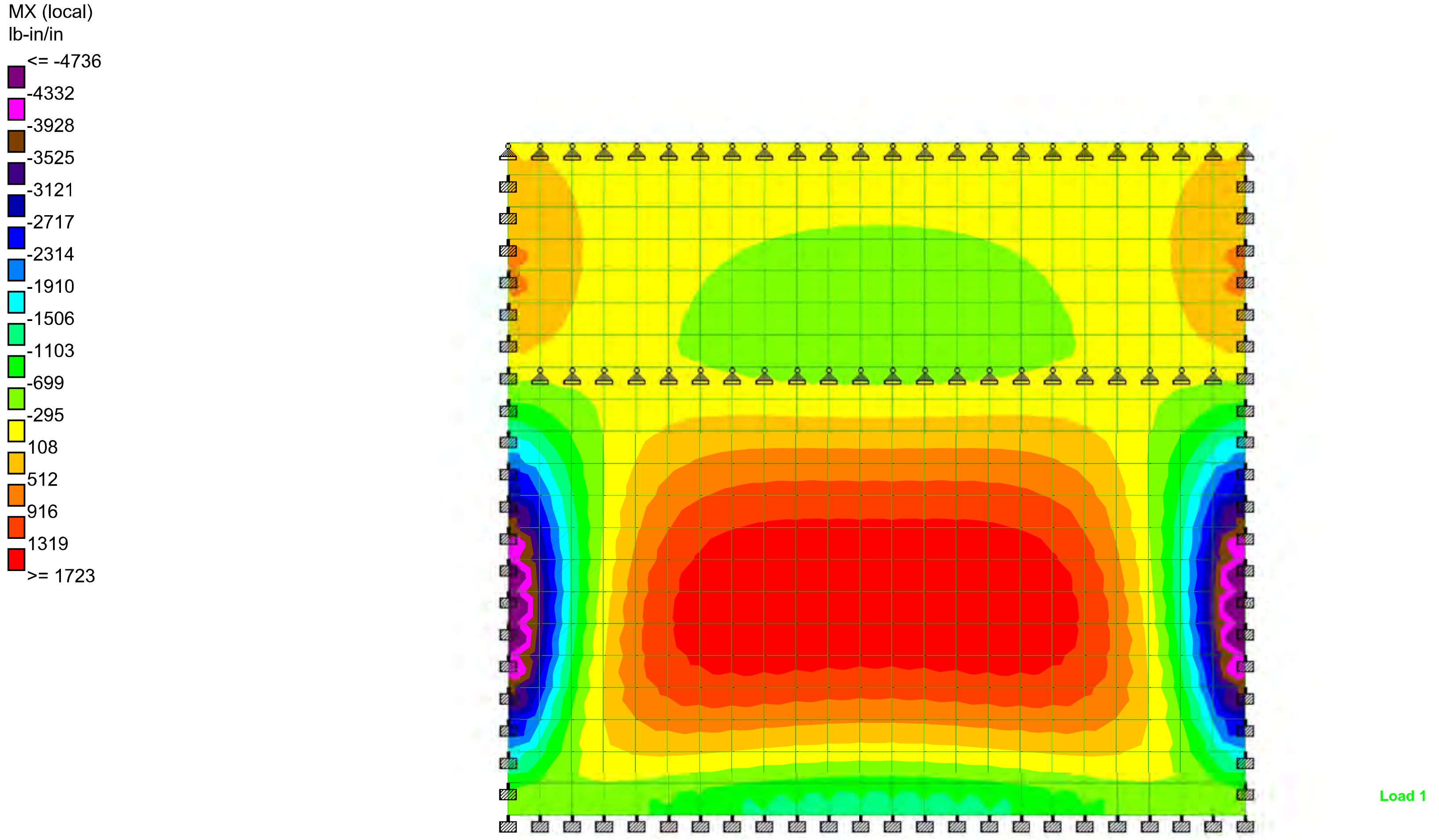
Vertical Span (Mid-Height)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.6(H+L)	1.41	4.13	5.82	17.50	***0.33***	0	126	***0.00***	***<- OK***
1.6H+1.4E	1.00	5.12	5.12	17.50	***0.29***	0	126	***0.00***	***<- OK***

Vertical Span (Bottom)

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.6(H+L)	1.41	7.96	11.22	33.50	***0.34***	30	126	***0.23***	***<- OK***
1.6H+1.4E	1.00	9.32	9.32	33.50	***0.28***	32	126	***0.26***	***<- OK***

Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
Job Title Area 6 - Filters	Part Wall 7		
Load Case: 1.6(H+L)	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 7.std	Date/Time 11-Aug-2017 13:31	



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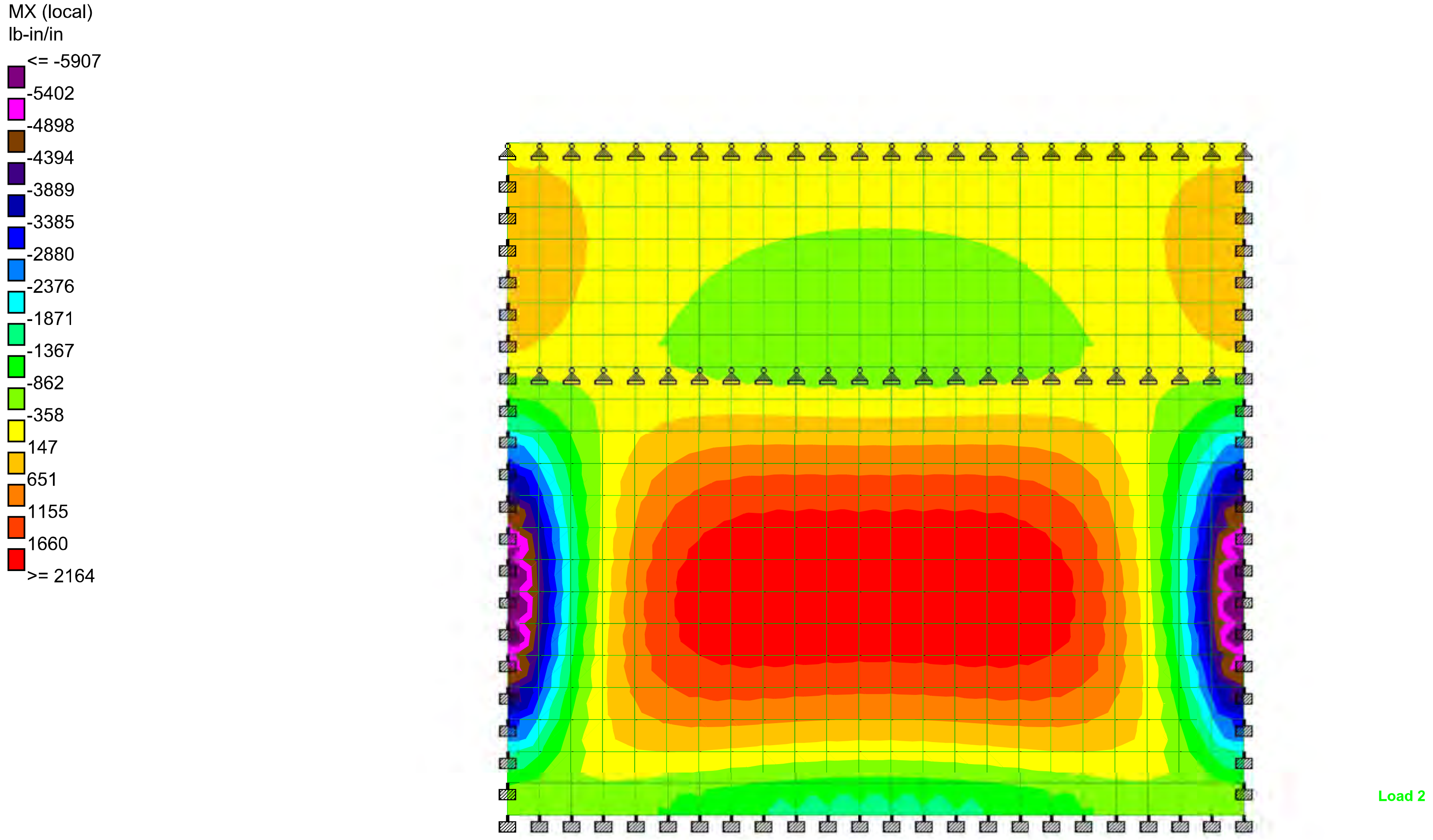
Job Title Area 6 - Filters Load Case: 1.6+1.4E	Job No 10721A.10	Sheet No 1		Rev
	Part Wall 7			
	Ref			
	By CC	Date 05-Aug-17	Chd	
Client Willamette River WTP	File Wall 7.std	Date/Time 11-Aug-2017 13:31		



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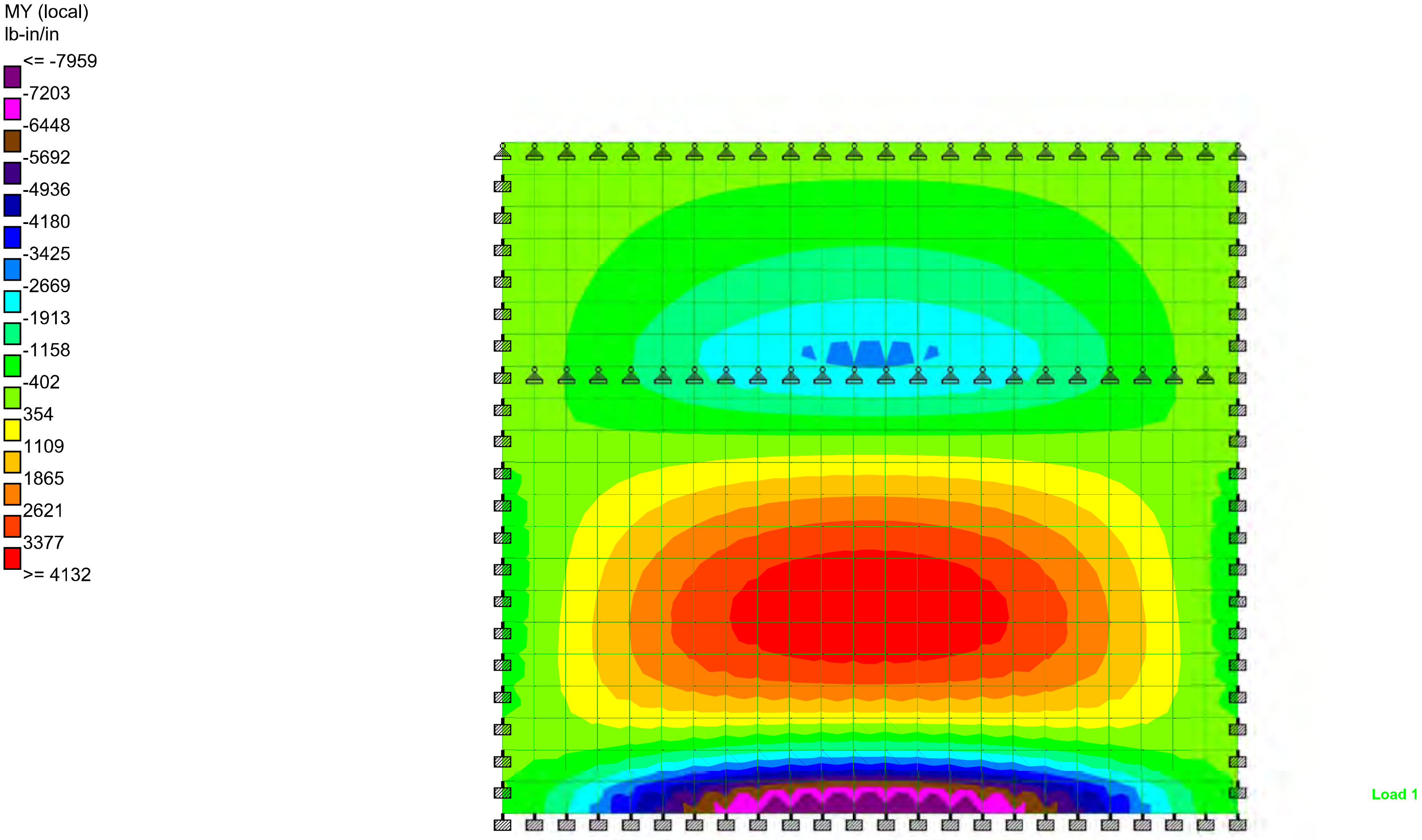
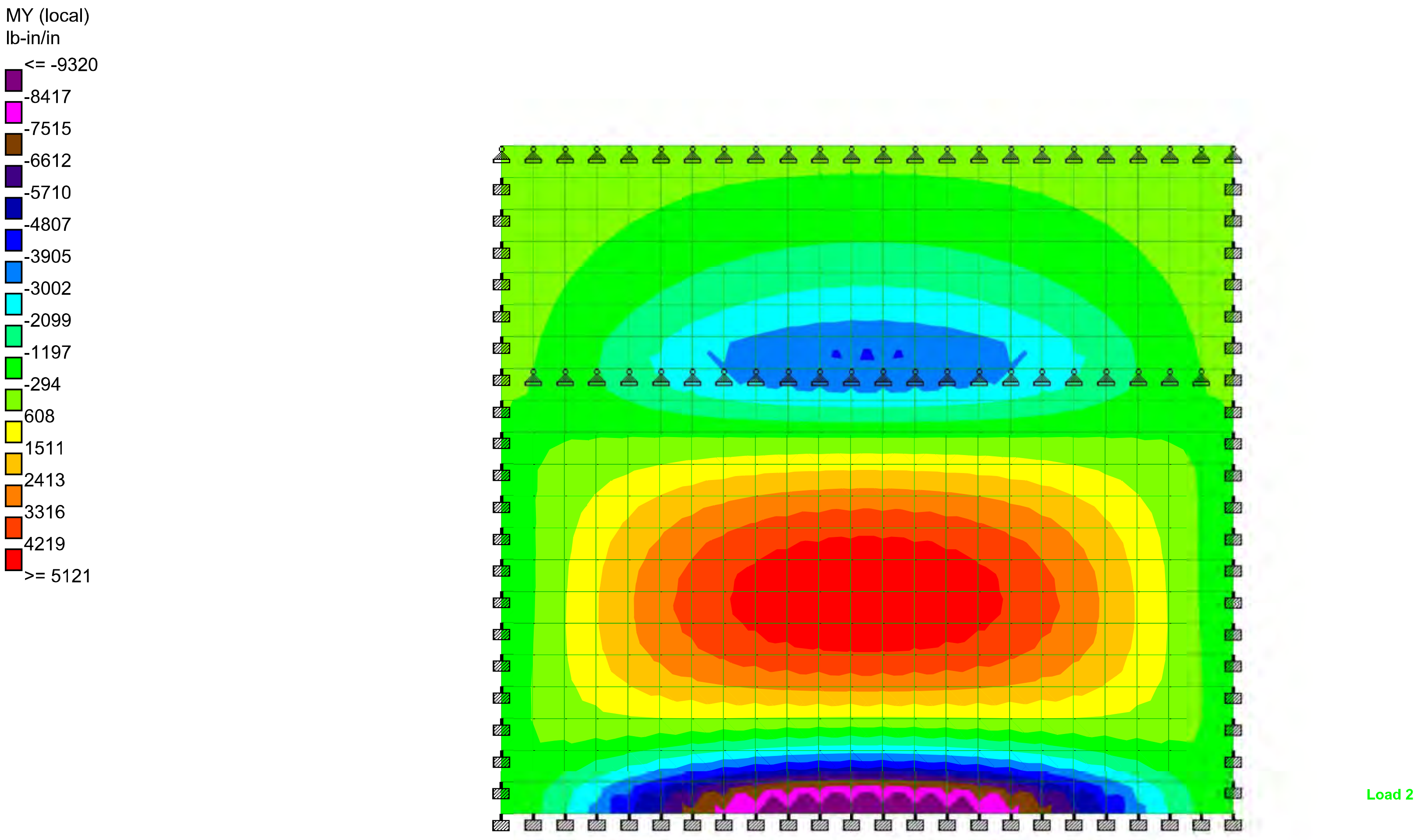
	Part Wall 7		
Job Title Area 6 - Filters	Ref		
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 7.std	Date/Time 11-Aug-2017 13:31	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1	Rev
Job Title Area 6 - Filters	Part Wall 7		
	Ref		
Load Case: 1.6+1.4E	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 7.std	Date/Time 11-Aug-2017 13:31	



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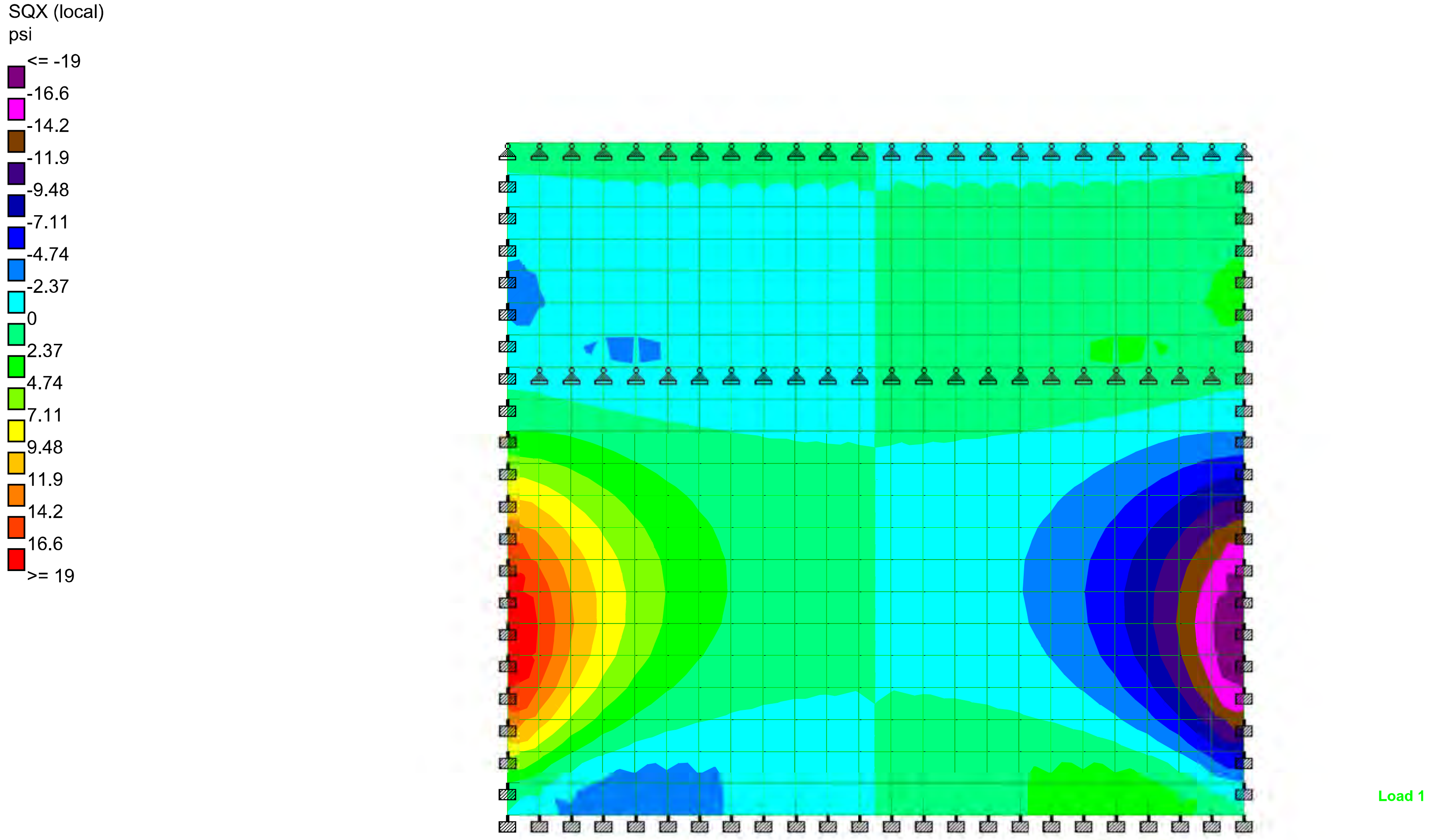
Job Title	Area 6 - Filters Load Case: 1.6(H+L)	Job No	10721A.10	Sheet No	1
		Rev			
		Part	Wall 7		
		Ref			
		By	CC	Date	05-Aug-17
		Chd			
Client	Willamette River WTP	File	Wall 7.std	Date/Time	11-Aug-2017 13:31



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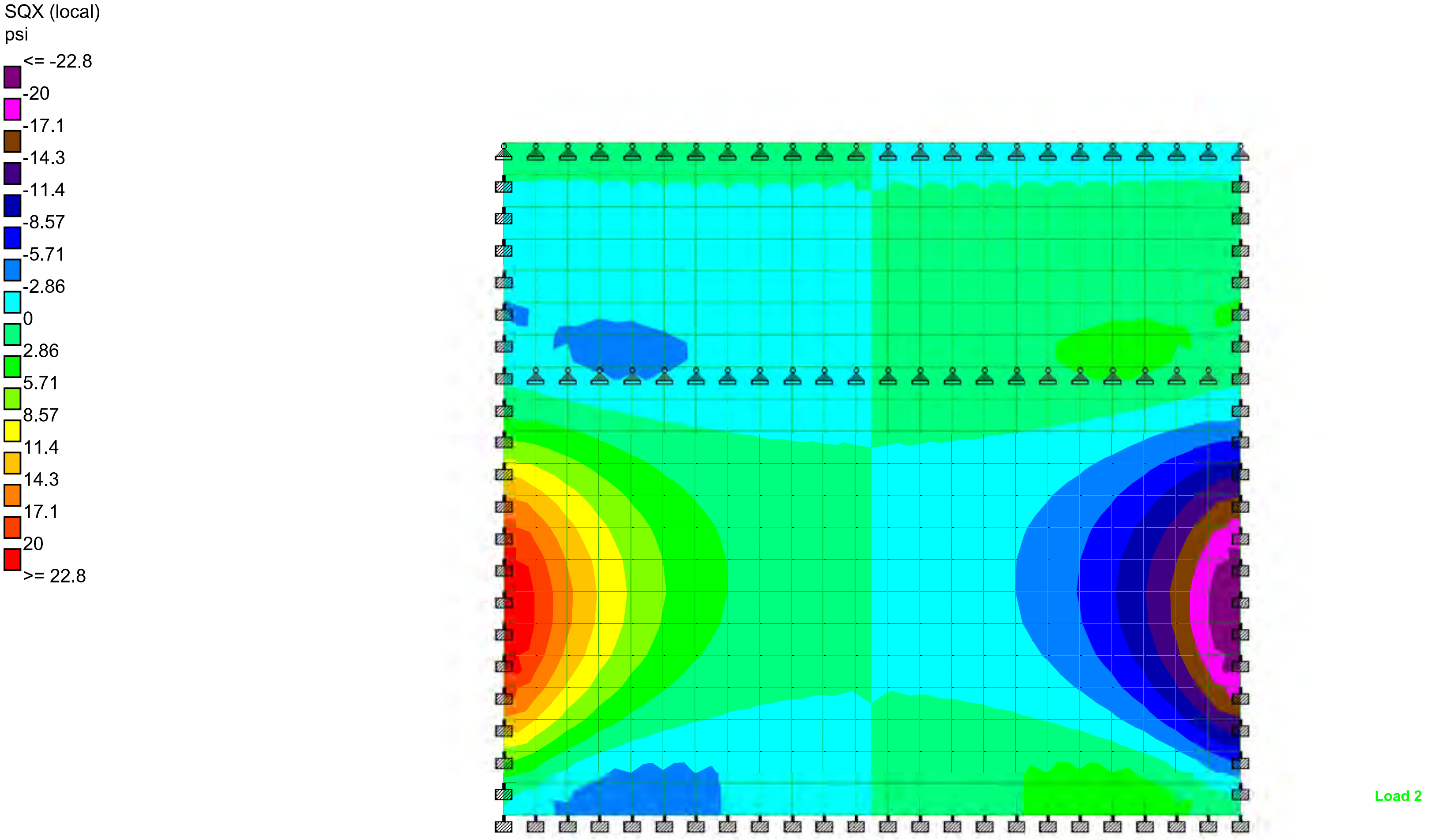
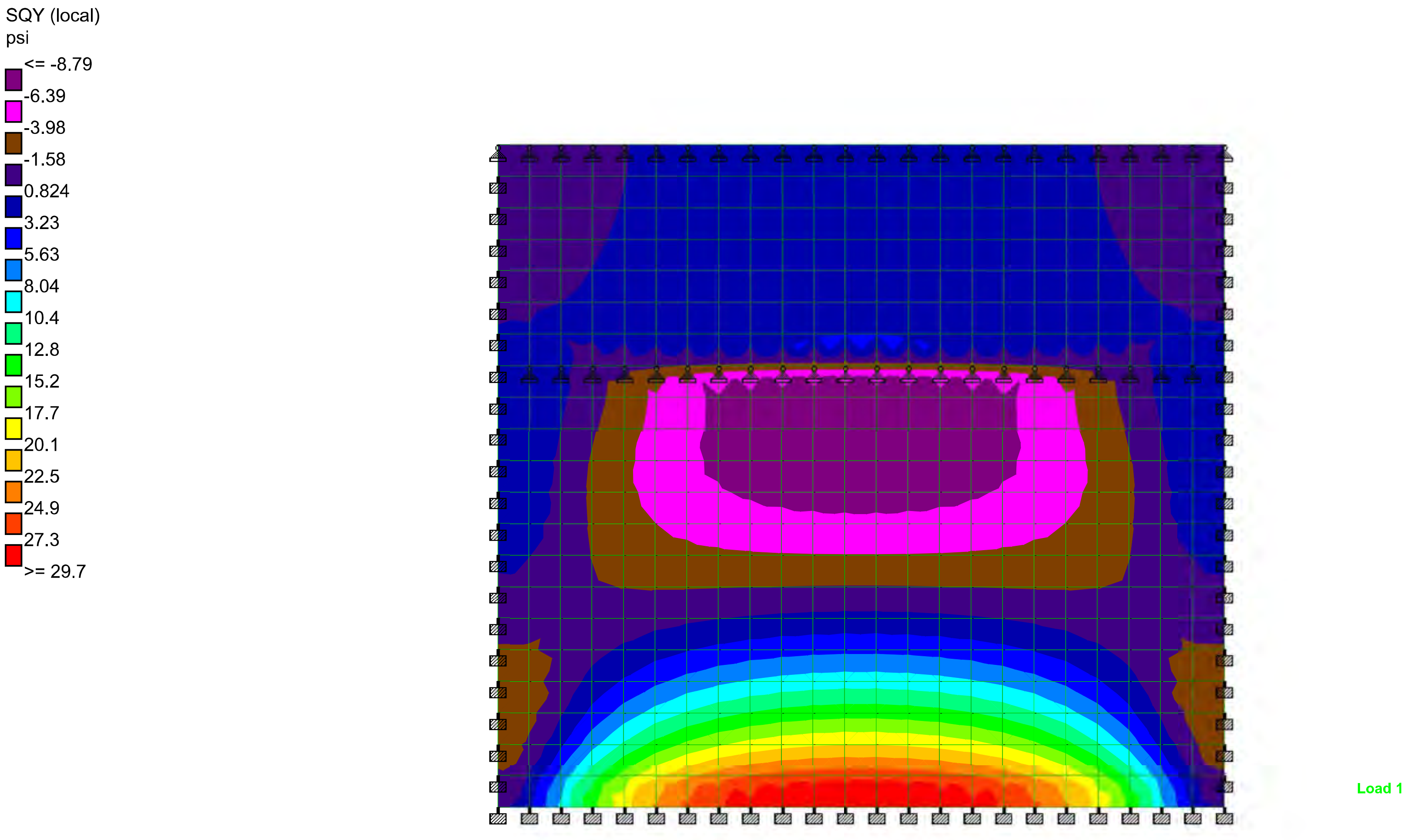
Job Title Area 6 - Filters Load Case: 1.6+1.4E	Job No 10721A.10	Sheet No 1	Rev
	Part Wall 7		
	Ref		
	By CC	Date 05-Aug-17	Chd
Client Willamette River WTP	File Wall 7.std	Date/Time 11-Aug-2017 13:31	



Software licensed to Carollo Engineers	Job No 10721A.10	Sheet No 1		Rev
Job Title Area 6 - Filters	Part Wall 7			
	Ref			
Load Case: 1.6(H+L)	By CC	Date 05-Aug-17		Chd
Client Willamette River WTP	File Wall 7.std		Date/Time 11-Aug-2017 13:31	



Software licensed to Carollo Engineers	Job No **10721A.10**	Sheet No **1**	Rev
Job Title Area 6 - Filters	Part Wall 7		
	Ref		
Load Case: 1.6+1.4E	By CC	Date 05-Aug-17	Chd
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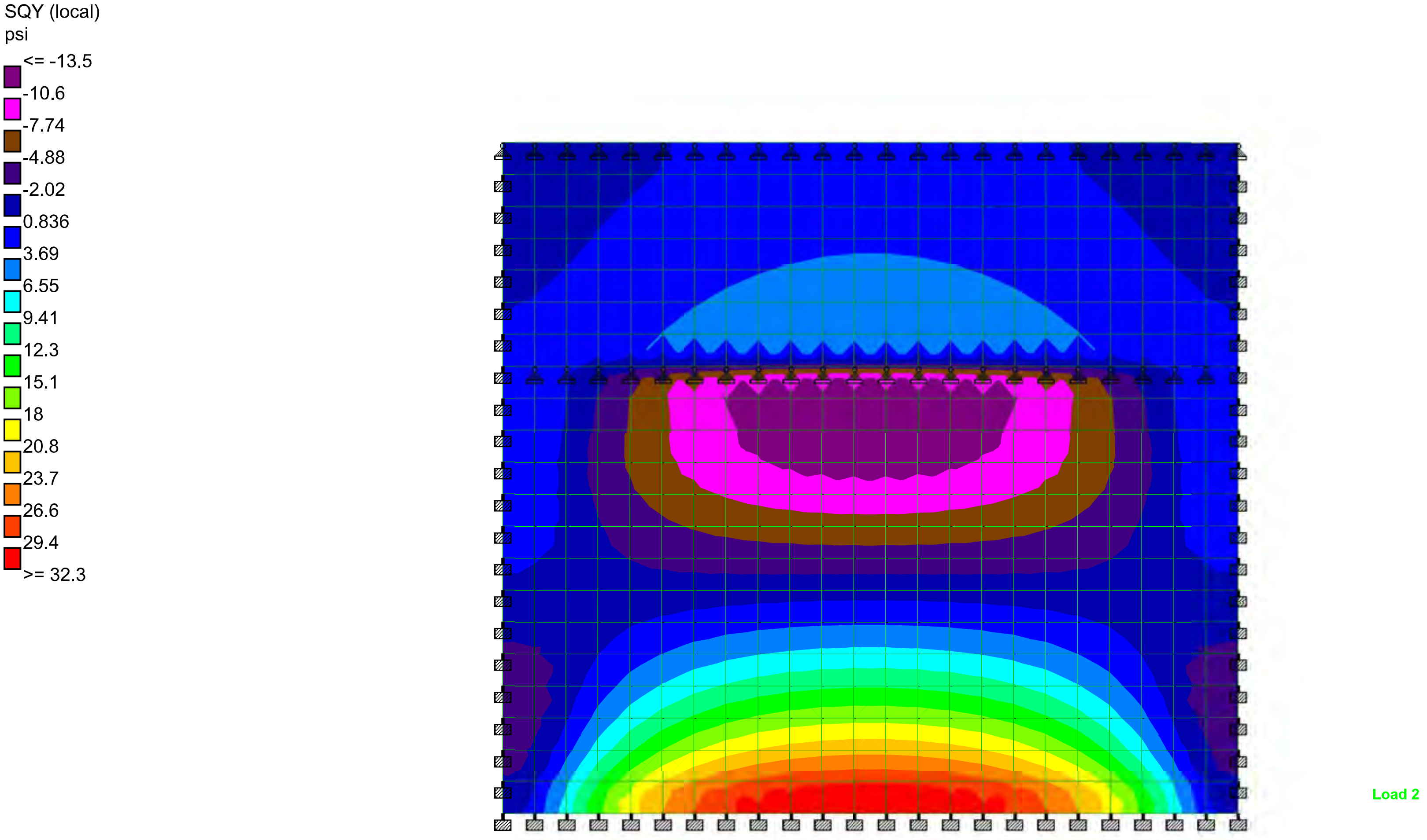


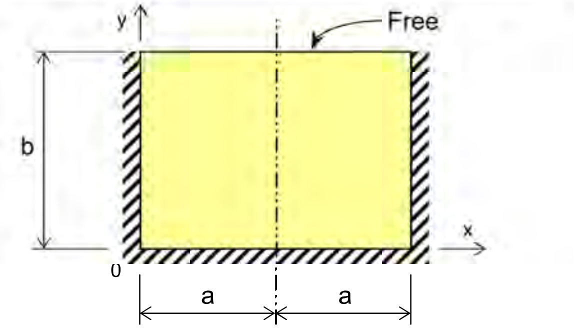
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil Static

Rectangular Plate:

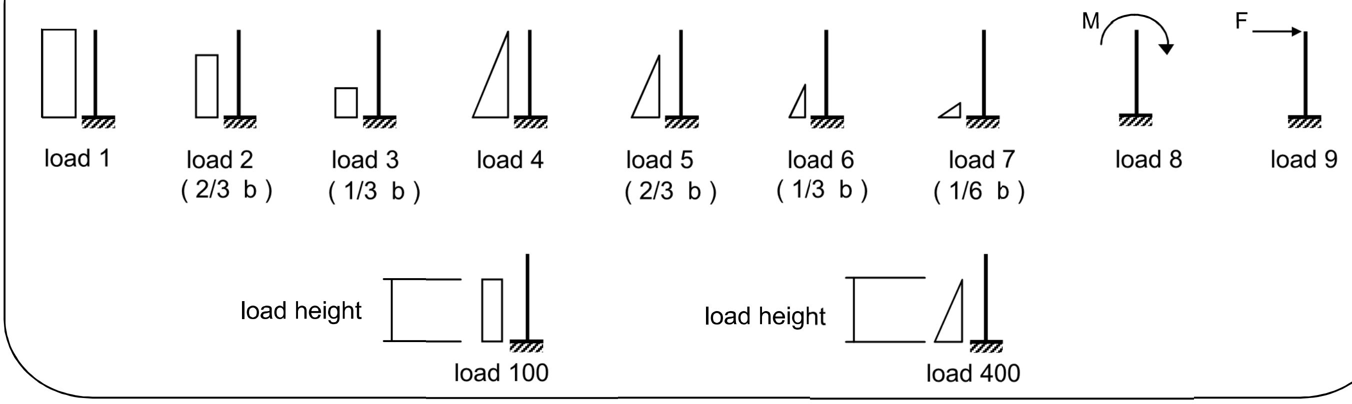
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 4 = 8 ft
plate dimension, a = **4** ft
plate dimension, b = **11** ft

plate sides ratio, a/b = 0.3636



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	for shear
A	**400**	**8.000**	**0.440**	**2.25**	**1.6**
B	**100**	**8.000**	**0.100**	**2.25**	**1.6**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

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Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil Static

M_x - Moment Summary

a = 4
b = 11
a / b = 0.3636

Loads: q , M , or F			
0.440	0.100		
Moment Coefficient Multipliers			
53.240	12.100		

Boundary Case 1

		Moment Coefficients				M_x Moments, ft-k/ft				SUMMARY Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0010	0.0080			0.05	0.10			0.15	0.34	0.01	0.36
0	0.8	0.0035	0.0160			0.19	0.19			0.38	0.86	0.02	0.36
0	0.6	0.0085	0.0303			0.45	0.37			0.82	1.84	0.05	0.36
0	0.4	0.0142	0.0340			0.76	0.41			1.17	2.63	0.07	0.36
0	0.2	0.0120	0.0202			0.64	0.24			0.88	1.99	0.05	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0007	0.0010			0.04	0.01			0.05	0.11	0.00	0.36
0.4	0	0.0016	0.0025			0.09	0.03			0.12	0.26	0.01	0.36
0.6	0	0.0024	0.0040			0.13	0.05			0.18	0.40	0.01	0.36
0.8	0	0.0031	0.0050			0.16	0.06			0.22	0.50	0.01	0.36
1	0	0.0033	0.0054			0.17	0.06			0.24	0.54	0.01	0.36
1	0.2	-0.0049	-0.0089			-0.26	-0.11			-0.37	-0.83	-0.02	-0.36
1	0.4	-0.0067	-0.0162			-0.36	-0.20			-0.55	-1.24	-0.03	-0.36
1	0.6	-0.0044	-0.0149			-0.23	-0.18			-0.41	-0.93	-0.02	-0.36
1	0.8	-0.0020	-0.0087			-0.11	-0.11			-0.21	-0.48	-0.01	-0.36
1	1	-0.0011	-0.0058			-0.06	-0.07			-0.13	-0.29	-0.01	-0.36
0.8	1	-0.0009	-0.0049			-0.05	-0.06			-0.11	-0.24	-0.01	-0.36
0.8	0.8	-0.0018	-0.0075			-0.09	-0.09			-0.18	-0.42	-0.01	-0.36
0.8	0.6	-0.0039	-0.0134			-0.21	-0.16			-0.37	-0.83	-0.02	-0.36
0.8	0.4	-0.0061	-0.0147			-0.33	-0.18			-0.50	-1.13	-0.03	-0.36
0.8	0.2	-0.0046	-0.0082			-0.25	-0.10			-0.34	-0.77	-0.02	-0.36

max negative moment, $M_{ux}(-)$ = -1.24 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.03 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 2.63 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.07 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil Static

M_y - Moment Summary

a = 4
b = 11
a / b = 0.3636

Loads: q , M , or F			
0.440	0.100		
Moment Coefficient Multipliers			
53.240	12.100		

Boundary Case 1

SUMMARY — Reinforcing: (d = 9.5")

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0	0.8	0.0007	0.0032			0.03	0.04			0.07	0.16	0.00	0.36
0	0.6	0.0017	0.0060			0.09	0.07			0.16	0.37	0.01	0.36
0	0.4	0.0028	0.0068			0.15	0.08			0.23	0.52	0.01	0.36
0	0.2	0.0024	0.0040			0.13	0.05			0.18	0.40	0.01	0.36
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
0.2	0	0.0033	0.0048			0.17	0.06			0.23	0.52	0.01	0.36
0.4	0	0.0082	0.0126			0.43	0.15			0.59	1.32	0.03	0.36
0.6	0	0.0124	0.0199			0.66	0.24			0.90	2.03	0.05	0.36
0.8	0	0.0152	0.0249			0.81	0.30			1.11	2.50	0.06	0.36
1	0	0.0161	0.0267			0.86	0.32			1.18	2.66	0.06	0.36
1	0.2	-0.0050	-0.0059			-0.27	-0.07			-0.34	-0.76	-0.02	-0.36
1	0.4	-0.0046	-0.0101			-0.24	-0.12			-0.37	-0.82	-0.02	-0.36
1	0.6	-0.0010	-0.0070			-0.05	-0.08			-0.14	-0.31	-0.01	-0.36
1	0.8	0.0005	0.0004			0.03	0.00			0.03	0.07	0.00	0.36
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.36
1	0.4	-0.0046	-0.0101			-0.24	-0.12			-0.37	-0.82	-0.02	-0.36
0.8	0.4	-0.0042	-0.0093			-0.23	-0.11			-0.34	-0.76	-0.02	-0.36
0.6	0.4	-0.0032	-0.0070			-0.17	-0.08			-0.25	-0.57	-0.01	-0.36
0.4	0.4	-0.0015	-0.0033			-0.08	-0.04			-0.12	-0.27	-0.01	-0.36
0.2	0.4	0.0005	0.0015			0.03	0.02			0.04	0.10	0.00	0.36

max negative moment, $M_{uy}(-)$ = -0.82 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.02 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 2.66 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.06 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil Static

Shear Summary

a = 4
b = 11
a / b = 0.3636

Loads: q , M , or F			
0.440	0.100		
Shear Coefficient Multipliers			
4.840	1.100		

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0074	0.0151			-0.04	0.02			-0.02	-0.03	10.81
0	0.8	0.0184	0.1032			0.09	0.11			0.20	0.32	10.81
0	0.6	0.0678	0.2949			0.33	0.32			0.65	1.04	10.81
0	0.4	0.1523	0.3564			0.74	0.39			1.13	1.81	10.81
0	0.2	0.1525	0.2186			0.74	0.24			0.98	1.57	10.81
0	0.00	0.0156	0.0025			0.08	0.00			0.08	0.13	10.81
0.2	0	0.0514	0.0324			0.25	0.04			0.28	0.46	10.81
0.4	0	0.1387	0.1650			0.67	0.18			0.85	1.36	10.81
0.6	0	0.1936	0.2586			0.94	0.28			1.22	1.95	10.81
0.8	0	0.2233	0.3131			1.08	0.34			1.43	2.28	10.81
1	0	0.2326	0.3309			1.13	0.36			1.49	2.38	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 2.38 k/ft **OK**
$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d$ = $(0.75*2*(4000)^{½} *12*9.5)/1000$ = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

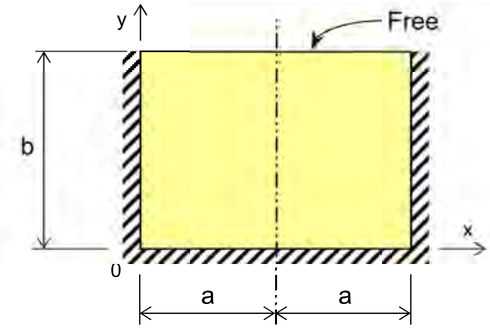
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil EQ

Rectangular Plate:

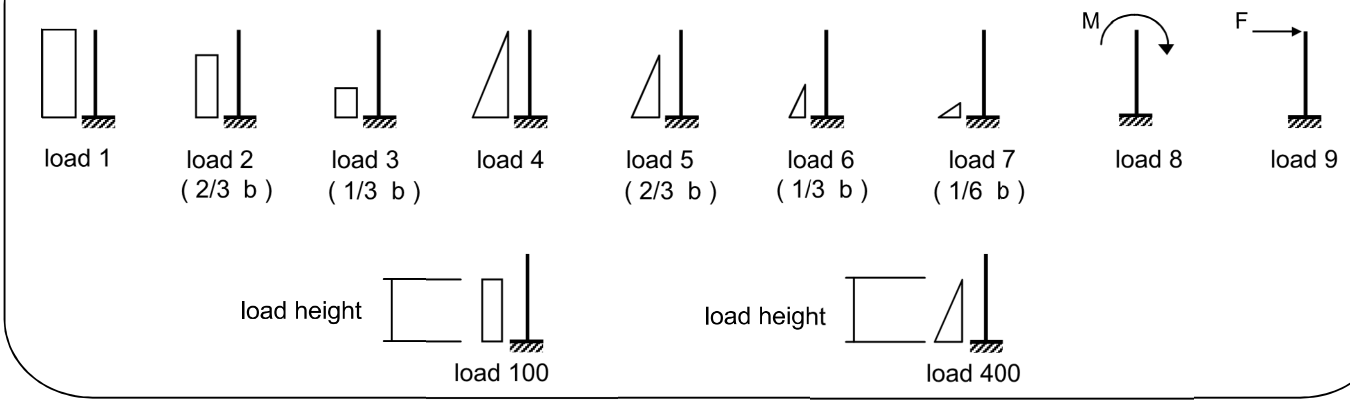
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 4 = 8 ft
plate dimension, a = **4** ft
plate dimension, b = **11** ft

plate sides ratio, a/b = 0.3636



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	for shear
A	**400**	**8.000**	**0.440**	**1.6**	**1.6**
B	**100**	**8.000**	**0.194**	**1.4**	**1.4**
C	**400**	**8.000**	**-0.194**	**1.4**	**1.4**
D	**1**		**0.037**	**1.4**	**1.4**

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil EQ

M_x - Moment Summary

a = 4
b = 11
a / b = 0.3636

Loads: q , M , or F			
0.440	0.194	-0.194	0.037
Moment Coefficient Multipliers			
53.240	23.474	-23.474	4.477

Boundary Case 1

		Moment Coefficients				M_x Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0010	0.0080	0.0010	0.0447	0.05	0.19	-0.02	0.20	0.42	0.60	0.01	0.36
0	0.8	0.0035	0.0160	0.0035	0.0439	0.19	0.38	-0.08	0.20	0.68	0.98	0.02	0.36
0	0.6	0.0085	0.0303	0.0085	0.0419	0.45	0.71	-0.20	0.19	1.15	1.70	0.04	0.36
0	0.4	0.0142	0.0340	0.0142	0.0363	0.76	0.80	-0.33	0.16	1.38	2.09	0.05	0.36
0	0.2	0.0120	0.0202	0.0120	0.0205	0.64	0.47	-0.28	0.09	0.92	1.42	0.04	0.36
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0.2	0	0.0007	0.0010	0.0007	0.0009	0.04	0.02	-0.02	0.00	0.05	0.07	0.00	0.36
0.4	0	0.0016	0.0025	0.0016	0.0025	0.09	0.06	-0.04	0.01	0.12	0.18	0.00	0.36
0.6	0	0.0024	0.0040	0.0024	0.0040	0.13	0.09	-0.06	0.02	0.18	0.28	0.01	0.36
0.8	0	0.0031	0.0050	0.0031	0.0051	0.16	0.12	-0.07	0.02	0.23	0.35	0.01	0.36
1	0	0.0033	0.0054	0.0033	0.0054	0.17	0.13	-0.08	0.02	0.25	0.38	0.01	0.36
1	0.2	-0.0049	-0.0089	-0.0049	-0.0091	-0.26	-0.21	0.12	-0.04	-0.40	-0.61	-0.02	-0.36
1	0.4	-0.0067	-0.0162	-0.0067	-0.0179	-0.36	-0.38	0.16	-0.08	-0.66	-0.99	-0.02	-0.36
1	0.6	-0.0044	-0.0149	-0.0044	-0.0212	-0.23	-0.35	0.10	-0.09	-0.57	-0.85	-0.02	-0.36
1	0.8	-0.0020	-0.0087	-0.0020	-0.0222	-0.11	-0.20	0.05	-0.10	-0.36	-0.53	-0.01	-0.36
1	1	-0.0011	-0.0058	-0.0011	-0.0233	-0.06	-0.14	0.03	-0.10	-0.27	-0.40	-0.01	-0.36
0.8	1	-0.0009	-0.0049	-0.0009	-0.0205	-0.05	-0.12	0.02	-0.09	-0.23	-0.34	-0.01	-0.36
0.8	0.8	-0.0018	-0.0075	-0.0018	-0.0196	-0.09	-0.18	0.04	-0.09	-0.32	-0.46	-0.01	-0.36
0.8	0.6	-0.0039	-0.0134	-0.0039	-0.0188	-0.21	-0.31	0.09	-0.08	-0.51	-0.76	-0.02	-0.36
0.8	0.4	-0.0061	-0.0147	-0.0061	-0.0160	-0.33	-0.35	0.14	-0.07	-0.60	-0.90	-0.02	-0.36
0.8	0.2	-0.0046	-0.0082	-0.0046	-0.0084	-0.25	-0.19	0.11	-0.04	-0.37	-0.56	-0.01	-0.36

max negative moment, $M_{ux}(-)$ = -0.99 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.02 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 2.09 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.05 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil EQ

M_y - Moment Summary

	Loads: q , M , or F					SUMMARY
a = 4	0.440	0.194	-0.194	0.037	Boundary Case 1	
b = 11	Moment Coefficient Multipliers					Final Moments / Reinforcing: (d = 9.5")
a / b = 0.3636	53.240	23.474	-23.474	4.477		

		Moment Coefficients				M_y Moments, ft-k/ft				M_y	M_{uy}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0	0.8	0.0007	0.0032	0.0007	0.0088	0.03	0.07	-0.02	0.04	0.13	0.19	0.00	0.36
0	0.6	0.0017	0.0060	0.0017	0.0083	0.09	0.14	-0.04	0.04	0.23	0.34	0.01	0.36
0	0.4	0.0028	0.0068	0.0028	0.0073	0.15	0.16	-0.07	0.03	0.28	0.42	0.01	0.36
0	0.2	0.0024	0.0040	0.0024	0.0041	0.13	0.09	-0.06	0.02	0.18	0.28	0.01	0.36
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
0.2	0	0.0033	0.0048	0.0033	0.0047	0.17	0.11	-0.08	0.02	0.23	0.36	0.01	0.36
0.4	0	0.0082	0.0126	0.0082	0.0127	0.43	0.30	-0.19	0.06	0.60	0.92	0.02	0.36
0.6	0	0.0124	0.0199	0.0124	0.0202	0.66	0.47	-0.29	0.09	0.93	1.43	0.03	0.36
0.8	0	0.0152	0.0249	0.0152	0.0252	0.81	0.58	-0.36	0.11	1.15	1.77	0.04	0.36
1	0	0.0161	0.0267	0.0161	0.0270	0.86	0.63	-0.38	0.12	1.23	1.89	0.04	0.36
1	0.2	-0.0050	-0.0059	-0.0050	-0.0048	-0.27	-0.14	0.12	-0.02	-0.31	-0.49	-0.01	-0.36
1	0.4	-0.0046	-0.0101	-0.0046	-0.0077	-0.24	-0.24	0.11	-0.03	-0.41	-0.62	-0.01	-0.36
1	0.6	-0.0010	-0.0070	-0.0010	-0.0060	-0.05	-0.16	0.02	-0.03	-0.22	-0.32	-0.01	-0.36
1	0.8	0.0005	0.0004	0.0005	-0.0040	0.03	0.01	-0.01	-0.02	0.01	0.01	0.00	0.36
1	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36
1	0.4	-0.0046	-0.0101	-0.0046	-0.0077	-0.24	-0.24	0.11	-0.03	-0.41	-0.62	-0.01	-0.36
0.8	0.4	-0.0042	-0.0093	-0.0042	-0.0071	-0.23	-0.22	0.10	-0.03	-0.38	-0.57	-0.01	-0.36
0.6	0.4	-0.0032	-0.0070	-0.0032	-0.0051	-0.17	-0.16	0.08	-0.02	-0.28	-0.43	-0.01	-0.36
0.4	0.4	-0.0015	-0.0033	-0.0015	-0.0019	-0.08	-0.08	0.04	-0.01	-0.13	-0.20	0.00	-0.36
0.2	0.4	0.0005	0.0015	0.0005	0.0024	0.03	0.04	-0.01	0.01	0.06	0.09	0.00	0.36

max negative moment, $M_{uy}(-)$ = -0.62 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.01 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 1.89 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.04 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 6 - Filters **JOB NO:** 9789A.10
DESIGN TASK: Wall 8 - Soil EQ

Shear Summary

a = 4
b = 11
a / b = 0.3636

Loads: q , M , or F			
0.440	0.194	-0.194	0.037
Shear Coefficient Multipliers			
4.840	2.134	-2.134	0.407

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0074	0.0151	-0.0074	0.3593	-0.04	0.03	0.02	0.15	0.16	0.21	10.81
0	0.8	0.0184	0.1032	0.0184	0.3769	0.09	0.22	-0.04	0.15	0.42	0.61	10.81
0	0.6	0.0678	0.2949	0.0678	0.3652	0.33	0.63	-0.14	0.15	0.96	1.41	10.81
0	0.4	0.1523	0.3564	0.1523	0.3465	0.74	0.76	-0.33	0.14	1.31	1.99	10.81
0	0.2	0.1525	0.2186	0.1525	0.2130	0.74	0.47	-0.33	0.09	0.97	1.50	10.81
0	0.00	0.0156	0.0025	0.0156	0.0012	0.08	0.01	-0.03	0.00	0.05	0.08	10.81
0.2	0	0.0514	0.0324	0.0514	0.0292	0.25	0.07	-0.11	0.01	0.22	0.36	10.81
0.4	0	0.1387	0.1650	0.1387	0.1615	0.67	0.35	-0.30	0.07	0.79	1.24	10.81
0.6	0	0.1936	0.2586	0.1936	0.2564	0.94	0.55	-0.41	0.10	1.18	1.84	10.81
0.8	0	0.2233	0.3131	0.2233	0.3123	1.08	0.67	-0.48	0.13	1.40	2.18	10.81
1	0	0.2326	0.3309	0.2326	0.3307	1.13	0.71	-0.50	0.13	1.47	2.28	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 2.28 k/ft **OK**
$\phi V_c = \phi*2*(f\,'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Area 8 - Washwater Basin Pump Station
ASCE 41 Evaluation

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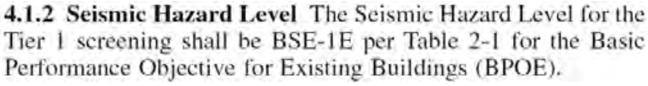
BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
SHEET					
CHKD BY		**DESCRIPTION**	Area 8 - Washwater Basin PS	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening) - Seismic				

SEISMIC HAZARD LEVEL & BASIC PERFORMANCE OBJECTIVE

Note:



4.1.2 Seismic Hazard Level The Seismic Hazard Level for the Tier 1 screening shall be BSE-1E per Table 2-1 for the Basic Performance Objective for Existing Buildings (BPOE).

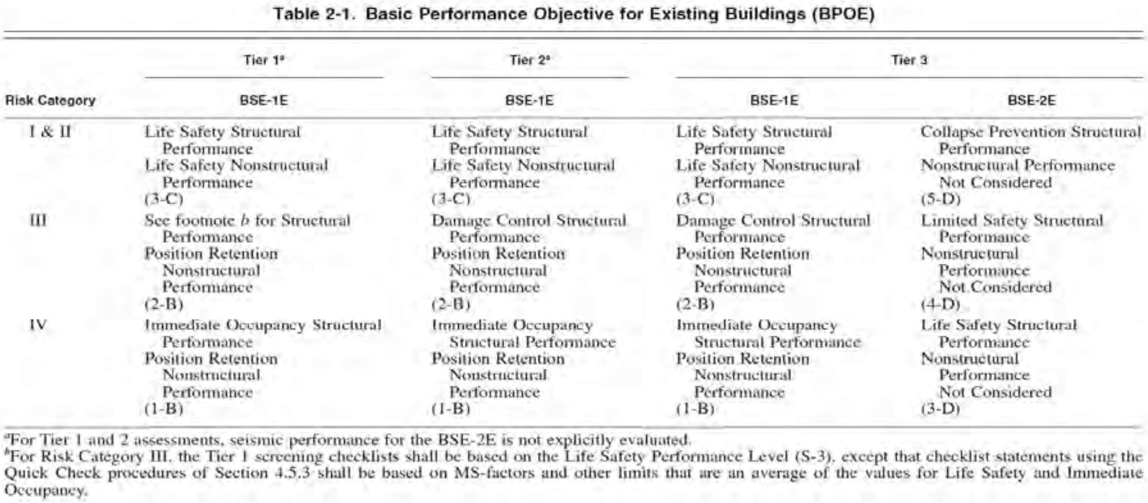


Table 2-1. Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1[a]	Tier 2[a]	Tier 3	
Risk Category	BSE-1E	BSE-1E	BSE-1E	BSE-2E
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III	See footnote *b* for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

[a] For Tier 1 and 2 assessments, seismic performance for the BSE-2E is not explicitly evaluated.

[b] For Risk Category III, the Tier 1 screening checklists shall be based on the Life Safety Performance Level (S-3), except that checklist statements using the Quick Check procedures of Section 4.5.3 shall be based on MS-factors and other limits that are an average of the values for Life Safety and Immediate Occupancy.

BUILDING PERIOD (SECTION 4.5.2.4)

building height, h_n = 11.33 ft

building period adjustment factor, C_t = 0.020

effective viscous damping ratio, β = 0.75

fundamental building period, T = 0.124 sec

SEISMIC PARAMETERS

Building Type = RM1 Table 3-1

modification factor, C = 1.00 Table 4-8

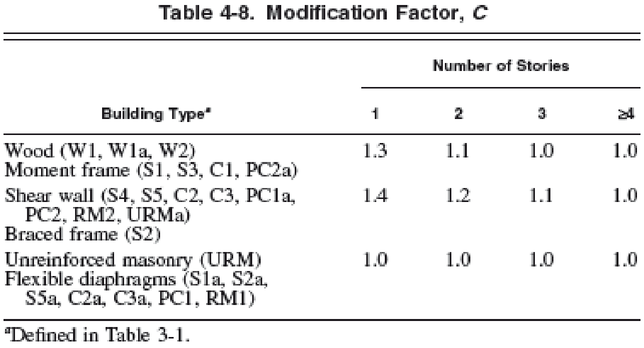


Table 4-8. Modification Factor, *C*

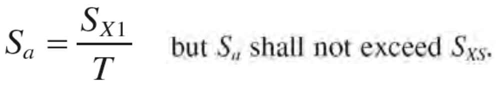
	Number of Stories			
Building Type[a]	1	2	3	≥4
Wood (W1, W1a, W2) Moment frame (S1, S3, C1, PC2a)	1.3	1.1	1.0	1.0
Shear wall (S4, S5, C2, C3, PC1a, PC2, RM2, URMa) Braced frame (S2)	1.4	1.2	1.1	1.0
Unreinforced masonry (URM) Flexible diaphragms (S1a, S2a, S5a, C2a, C3a, PC1, RM1)	1.0	1.0	1.0	1.0

[a] Defined in Table 3-1.

spectral acceleration at 1-sec for BSE-1E, S_{x1} = 0.372 g USGS Seismic Map

spectral acceleration at short period for BSE-1E, S_{xs} = 0.611 g USGS Seismic Map

spectral acceleration, S_a = 0.611 g



$S_a = \frac{S_{X1}}{T}$ but S_a shall not exceed S_{XS}.

base shear coefficient, V = 0.611 W Eq 4-1

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
CHKD BY		**DESCRIPTION**	Area 8 - Washwater Basin PS	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening) - Building Weight & Base Shear			**SHEET**	

DEAD LOAD (Seismic Weight)

Roof Weight

Roofing	=	5.00	psf
Metal Roof Deck	=	3.00	psf
Steel Joist	=	7.00	psf
Miscellaneous (MEP)	=	5.00	psf
	Total =	20.00	psf

Roof Length	=	36.67	ft
Roof Width	=	16.67	ft
	Total Roof Weight =	12.23	kips

	UW (in)	Trib Ht (ft)	Length (ft)			
Parapet Wall	84.00	2.00	109.34	=	18.37	kips
Wall Below	84.00	5.67	109.34	=	52.03	kips

Roof Seismic Weight = 82.63 kips

Seismic Weight & Base Shear

Base Shear Coefficient	=	0.611	g
Total Seismic Weight	=	83	kips
Design Base Shear	=	50	kips

LIVE LOAD

Roof Live Load = 20.0 psf

BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 8 - Washwater Basin PS **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening) - CMU Wall Story Rigidity

SHEAR WALL RIGIDITY

$P =$ 1000 kip -- applied unit force

$f'_m =$ 1500 psi -- concrete compressive strength
$E_{mc} =$ 194400 ksf -- modulus of elasticity
$E_{mv} =$ 77760 ksf -- shear modulus

Cantilever at Top of Each Floor:

$$\delta_c = \frac{4P}{Et}\left[\left(\frac{H}{L}\right)^3 + 0.75\frac{H}{L}\right]$$

Fixed at Openings:

$$\delta_f = \frac{P}{Et}\left[\left(\frac{H}{L}\right)^3 + 3\frac{H}{L}\right]$$

	Thick (in)	Height (ft)	Length (ft)	I (ft^3)	Δ (in)	R 1/Δ
CMU Walls NS-Direction						
East	7.63	13.33	38.00	2907	0.1189	8.41
West	7.63	13.33	38.00	2907	0.1189	8.41
					ΣR =	***16.82***

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CHKD BY **DESCRIPTION** Area 8 - Washwater Basin PS **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening) - Concrete Wall Story Rigidity

SOFT STORY CHECK (Relative Rigidity for Story Drift)

$P =$ 1000 kip -- applied unit force

$f'_c =$ 4000 psi -- concrete compressive strength
$E_{mc} =$ 519119.5 ksf -- modulus of elasticity
$E_v =$ 207647.8 ksf -- shear modulus

Cantilever at Top of Each Floor:

$$\delta_c = \frac{4P}{Et}\left[\left(\frac{H}{L}\right)^3 + 0.75\,\frac{H}{L}\right]$$

Fixed at Openings:

$$\delta_f = \frac{P}{Et}\left[\left(\frac{H}{L}\right)^3 + 3\,\frac{H}{L}\right]$$

	Thick (in)	Height (ft)	Length (ft)	I (ft^3)	Δ (in)	R 1/Δ
Concrete Walls Below CMU Walls in NS-Direction						
East	18.00	17	10.00	125	0.3814	2.62
West	18.00	17	38.00	6859	0.0262	38.16
					ΣR =	***40.79***

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
CHKD BY		**DESCRIPTION**	Area 8 - Washwater Basin PS	**JOB NO.**	10721A.00
DESIGN TASK			ASCE 41 (Tier 1 Screening "Damage Control") - Shear Stress	**SHEET**	

SEISMIC LOAD VERTICAL DISTRIBUTION

Wall Shear Stress Check

4.5.3.3 Shear Stress in Shear Walls The average shear stress in shear walls, v_j^{avg}, shall be calculated in accordance with Eq. (4-9).

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{A_w}\right) \qquad (4\text{-}9)$$

where V_j = Story shear at level j computed in accordance with Section 4.5.2.2.

A_w = Summation of the horizontal cross-sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration where computing A_w. For masonry walls, the net area shall be used. For wood-framed walls, the length shall be used rather than the area.

M_s = System modification factor; M_s shall be taken from Table 4-9.

Table 4-9. M_s Factors for Shear Walls

Wall Type	Level of Performance LS	Level of Performance IO
Reinforced concrete, precast concrete, wood, and reinforced masonry	4.0	2.0
Unreinforced masonry	1.5	1.0

Table 4-10. M_s Factors for Diagonal Braces

Brace Type	d/t[a]	Level of Performance LS	Level of Performance IO
Tube[b]	$<90/(F_{ye})^{1/2}$	6.0	2.5
	$>190/(F_{ye})^{1/2}$	3.0	1.5
Pipe[b]	$<1500/F_{ye}$	6.0	2.5
	$>6000/F_{ye}$	3.0	1.5
Tension-only		3.0	1.5
All others		6.0	2.5

[a] Depth-to-thickness ratio.

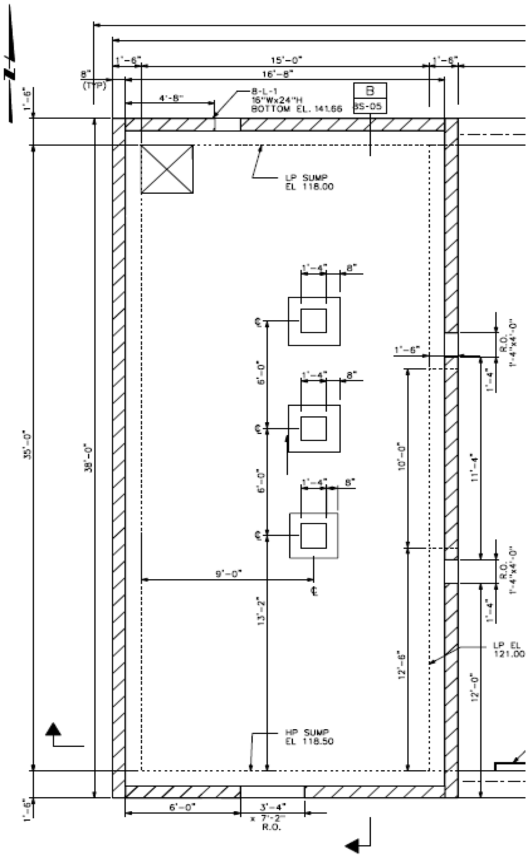
[b] Interpolation to be used for tubes and pipes.

$F_{ye} = 1.25F_y$; expected yield stress.

$v_{s,allow}$ = 70 psi

M_s = 3.0 <-- "Damage Control (between "LS" & "IO")

	t_{wall} (in)	$L_{net,\ wall}$ (ft)	A_{wall} (in^2)	*V (kips)*	*v shear (psi)*	
Walls in NS-Dir	7.63	70.67	6466	*50.00*	*2.58*	***<= OK***
Walls in EW-Dir	7.63	31.34	2868	*50.00*	*5.81*	***<= OK***



BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 8 - Washwater Basin PS **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in Transverse Direction

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, κ = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 36.67 ft
diaphragm depth, L_{diaph} = 16.67 ft

spectral acceleration, S_a = 0.611 g
building seismic weight, W = 83 kips

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 71 kips
diaph shear, $Q_{UD} = F_d / (2*L_{diaph})$ = 2130 plf

allowable diaphragm shear = 1069 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1710 plf
$m_1*\kappa*Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

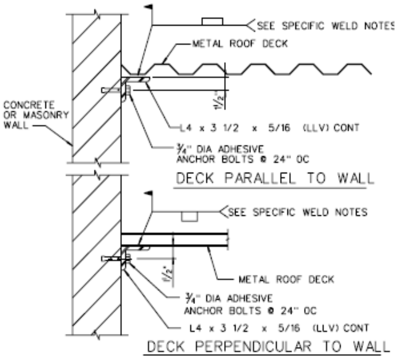
chord force, $Q_{UD} = (F_d*L_{span}) / (8*L_{diaph)}$ = 19522 lbs

strength reduction factor, ϕ = 1.00
Number of Bars = 2 bars
Bar Size = #5
Yield Stress f_y = 60,000 psi
$A_{s,total}$ = 0.62 in^2
Tensile Capacity at Opng, ϕT_n = 37200 lbs
$m_2*\kappa*Q_{CE}$ = 134850 lbs

Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f_m = 1500 psi



DECK PARALLEL TO WALL

DECK PERPENDICULAR TO WALL

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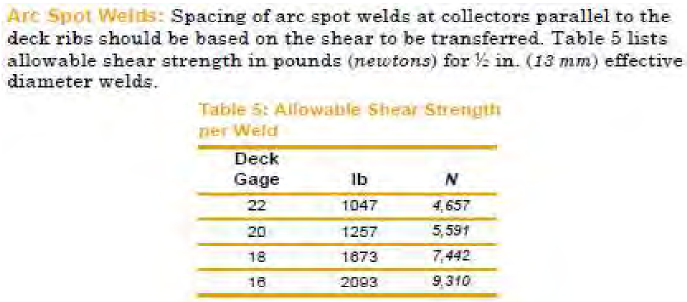
CHKD BY **DESCRIPTION** Area 8 - Washwater Basin PS **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in Transverse Direction

anchor bolt shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12) =$ 4259 lbs /bolt
$Q_{UF} = Q_E / (J*C_1*C_2) =$ 1521 lbs /bolt

projected area of anchor bolt shear, $A_{pv} =$ 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, $A_{pt} =$ 76.97 in^2 lbs /bolt
cross section area of anchor bolt, $A_b =$ 0.44 in^2 lbs /bolt

strength reduction factor, $\phi =$ 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5} =$ 5962 lbs /bolt masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4} =$ 5327 lbs /bolt masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5} =$ 23848 lbs /bolt anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y =$ 15904 lbs /bolt steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddle weld shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12) =$ 2130 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2) =$ 761 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, $C_{WELD} =$ 1.65 per IAPMO-ER #0217
$KQ_{CL} =$ 2074 lbs /weld

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = 0.77 <-- ***OK*** diaphragm shear
demand capcity ratio, DCR = *0.14* <-- ***OK*** diaphragm chord
demand capcity ratio, DCR = *0.26* <-- ***OK*** masonry breakout
demand capcity ratio, DCR = *0.29* <-- ***OK*** masonry crushing
demand capcity ratio, DCR = *0.06* <-- ***OK*** anchor bolt pryout
demand capcity ratio, DCR = *0.10* <-- ***OK*** steel yielding
demand capcity ratio, DCR = 0.37 <-- ***OK*** puddle weld strength

BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 8 - Washwater Basin PS **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in Longitudinal Direction

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, $\mathcal{K}$ = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 16.67 ft
diaphragm depth, L_{diaph} = 36.67 ft

spectral acceleration, S_a = 0.611 g
building seismic weight, W = 83 kips

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 71 kips
diaph shear, $Q_{UD} = F_d / (2{*}L_{diaph})$ = 968 plf

allowable diaphragm shear = 1069 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1710 plf allowable multiplied by 1.4 for strength level
$m_1{*}\mathcal{K}{*}Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

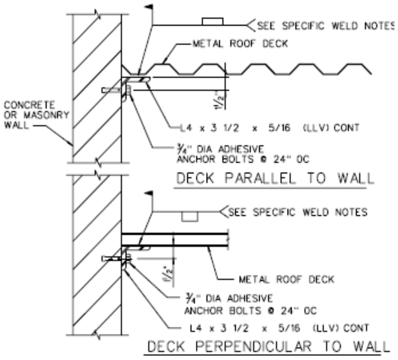
chord force, $Q_{UD} = (F_d{*}L_{span}) / (8{*}L_{diaph})$ = 4034 lbs

strength reduction factor, ϕ = 1.00
Number of Bars = 2 bars
Bar Size = #5
Yield Stress f_y = 60,000 psi
$A_{s,total}$ = 0.62 in^2
Tensile Capacity at Opng, ϕT_n = 37200 lbs
$m_2{*}\mathcal{K}{*}Q_{CE}$ = 134850 lbs

Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f_m = 1500 psi



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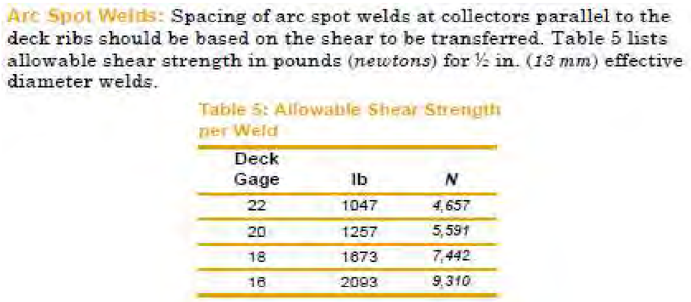
BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 8 - Washwater Basin PS **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in Longitudinal Direction

anchor bolt shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12) =$ 1936 lbs /bolt
$Q_{UF} = Q_E / (J*C_1*C_2) =$ 691 lbs /bolt

projected area of anchor bolt shear, $A_{pv} =$ 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, $A_{pt} =$ 76.97 in^2 lbs /bolt
cross section area of anchor bolt, $A_b =$ 0.44 in^2 lbs /bolt

strength reduction factor, $\phi =$ 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5} =$ 5962 lbs /bolt masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4} =$ 5327 lbs /bolt masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5} =$ 23848 lbs /bolt anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y =$ 15904 lbs /bolt steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddle weld shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12) =$ 968 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2) =$ 346 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, $C_{WELD} =$ 1.65 per IAPMO- allowable multiplied by 1.4 for
$KQ_{CL} =$ 2074 lbs /weld

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.35	<--	**OK**	diaphragm shear
demand capcity ratio, DCR =	*0.03*	<--	**OK**	diaphragm chord
demand capcity ratio, DCR =	*0.12*	<--	**OK**	masonry breakout
demand capcity ratio, DCR =	*0.13*	<--	**OK**	masonry crushing
demand capcity ratio, DCR =	*0.03*	<--	**OK**	anchor bolt pryout
demand capcity ratio, DCR =	*0.04*	<--	**OK**	steel yielding
demand capcity ratio, DCR =	0.17	<--	**OK**	puddle weld strength

BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 8 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Joist Supports

WALL ANCHORAGE FORCE

4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \tag{4-13}$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

wall height to diaphragm, h_w = 11.33 ft
parapet height, h_p = 2.00 ft

unit weight of wall, w_p = 84.00 psf
Ψ ("IO") = 1.50 <-- "Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

beam spacing = 6.11 ft
wall out-of-plane load = 590 lbs/ ft

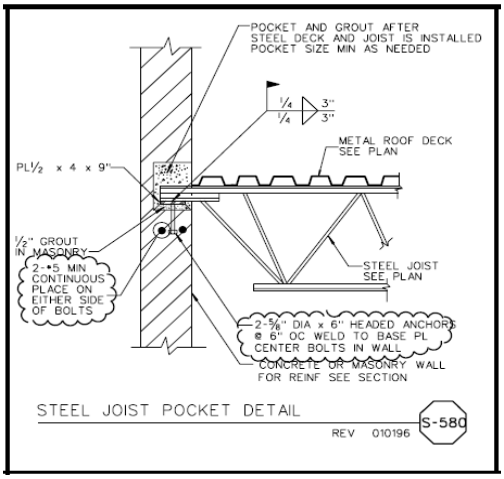
wall anchorage force, T_c = 3605 lbs

Masonry & Steel Strength

number of anchor bolts = 2
anchor bolt size = 0.625 in
anchor bolt embed = 6.00 in
anchor bolt edge distance = 3.81 in
anchorage spacing = 6.00 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

projected area of anchor bolt shear, A_{pv} = 46 in^2
projected area of anchor bolt tension, A_{pt} = 137 in^2
cross section area of anchor bolt, A_b = 0.31 in^2



STEEL JOIST POCKET DETAIL

$\phi B_{vnb} = 1.0 * 4 * A_{pv} * (f'_m)^{0.5}$ = 7,074 lbs masonry breakout
$\phi B_{vnpry} = 1.0 * 1050 * (f'_m * A_b)^{1/4}$ = 9,726 lbs masonry crushing
$\phi B_{vnpry} = 1.0 * 8 * A_{pt} * (f'_m)^{0.5}$ = 42,525 lbs anchor bolt pryout
$\phi B_{vns} = 1.0 * 0.6 * A_b * f_y$ = 13,254 lbs steel yielding

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = *0.51* <-- *OK* masonry breakout
demand capcity ratio, DCR = *0.37* <-- *OK* masonry crushing
demand capcity ratio, DCR = *0.08* <-- *OK* anchor bolt pryout
demand capcity ratio, DCR = *0.27* <-- *OK* steel yielding

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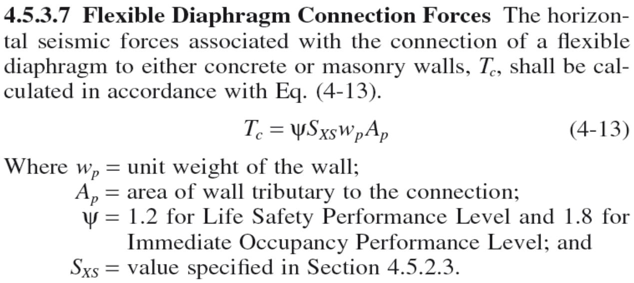
BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 8 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger

WALL ANCHORAGE FORCE



4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \qquad (4\text{-}13)$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

wall height to diaphragm, h_w = 11.33 ft
parapet height, h_p = 2.00 ft

unit weight of wall, w_p = 84.00 psf
Ψ ("IO") = 1.50 <-- "Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

anchor bolts spacing = 24.00 in
wall out-of-plane load = 590 lbs/ ft

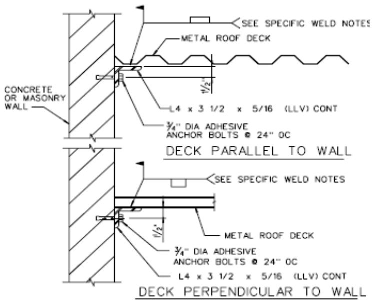
wall anchorage force, T_c = 1180 lbs /bolt

Masonry & Steel Strength

anchor bolt size = 0.750 in
anchor bolt embed = 3.50 in
anchor bolt edge distance = 3.81 in
anchorage spacing = 6.00 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

projected area of anchor bolt tension, A_{pt} = 38 in^2
cross section area of anchor bolt, A_b = 0.44 in^2



$\phi B_{anb} = 1.0*4*A_{pt}*(f'_m)^{0.5}$ = 5,962 lbs masonry breakout
$\phi B_{ans} = 1.0*A_b*f_y$ = 15,904 lbs steel yielding

Ledger Angle

yield strength, f_y = 36,000 psi
ledger angle thick, t = 0.31 in
moment arm, l_{arm} = 1.19 in distance from top of ledger to center of AB
effective width, b = 3.00 in
section modulus, S = 0.0488 in^3

shear stress = 1,259 psi

moment = 1,404 lb-in
flexural stress = 28,763 psi

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 8 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger					

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	*0.20*	**<--**	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.07*	**<--**	***OK***	steel yielding
demand capcity ratio, DCR =	*0.03*	**<--**	***OK***	ledger shear
demand capcity ratio, DCR =	*0.80*	**<--**	***OK***	ledger flexural

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
CHKD BY		**DESCRIPTION**	Area 8 - Washwater Basin PS	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck				

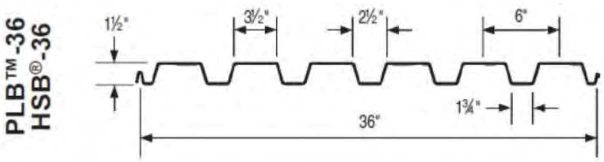
SHEET

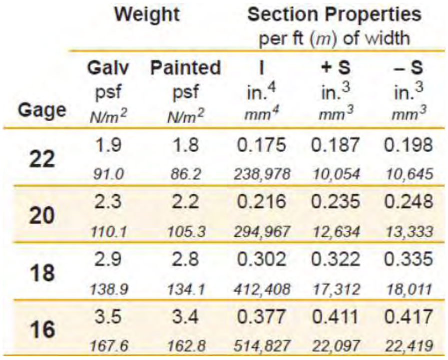
STEEL DECK PROPERTIES (ASTM A653, Grade 33)

Modulus of Elasticity, E = 29500 ksi

Yield Strength, F_y = 38 ksi

Ultimate Strength, F_u = 52 ksi





Gage	Weight Galv psf *N/m²*	Weight Painted psf *N/m²*	Section Properties per ft (*m*) of width I in.⁴ *mm⁴*	Section Properties per ft (*m*) of width + S in.³ *mm³*	Section Properties per ft (*m*) of width – S in.³ *mm³*
22	1.9 *91.0*	1.8 *86.2*	0.175 *238,978*	0.187 *10,054*	0.198 *10,645*
20	2.3 *110.1*	2.2 *105.3*	0.216 *294,967*	0.235 *12,634*	0.248 *13,333*
18	2.9 *138.9*	2.8 *134.1*	0.302 *412,408*	0.322 *17,312*	0.335 *18,011*
16	3.5 *167.6*	3.4 *162.8*	0.377 *514,827*	0.411 *22,097*	0.417 *22,419*

Steel Deck = HSB-36

Gage = 20

Deck Span, L = 5.67 ft

DESIGN LOAD (Service Level)

Roof Load, w = 30 psf *--- steel deck gravity*

Wall Out-of-Plane Load, F = 590 lb/ft *--- deck axial load*

Design Flexural Moment :

Neutral Axis, y_b = 0.919 in

M_{roof} = 1.447 kip-in /ft *--- moment due to gravity load = w * L2 / 8*

M_{ecc} = 0.387 kip-in /ft *--- moment due to wall out-of-plane = (F/1.4) * yb*

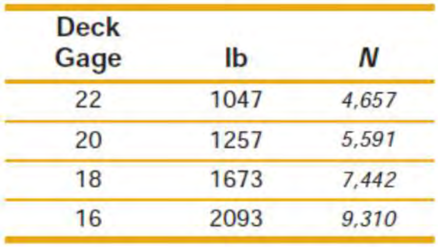
M_{total} = 1.834 kip-in /ft

ARC-SPOT WELD (WALL OUT-OF-PLANE)

Effective Weld Size Dia, d_e = 1/2 in

Weld Pattern = 5 per 36/sheet

Allowable Weld Capacity = 2.10 kip/ft **<= OK**



Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

Allowable shear strength for 1/2" effective diameter puddle welds.

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BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 8 - Washwater Basin PS **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck

STEEL DECK ALLOWABLE COMPRESSION

Effective Length Factor, K = 1.00

Deck Thickness, t = 0.0359 in

Width of Top Flange, w = 3.50 in

Gross Section Area, A_g = 0.599 in^2/ft

radius of gyration, r = 0.601 in

KL/r = 113

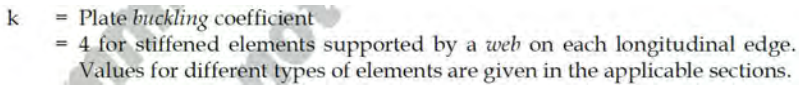
λ_c = 1.29

F_n = 18.85 ksi

Effective Width of Top & Bottom Flange Under Compression
(Assume Bottom Flange Fully Effective)

Ω_c = 1.8 --- *factor of safety*

k = 4



k = Plate *buckling* coefficient
= 4 for stiffened elements supported by a *web* on each longitudinal edge. Values for different types of elements are given in the applicable sections.

Poisson's Ratio = 0.300

F_{cr} = 11.22

λ = 1.296

ρ = 0.641

Effective Flange Width, b = 2.242 in --- *effective flange width =* ρw

Effective Section Area, A_e = 0.554 in^2/ft --- *effective section area*

P_n / Ω_c = 5.80 kip /ft **<= OK** --- $A_e * F_n / \Omega_c$

STEEL DECK ALLOWABLE TENSION

Gross Section Area, A_g = 0.599 in^2/ft

Ω_{T1} = 1.67

T_{n1} / Ω_{T1} = 13.63 kip /ft **<= OK** --- $A_g * F_y / \Omega_{T1}$

Ω_{T2} = 2.00

T_{n2} / Ω_{T2} = 15.57 kip /ft **<= OK** --- $A_g * F_u / \Omega_{T2}$

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**	Area 8 - Washwater Basin PS			**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck					

STEEL DECK ALLOWABLE BENDING

Ω_b = 1.67

S_+ = 0.235 in^3/ft --- *positive section modulus*

M_n / Ω_b = 5.35 kip-in /ft **<= OK** --- $S_+ * F_y / \Omega_b$

COMBINED LOAD INTERACTION

Bending-Tension Interaction:

DCR = 0.386 **<= OK**

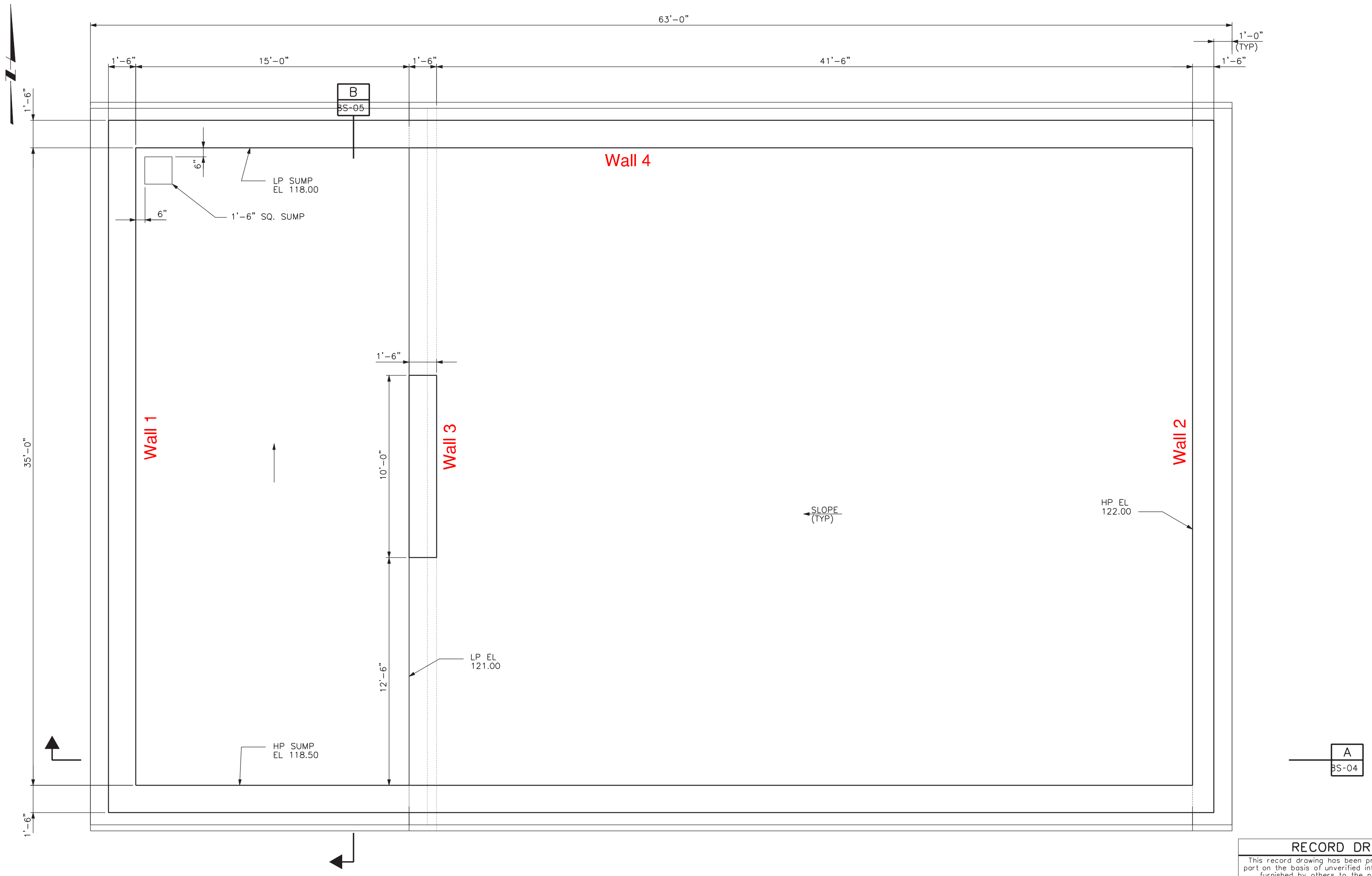
Bending-Compression Interaction:

DCR = 0.445 **<= OK**

Area 8 - Washwater Basin Concrete Structure
ACI 350 Evaluation

WALL IDENTIFICATION

Job No: 1076081 File: P:\Wilsonville, City Of\Willamette WTP D-B\FILE-TRANSFER\cad_drawings\str\wj08s01.dgn Plot Date: 04/24/2003 01:32:02 PM



FOUNDATION PLAN

RECORD DRAWING

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REV	DATE	BY	DESCRIPTION
R	12-02	AP	RECORD DRAWING

SCALE 3/8"=1'-0"

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

DESIGNED B. CROOK
DRAWN B. CROOK
CHECKED

SUBMITTED BY
LICENSE NO. DATE
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Portland
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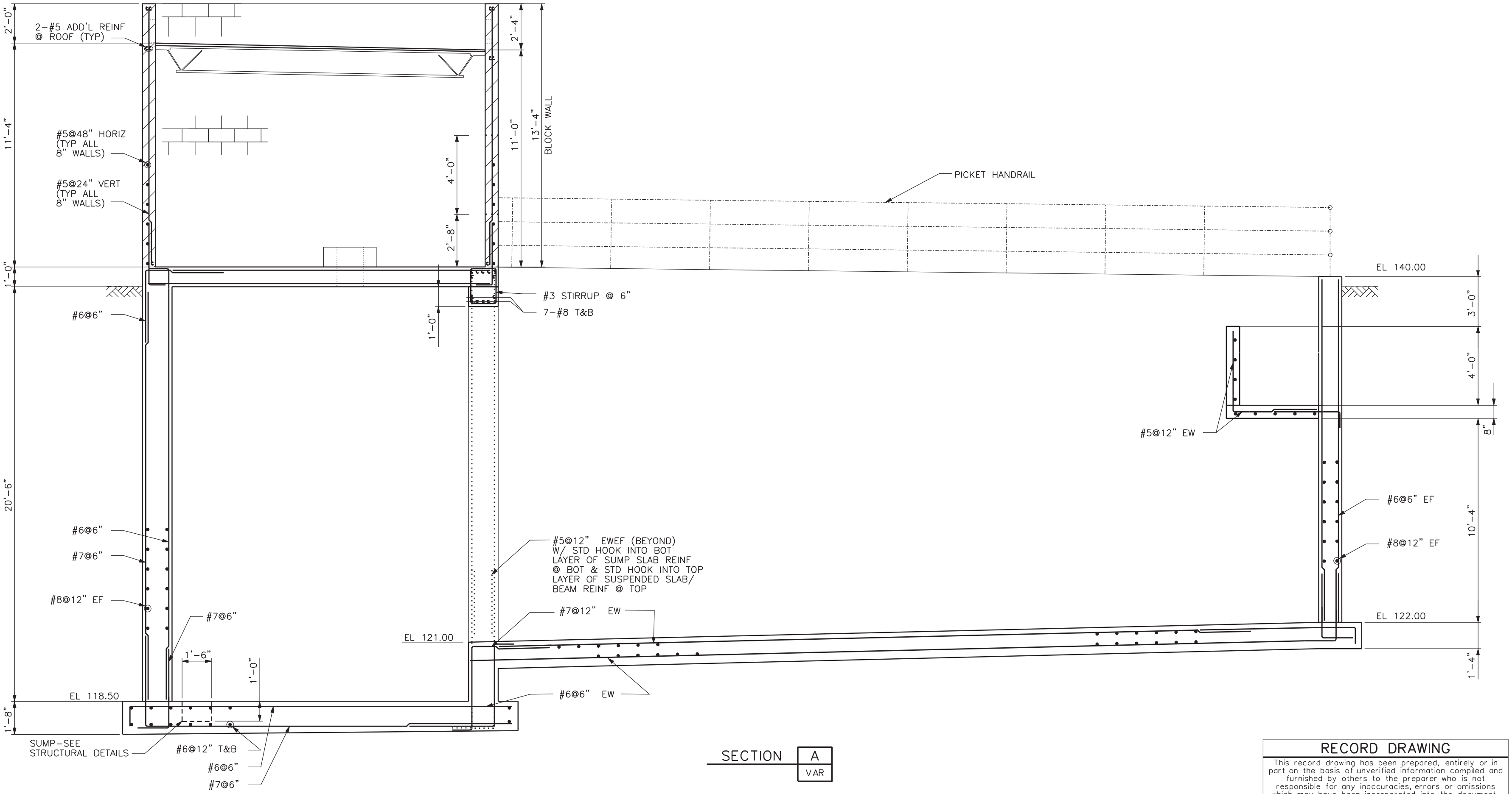
in OREGON

CITY OF WILSONVILLE
WILLAMETTE RIVER WATER TREATMENT PLANT
WASTE WASHWATER BASIN AND PUMP
STATION–STRUCTURAL
FOUNDATION PLAN

SHEET
8S–01

Job No: 1076081 File: P:\Wilsonville, City Of\Willamette WTP D-B\FILE-TRANSFER\cad_drawings\str\wi08s04 Plot Date: 01/24/2003 01:35:20 PM



SECTION A
VAR

RECORD DRAWING

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REV	DATE	BY	DESCRIPTION
R	12-02	AP	RECORD DRAWING

SCALE 3/8"=1'-0"

WARNING 0 ½ 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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CITY OF WILSONVILLE
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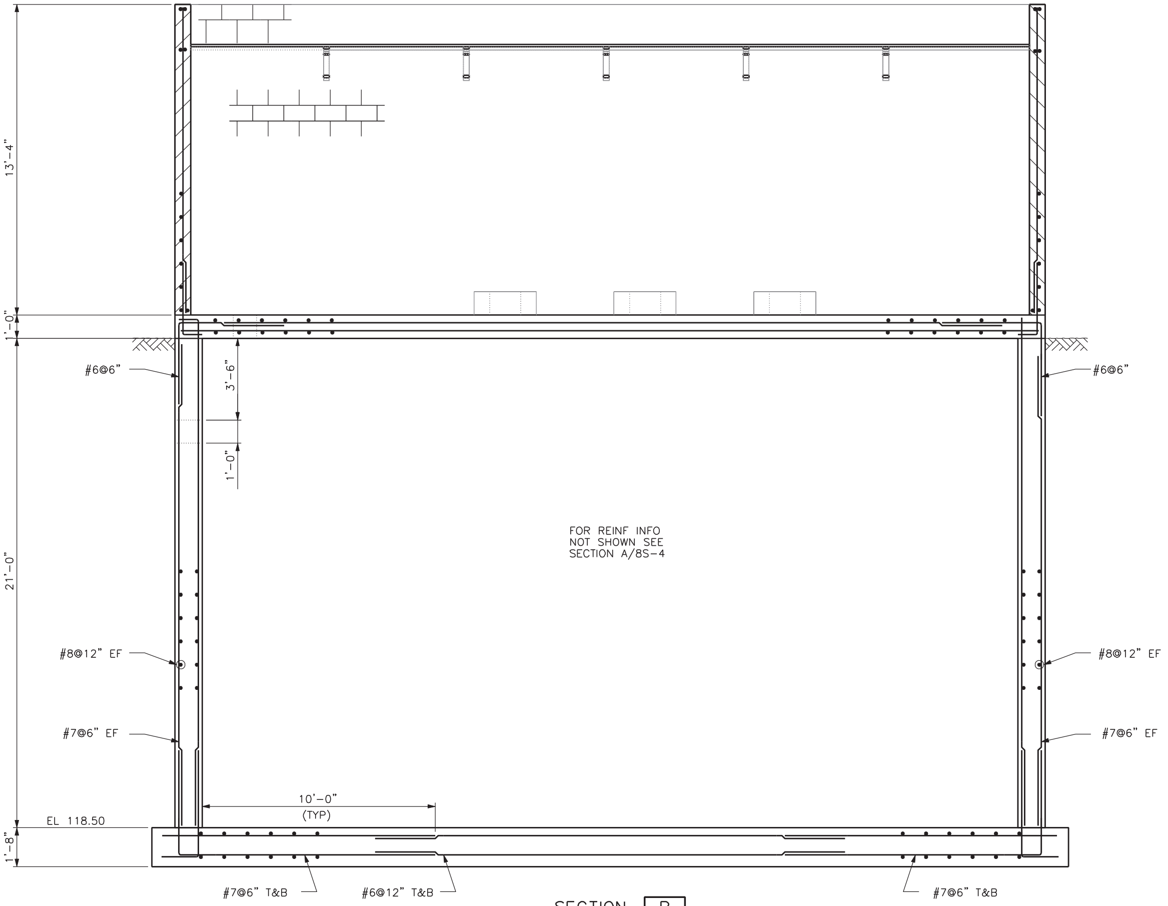
WASTE WASHWATER BASIN AND PUMP STATION-STRUCTURAL SECTION

SHEET
8S-04



SECTION B
VAR

RECORD DRAWING

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Plot Date: 01/24/2003 01:37:27 PM

REV	DATE	BY	DESCRIPTION
R	12-02	AP	RECORD DRAWING

SCALE
3/8"=1'-0"

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

DESIGNED B. CROOK
DRAWN B. CROOK
CHECKED

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WASTE WASHWATER BASIN AND PUMP
STATION–STRUCTURAL
SECTION

SHEET
8S-05

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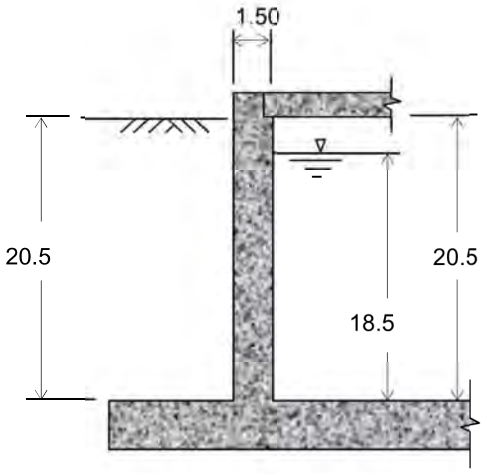
BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 1 - Pressures

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **58** ft
tank wall thickness, t_w = **18** inch
wall height to underside of roof, H_w = **20.5** ft

liquid height, H_L = **18.5** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION

(wall fixity = pinned at roof & fixed at floor)

Soil Data

The site has no groundwater.

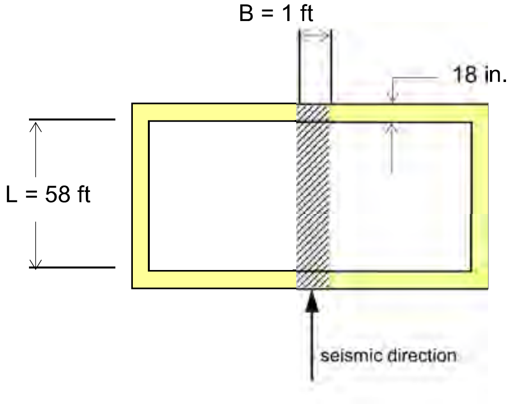
soil height above top of foundation base = **20.5** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0** k/ft^3
live load lateral surcharge = **0.100** ksf
0

concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.15**
Response modification factor, R_{wc} = **1.3**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:** Sep-17	**CLIENT:** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**JOB NO:**	10721A.10
DESIGN TASK:			Wall 1 - Pressures		

Weights:

unit 1-ft width wall mass, W_w = (18/12) * (20.5) * 0.15 = 4.61 kip

wall c.g. relative to base, h_w = 20.5 / 2 = 10.250 ft

unit width liquid mass, W_L = (58) * (1) * (18.5) * 32.17 = 66.96 kip

Seismic:

1). structure stiffness and dynamic property:

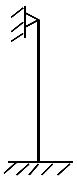
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.14338 $k\text{-}sec^2/ft^2$

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.37999 $k\text{-}sec^2/ft^2$

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 7.845 ft



wall fixity condition is pinned at roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 2632.44 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (2632.44 / (0.1434 + 0.38))\hat{}½ = 70.9214 \text{ rad/sec}$$

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 70.9214 = 0.0886 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = \quad (3.16*32.2*\tanh(3.16*(0.319)))\hat{}½ = 8.8181$$

$$\omega_c = \frac{\lambda}{\sqrt{L}} = \quad 8.8181 / (58)\hat{}½ = 1.1579 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 1.1579 = 5.4265 sec

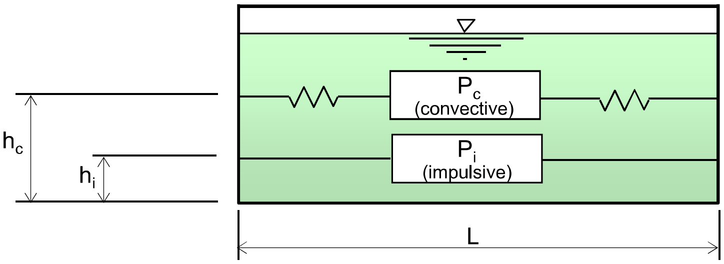
Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.181 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ ,\quad \text{but} \leq 1.0 = \quad 0.5712$$

Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 1 - Pressures



Dynamic Model

$L =$ 58 ft
$B =$ 1 ft
$H_L =$ 18.5 ft
$W_L =$ 66.96 kip

$L / H_L =$ 3.13514
$H_L / L =$ 0.31897

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L \left(\frac{\tanh\left(0.866 \frac{L}{H_L}\right)}{0.866 \frac{L}{H_L}} \right) = \quad 66.96*(\tanh(0.866*(3.1351)) / 0.866*(3.1351)) = \quad 24.45 \text{ kip}$$

hi (EBP) = HL * 0.375 = 18.5 * 0.375 = 6.938 ft
hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 23.023 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_{wi}} \right) W_i = \quad (0.611 * 1.25 / 2.15)*24.45 = \quad 8.7 \text{ kip}$$

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L \left(0.264 \left(\frac{L}{H_L} \right) \tanh\left(3.16 \left(\frac{H_L}{L} \right) \right) \right) = \quad 66.96*(0.264*(3.1351)*\tanh(3.16*(0.319))) = \quad 42.39 \text{ kip}$$

$$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 9.961 \text{ ft}$$

$$h_{c\ (IBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) = \quad 25.572 \text{ ft}$$

$$\text{convective force, } P_c = \left(\frac{S_{ac}\ I}{R_{wc}} \right) W_c = \quad (0.1813 * 1.25 / 1.3)*42.39 = \quad 7.4 \text{ kip}$$

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**SHEET:**	
DESIGN TASK:	Wall 1 - Pressures			**JOB NO:**	10721A.10

5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 4.61 kip

wall c.g. relative to base, h_w = 10.250 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (0.611*1.25*0.5712/2.15)*4.61 = 0.94 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (58/2)*(0.1813/1.4*1.25) = 4.69 \text{ ft}$$

Wave height is greater than the freeboard of 2-ft. Check possible effects on the roof.

7). vertical acceleration:

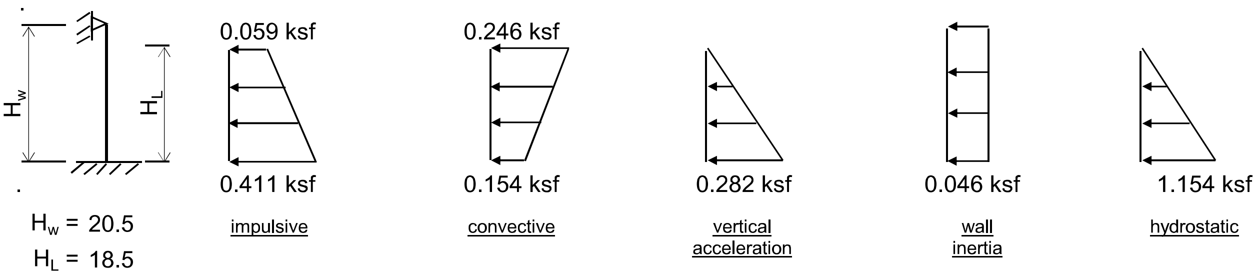
design horizontal accereration, S_{DS} = 0.611 *g

vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4*S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444*1*1/1 = 0.2444 \text{ g}$$

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 8.70 kip

h_i = 6.938 ft

at $y = H_L$, p_{iy} = 0.059 ksf

at base $y = 0$, p_{iy} = 0.411 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 7.40 kip

h_c = 9.961 ft

at $y = H_L$, p_{cy} = 0.246 ksf

at base $y = 0$, p_{cy} = 0.154 ksf

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vertical acceleration:

$\ddot{u} = 0.2444$

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

at $y = H_L$, p_{vy} = 0.000 ksf

at base $y = 0$, p_{vy} = 0.282 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ \ I\ \ \varepsilon\,\gamma_c\ (t_w/12)}{R_{wi}} =$$

p_{wy} = 0.2029 $* \gamma_c * (t_w/12)$

at $y = H_w$, p_{wy} = 0.046 ksf

at base $y = 0$, p_{wy} = 0.046 ksf

hydrostatic:

$q_{hy} = \gamma_L\,(H_L - y) =$

at $y = H_L$, q_{hy} = 0.000 ksf

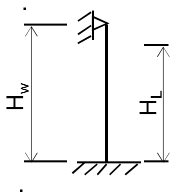
at base $y = 0$, q_{hy} = 1.154 ksf

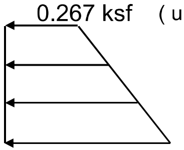
combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at $y = H_w$, p_y = 0.267 ksf

at base $y = 0$, p_y = 0.559 ksf





0.267 ksf (unfactored = 0.267 / 1.4 = 0.191 ksf)

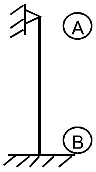
0.559 ksf (unfactored = 0.559 / 1.4 = 0.399 ksf)

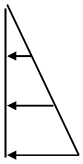
resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

wall height, H_w = 20.5 ft

liquid height, H_L = 18.5 ft

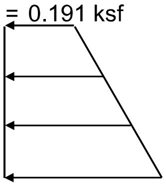




1.154 ksf

hydrostatic

unfactored load = 0.191 ksf



unfactored load = 0.399 ksf

resultant dynamic pressures

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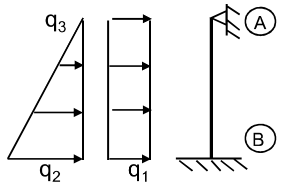
DESIGN TASK:	Wall 1 - Pressures				

10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 20.5 ft

soil height above top of base = 20.5 ft

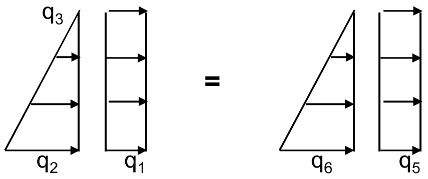
groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:



LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 1.1275 ksf

unfactored soil, q3 = 0.0000 ksf

equivalent soil loadings:

unfactored q5 = 0.1000 ksf

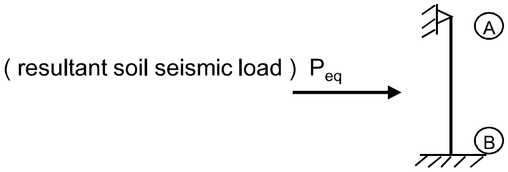
unfactored q6 = 1.1275 ksf

soil seismic:

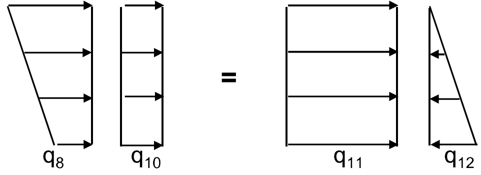
resultant factored soil seismic load per foot of wall width, $P_{u\ (eq)}$ = **7.14** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **13.66** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0007 ksf

equivalent soil seismic, q9 = 0.6959 ksf

wall seismic (see wall page 5), q10 = 0.0457 ksf

equivalent soil seismic, q11 = q9 + q10 = 0.7416 ksf

equivalent soil seismic, q12 = q8 - q9 = -0.6952 ksf

unfactored equivalent soil seismic, q8 =0.0007 / 1.4 = 0.0005 ksf

unfactored equivalent soil seismic, q9 =0.6959 / 1.4 = 0.4971 ksf

unfactored wall seismic , q10 = 0.0457 / 1.4 = 0.0326 ksf

unfactored equivalent soil seismic, q11 =0.7416 / 1.4 = 0.5297 ksf

unfactored equivalent soil seismic, q12 =-0.6952 / 1.4 = -0.4966 ksf

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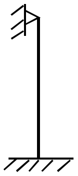
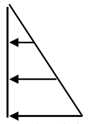
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

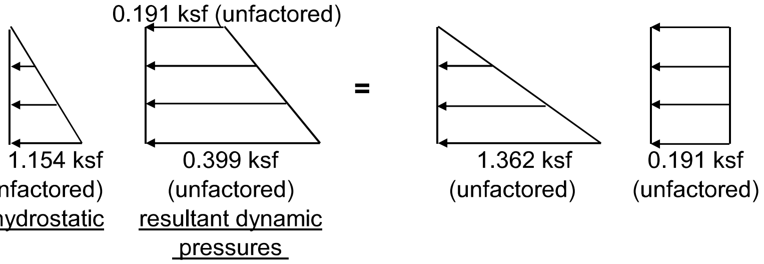
a). load case 1: hydrostatic water

wall height = 20.5 ft
water depth = 18.5 ft



(unfactored) 1.154 ksf

b). load case 2: hydrostatic + dynamic:

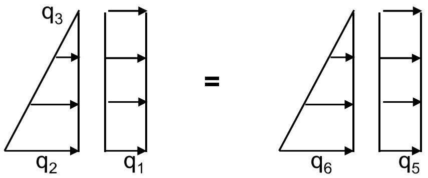


wall height = 20.5 ft
water depth = 18.5 ft

c). load case 3: static soil + LL surcharge:

wall height = 20.5 ft
soil height on wall = 20.5 ft

equivalent static soil & surcharge loadings...

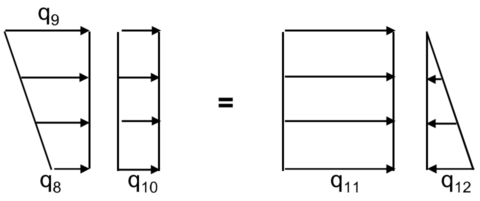


LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 1.128 ksf
unfactored soil, q3 = 0.000 ksf

equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 1.128 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.5 ft
soil height on wall = 20.5 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.497 ksf
unfactored equivalent soil seismic, q10 = 0.033 ksf
unfactored equivalent soil seismic, q11 = 0.530 ksf
unfactored equivalent soil seismic, q12 = -0.497 ksf

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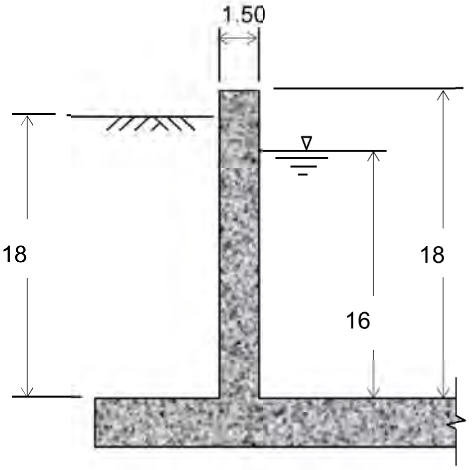
DESIGN TASK:			Wall 2 - Pressures		

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **no roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **58** ft
tank wall thickness, t_w = **18** inch
wall height, H_w = **18** ft

liquid height, H_L = **16** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION

Soil Data

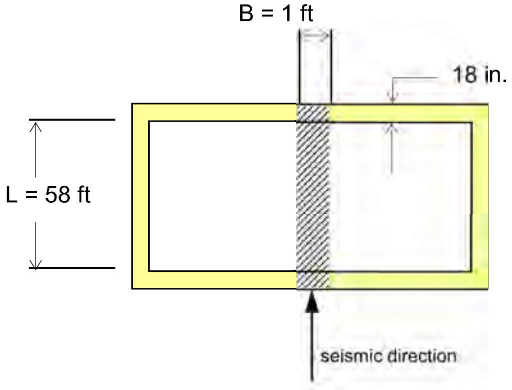
The site has no groundwater.

soil height above top of foundation base = **18** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0** k/ft^3
live load lateral surcharge = **0.100** ksf
0
concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **3**
Response modification factor, R_{wc} = **1**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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DESIGN TASK:		Wall 2 - Pressures					

Weights:

unit 1-ft width wall mass, W_w = (18/12) * (18) * 0.15 = 4.05 kip
wall c.g. relative to base, h_w = 18 / 2 = 9.000 ft

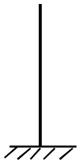
unit width liquid mass, W_L = (58) * (1) * (16) * 32.17 = 57.91 kip

Seismic:

1). structure stiffness and dynamic property:

Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.
wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.12589 $\text{k-sec}^2/\text{ft}^2$
liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.28566 $\text{k-sec}^2/\text{ft}^2$
centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 6.918 ft



wall fixity condition is no roof & fixed at floor:
wall stiffness is determined using a unit mass load located at the centroidal distance h.
wall flexure stiffness, $k = Ec*(tw/h)^3 / 48$ = 1322.94 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (1322.94 / (0.1259 + 0.2857))\hat{}½ = 56.6968 \text{ rad/sec}$$

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 56.6968 = 0.1108 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)
design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = \quad (3.16*32.2*\tanh(3.16*(0.2759)))\hat{}½ = 8.4492$$

$$\omega_c = \frac{\lambda}{\sqrt{L}} = \quad 8.4492 / (58)\hat{}½ = 1.1094 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 1.1094 = 5.6634 sec
Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec
design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.174 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021 \text{ , but } \le 1.0 = \quad 0.5278$$

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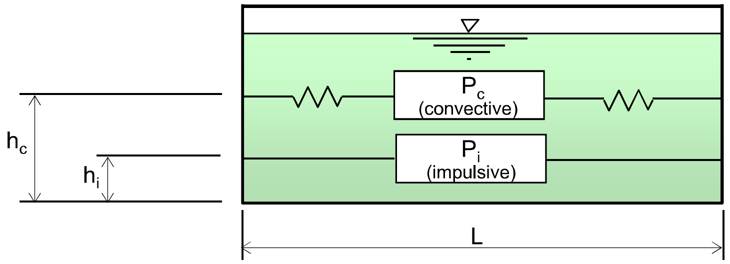

Dynamic Model

L =	58	ft
B =	1	ft
H_L =	16	ft
W_L =	57.91	kip
L / H_L =	3.62500	
H_L / L =	0.27586	

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L \left(\frac{\tanh\left(0.866 \frac{L}{H_L}\right)}{0.866 \frac{L}{H_L}} \right) =$$ 57.91*(tanh(0.866*(3.625)) / 0.866*(3.625)) = 18.38 kip

hi (EBP) = HL * 0.375 = 16 * 0.375 = 6 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 23.208 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_{wi}} \right) W_i =$$ (0.611 * 1.25 / 3)*18.38 = 4.7 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L \left(0.264 \left(\frac{L}{H_L} \right) \tanh\left(3.16 \left(\frac{H_L}{L} \right) \right) \right) =$$ 57.91*(0.264*(3.625)*tanh(3.16*(0.2759))) = 38.92 kip

$$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) =$$ 8.471 ft

$$h_{c\ (IBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) =$$ 27.264 ft

$$\text{convective force, } P_c = \left(\frac{S_{ac}\ I}{R_{wc}} \right) W_c =$$ (0.1737 * 1.25 / 1)*38.92 = 8.5 kip

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5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 4.05 kip
wall c.g. relative to base, h_w = 9.000 ft

wall inertia force, $P_w = \left(\dfrac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right)W_w =$ (0.611*1.25*0.5278/3)*4.05 = 0.54 kip

6). maximum wave slosh height displacement:

$d_{(max)} = \left(\dfrac{L}{2}\right)\left(\dfrac{S_{ac}}{1.4}\ I\right) =$ (58 / 2) * (0.1737 / 1.4 * 1.25) = 4.50 ft

Wave height is greater than the freeboard of 2-ft. Check effects of wave spillage.

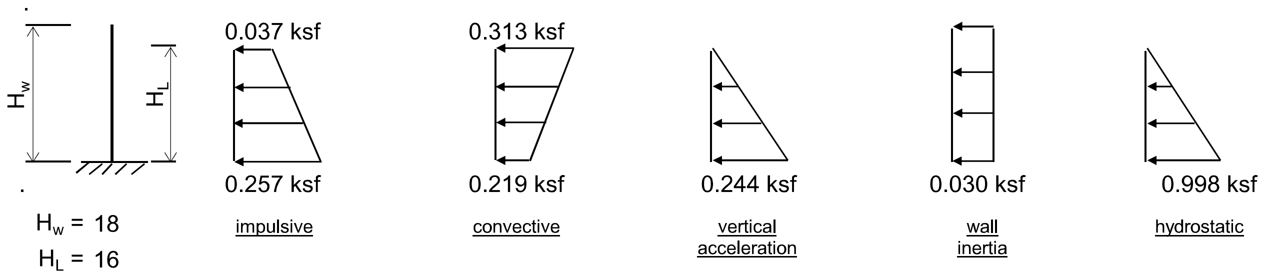
7). vertical acceleration:

design horizontal accereration, S_{DS} = 0.611 *g
vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4{*}S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \dfrac{S_{av}\ I\ b}{R_i} =$ 0.2444*1*1/1 = 0.2444 g

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



H_w = 18
H_L = 16

impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\dfrac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 4.70 kip
h_i = 6 ft
at $y = H_L$, p_{iy} = 0.037 ksf
at base $y = 0$, p_{iy} = 0.257 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\dfrac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 8.50 kip
h_c = 8.471 ft
at $y = H_L$, p_{cy} = 0.313 ksf
at base $y = 0$, p_{cy} = 0.219 ksf

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DESIGN TASK:					Wall 2 - Pressures		

vertical acceleration:

$ü = 0.2444$

$$p_{vy} = ü\,\gamma_L\,(H_L - y) =$$

at $y = H_L$, p_{vy} = 0.000 ksf

at base $y = 0$, p_{vy} = 0.244 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ I\ \varepsilon\,\gamma_c\,(t_w/12)}{R_{wi}} =$$

p_{wy} = 0.1344 $* \gamma_c * (t_w/12)$

at $y = H_w$, p_{wy} = 0.030 ksf

at base $y = 0$, p_{wy} = 0.030 ksf

hydrostatic:

$$q_{hy} = \gamma_L\,(H_L - y) =$$

at $y = H_L$, q_{hy} = 0.000 ksf

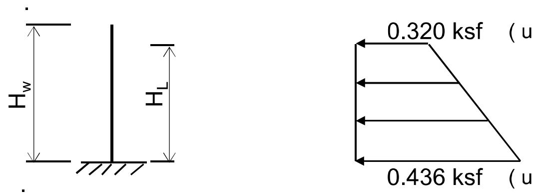
at base $y = 0$, q_{hy} = 0.998 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at $y = H_w$, p_y = 0.320 ksf

at base $y = 0$, p_y = 0.436 ksf



0.320 ksf (unfactored = 0.32 / 1.4 = 0.228 ksf)

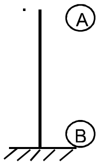
0.436 ksf (unfactored = 0.436 / 1.4 = 0.311 ksf)

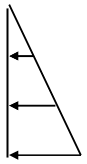
resultant dynamic pressures

9). wall design pressures for hydrostatic + dynamic:

wall height, H_w = 18 ft

liquid height, H_L = 16 ft

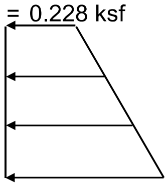




0.998 ksf

hydrostatic

unfactored load = 0.228 ksf



unfactored load = 0.311 ksf

resultant dynamic pressures

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP
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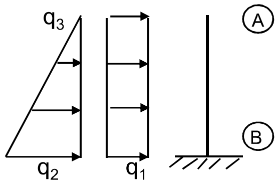
DESIGN TASK:	Wall 2 - Pressures				

10). wall design pressures for external soil loading:

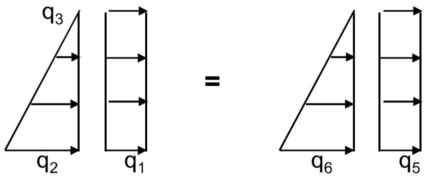
static soil:



The site has no groundwater.

wall height =	18	ft
soil height above top of base =	18	ft
groundwater ht. above base =	0	ft
dry soil lateral pressure =	0.055	k/ft^3
sat. soil lateral pressure =	0.000	k/ft^3
live load lateral surcharge =	0.100	ksf

equivalent static soil loadings:



LL lateral surcharge, q1 =	0.1000	ksf
unfactored soil, q2 =	0.9900	ksf
unfactored soil, q3 =	0.0000	ksf

equivalent soil loadings:

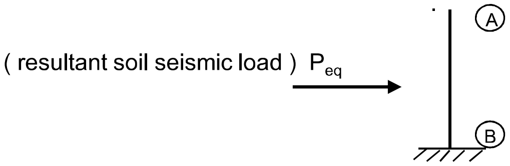
unfactored q5 =	0.1000	ksf
unfactored q6 =	0.9900	ksf

soil seismic:

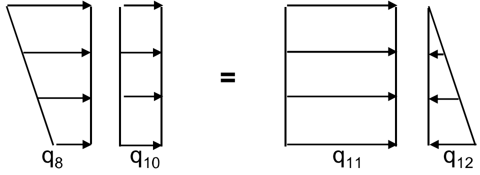
resultant factored soil seismic load per foot of wall width, $P_{u\ (eq)}$ = **5.51** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **12** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 =	0.0000	ksf
equivalent soil seismic, q9 =	0.6122	ksf
wall seismic (see wall page 5), q10 =	0.0302	ksf
equivalent soil seismic, q11 = q9 + q10 =	0.6425	ksf
equivalent soil seismic, q12 = q8 - q9 =	-0.6122	ksf

unfactored equivalent soil seismic, q8 =0 / 1.4 =	0.0000	ksf
unfactored equivalent soil seismic, q9 =0.6122 / 1.4 =	0.4373	ksf
unfactored wall seismic , q10 = 0.0302 / 1.4 =	0.0216	ksf
unfactored equivalent soil seismic, q11 =0.6425 / 1.4 =	0.4589	ksf
unfactored equivalent soil seismic, q12 =-0.6122 / 1.4 =	-0.4373	ksf

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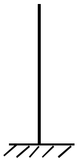
DESIGN TASK: Wall 2 - Pressures

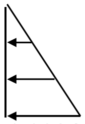
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

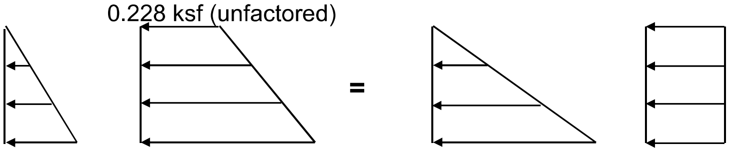
wall height = 18 ft
water depth = 16 ft



(unfactored) 0.998 ksf

b). load case 2: hydrostatic + dynamic:

wall height = 18 ft
water depth = 16 ft

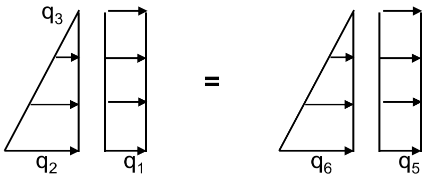


0.998 ksf	0.311 ksf	1.081 ksf	0.228 ksf
(unfactored)	(unfactored)	(unfactored)	(unfactored)
hydrostatic	resultant dynamic pressures		

c). load case 3: static soil + LL surcharge:

wall height = 18 ft
soil height on wall = 18 ft

equivalent static soil & surcharge loadings...

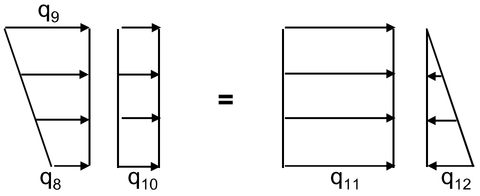


LL lateral surcharge, q1 = 0.100 ksf
unfactored soil, q2 = 0.990 ksf
unfactored soil, q3 = 0.000 ksf

equivalent soil loadings:
unfactored q5 = 0.100 ksf
unfactored q6 = 0.990 ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 18 ft
soil height on wall = 18 ft



unfactored equivalent soil seismic, q8 = 0.000 ksf
unfactored equivalent soil seismic, q9 = 0.437 ksf
unfactored equivalent soil seismic, q10 = 0.022 ksf
unfactored equivalent soil seismic, q11 = 0.459 ksf
unfactored equivalent soil seismic, q12 = -0.437 ksf

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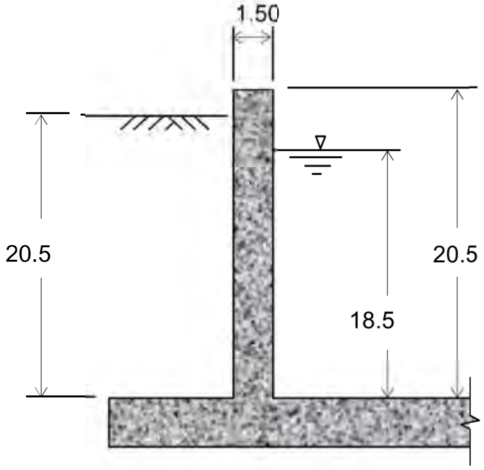
DESIGN TASK:				Wall 4 - Pressures			

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **no roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **35** ft
tank wall thickness, t_w = **18** inch
wall height, H_w = **20.5** ft

liquid height, H_L = **18.5** ft
liquid specific gravity = **1**
liquid density, γ_L = (sp.gr.)*γ_w = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 k-sec^2/ft^4



WALL SECTION

Soil Data

The site has no groundwater.

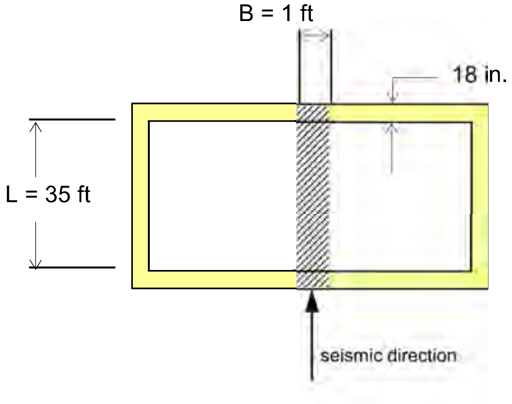
soil height above top of foundation base = **20.5** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0** k/ft^3
live load lateral surcharge = **0.100** ksf
0

concrete strength, f '$_c$ = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 k-sec^2/ft^4

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **3**
Response modification factor, R_{wc} = **1**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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DESIGN TASK:					Wall 4 - Pressures		

Weights:

unit 1-ft width wall mass, W_w = (18/12) * (20.5) * 0.15 = 4.61 kip

wall c.g. relative to base, h_w = 20.5 / 2 = 10.250 ft

unit width liquid mass, W_L = (35) * (1) * (18.5) * 32.17 = 40.40 kip

<u>Seismic:</u>

1). <u>structure stiffness and dynamic property:</u>

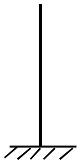
Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.

wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.14338 k-sec^2/ft^2

liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.35534 k-sec^2/ft^2

centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 7.89 ft



wall fixity condition is no roof & fixed at floor:

wall stiffness is determined using a unit mass load located at the centroidal distance h.

wall flexure stiffness, $k = Ec*(tw/h)^3 / 48$ = 891.76 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} =$$ (891.76 / (0.1434 + 0.3553))ˆ½ = 42.2863 rad/sec

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 42.2863 = 0.1486 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). <u>Dynamic properties, Spectral amplification factors, and Effective mass coefficient:</u>

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} =$$ (3.16*32.2*tanh(3.16*(0.5286)))ˆ½ = 9.7315

$$\omega_c = \frac{\lambda}{\sqrt{L}} =$$ 9.7315 / (35)ˆ½ = 1.6449 rad/sec,

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 1.6449 = 3.8197 sec

Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.258 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ ,\quad \text{but} \le 1.0 =$$ 0.7141

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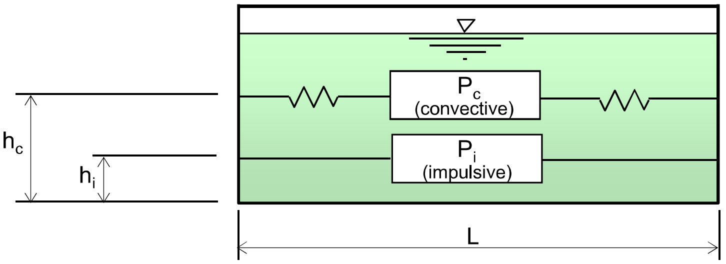
DESIGN TASK:					Wall 4 - Pressures		



Dynamic Model

L =	35	ft
B =	1	ft
H_L =	18.5	ft
W_L =	40.4	kip
L / H_L =	1.89189	
H_L / L =	0.52857	

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L \left(\frac{\tanh\left(0.866 \frac{L}{H_L}\right)}{0.866 \frac{L}{H_L}} \right) =$$ 40.4*(tanh(0.866*(1.8919)) / 0.866*(1.8919)) = 22.86 kip

hi (EBP) = HL * 0.375 = 18.5 * 0.375 = 6.938 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 14.032 ft

impulsive force, $P_i = \left(\frac{S_{ai}\ I}{R_{wi}} \right) W_i =$ (0.611 * 1.25 / 3)*22.86 = 5.8 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L \left(0.264 \left(\frac{L}{H_L} \right) \tanh\left(3.16 \left(\frac{H_L}{L} \right) \right) \right) =$$ 40.4*(0.264*(1.8919)*tanh(3.16*(0.5286))) = 18.8 kip

$$h_{c\ (EBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) =$$ 10.933 ft

$$h_{c\ (IBP)} = H_L \left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)} \right) =$$ 15.298 ft

convective force, $P_c = \left(\frac{S_{ac}\ I}{R_{wc}} \right) W_c =$ (0.2576 * 1.25 / 1)*18.8 = 6.1 kip

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5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 4.61 kip
wall c.g. relative to base, h_w = 10.250 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w =$ (0.611*1.25*0.7141/3)*4.61 = 0.84 kip

6). maximum wave slosh height displacement:

$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) =$ (35 / 2) * (0.2576 / 1.4 * 1.25) = 4.03 ft

Wave height is greater than the freeboard of 2-ft. Check effects of wave spillage.

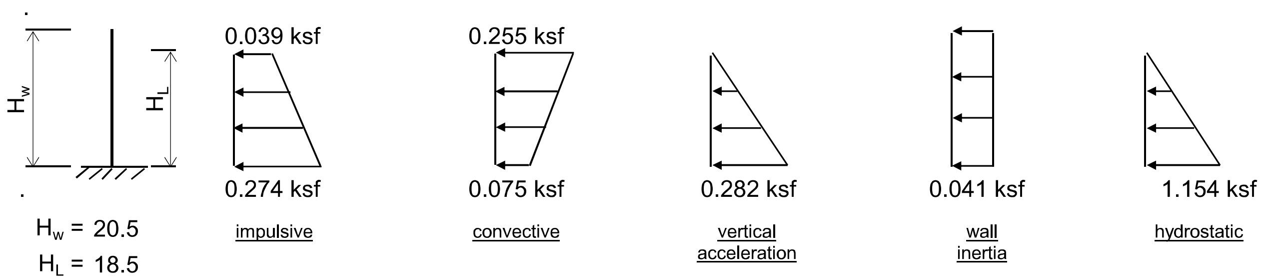
7). vertical acceleration:

design horizontal accereration, S_{DS} = 0.611 *g
vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4 S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

Design vertical acceleration, $\ddot{u} = \frac{S_{av}\ I\ b}{R_i} =$ 0.2444*1*1/1 = 0.2444 g

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 5.80 kip
h_i = 6.938 ft
at $y = H_L$, p_{iy} = 0.039 ksf
at base $y = 0$, p_{iy} = 0.274 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 6.10 kip
h_c = 10.933 ft
at $y = H_L$, p_{cy} = 0.255 ksf
at base $y = 0$, p_{cy} = 0.075 ksf

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vertical acceleration:

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

$\ddot{u} =$ 0.2444
at $y = H_L$, $p_{vy} =$ 0.000 ksf
at base $y = 0$, $p_{vy} =$ 0.282 ksf

wall inertia:

$p_{wy} = \dfrac{S_{ai}\ I\ \varepsilon\,\gamma_c\,(t_w/12)}{R_{wi}} =$

$p_{wy} =$ 0.1818 $* \gamma_c * (t_w/12)$
at $y = H_w$, $p_{wy} =$ 0.041 ksf
at base $y = 0$, $p_{wy} =$ 0.041 ksf

hydrostatic:

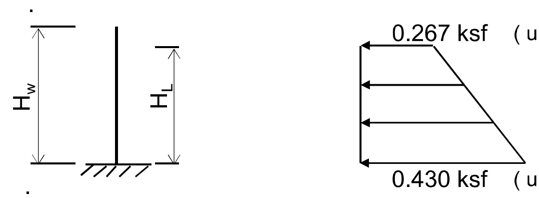
$q_{hy} = \gamma_L\,(H_L - y) =$

at $y = H_L$, $q_{hy} =$ 0.000 ksf
at base $y = 0$, $q_{hy} =$ 1.154 ksf

combine the effects of the dynamic pressures on the wall:

$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$

at $y = H_w$, $p_y =$ 0.267 ksf
at base $y = 0$, $p_y =$ 0.430 ksf



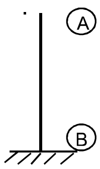
(unfactored = 0.267 / 1.4 = 0.191 ksf)

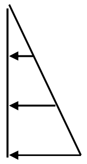
(unfactored = 0.43 / 1.4 = 0.307 ksf)

resultant dynamic pressures

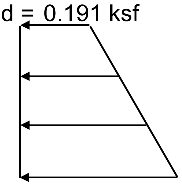
9). wall design pressures for hydrostatic + dynamic:

wall height, $H_w =$ 20.5 ft
liquid height, $H_L =$ 18.5 ft





hydrostatic



resultant dynamic pressures

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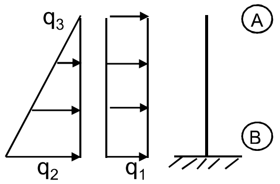
BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 4 - Pressures

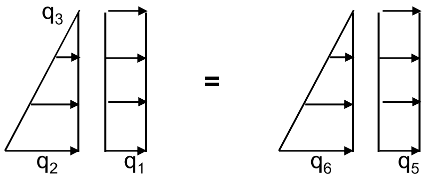
10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.
wall height = 20.5 ft
soil height above top of base = 20.5 ft
groundwater ht. above base = 0 ft
dry soil lateral pressure = 0.055 k/ft^3
sat. soil lateral pressure = 0.000 k/ft^3
live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:



LL lateral surcharge, q1 = 0.1000 ksf
unfactored soil, q2 = 1.1275 ksf
unfactored soil, q3 = 0.0000 ksf

equivalent soil loadings:
unfactored q5 = 0.1000 ksf
unfactored q6 = 1.1275 ksf

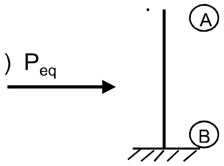
soil seismic:

resultant factored soil seismic load per foot of wall width, $P_{u\,(eq)}$ = **7.14** k/ft

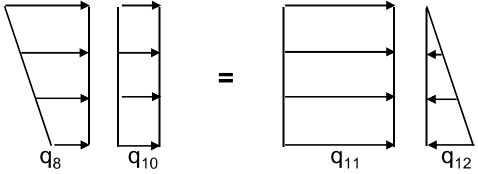
centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **13.66** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…

(resultant soil seismic load) P_{eq}



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0007 ksf
equivalent soil seismic, q9 = 0.6959 ksf
wall seismic (see wall page 5), q10 = 0.0409 ksf
equivalent soil seismic, q11 = q9 + q10 = 0.7368 ksf
equivalent soil seismic, q12 = q8 - q9 = -0.6952 ksf

unfactored equivalent soil seismic, q8 =0.0007 / 1.4 = 0.0005 ksf
unfactored equivalent soil seismic, q9 =0.6959 / 1.4 = 0.4971 ksf
unfactored wall seismic , q10 = 0.0409 / 1.4 = 0.0292 ksf
unfactored equivalent soil seismic, q11 =0.7368 / 1.4 = 0.5263 ksf
unfactored equivalent soil seismic, q12 =-0.6952 / 1.4 = -0.4966 ksf

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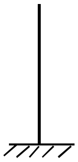
CHKD:		**DESCRIPTION:**		Area 8 - Washwater Basin PS		**JOB NO:**	10721A.10
DESIGN TASK:		Wall 4 - Pressures					

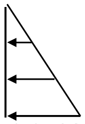
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

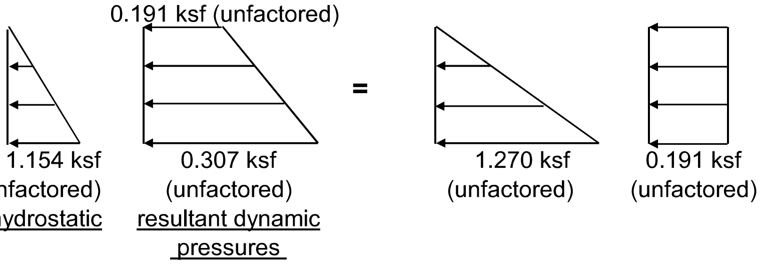
wall height = 20.5 ft
water depth = 18.5 ft



(unfactored) 1.154 ksf

b). load case 2: hydrostatic + dynamic:

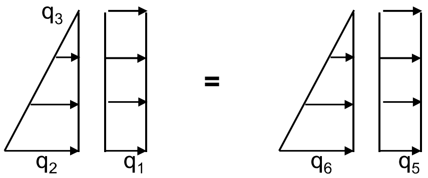
wall height = 20.5 ft
water depth = 18.5 ft



c). load case 3: static soil + LL surcharge:

wall height = 20.5 ft
soil height on wall = 20.5 ft

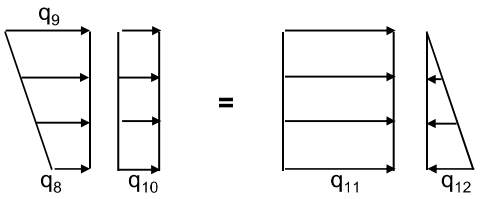
equivalent static soil & surcharge loadings...



LL lateral surcharge, q1 =	0.100	ksf
unfactored soil, q2 =	1.128	ksf
unfactored soil, q3 =	0.000	ksf
equivalent soil loadings:		
unfactored q5 =	0.100	ksf
unfactored q6 =	1.128	ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 20.5 ft
soil height on wall = 20.5 ft



unfactored equivalent soil seismic, q8 =	0.000	ksf
unfactored equivalent soil seismic, q9 =	0.497	ksf
unfactored equivalent soil seismic, q10 =	0.029	ksf
unfactored equivalent soil seismic, q11 =	0.526	ksf
unfactored equivalent soil seismic, q12 =	-0.497	ksf

Area 8 - Washwater Basin
Wall 1 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	17.89	28.81	55.00	***0.52***	7.89	23.53	***0.34***	***<- OK***
1.2F+1.4E	1.00	25.17	25.17	55.00	***0.46***	10.85	23.53	***0.46***	***<- OK***
1.6(H+L)	1.41	27.79	39.19	55.00	***0.71***	11.27	23.53	***0.48***	***<- OK***
1.6H+1.4E	1.00	35.79	35.79	55.00	***0.65***	13.63	23.53	***0.58***	***<- OK***

Vertical Span (Mid-Height) - Outside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.12	13.43	15.04	88.50	***0.17***	0.00	23.53	***0.00***	***<- OK***
1.2F+1.4E	1.00	18.73	18.73	88.50	***0.21***	0.00	23.53	***0.00***	***<- OK***

Vertical Span (Bottom) - Outside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.6(H+L)	1.00	48.70	48.70	88.50	***0.55***	16.61	23.53	***0.71***	***<- OK***
1.6H+1.4E	1.00	56.68	56.68	88.50	***0.64***	18.16	23.53	***0.77***	***<- OK***

Vertical Span (Mid-Height) - Inside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.6(H+L)	1.00	20.91	20.91	66.00	***0.32***	0.00	23.53	***0.00***	***<- OK***
1.6H+1.4E	1.00	27.42	27.42	66.00	***0.42***	0.00	23.53	***0.00***	***<- OK***

Vertical Span (Bottom) - Inside Face

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.12	34.01	38.09	88.50	***0.43***	12.29	23.53	***0.52***	***<- OK***
1.2F+1.4E	1.00	46.25	46.25	88.50	***0.52***	16.06	23.53	***0.68***	***<- OK***

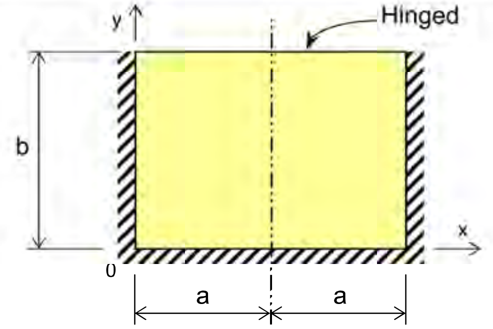
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Hydrostatic

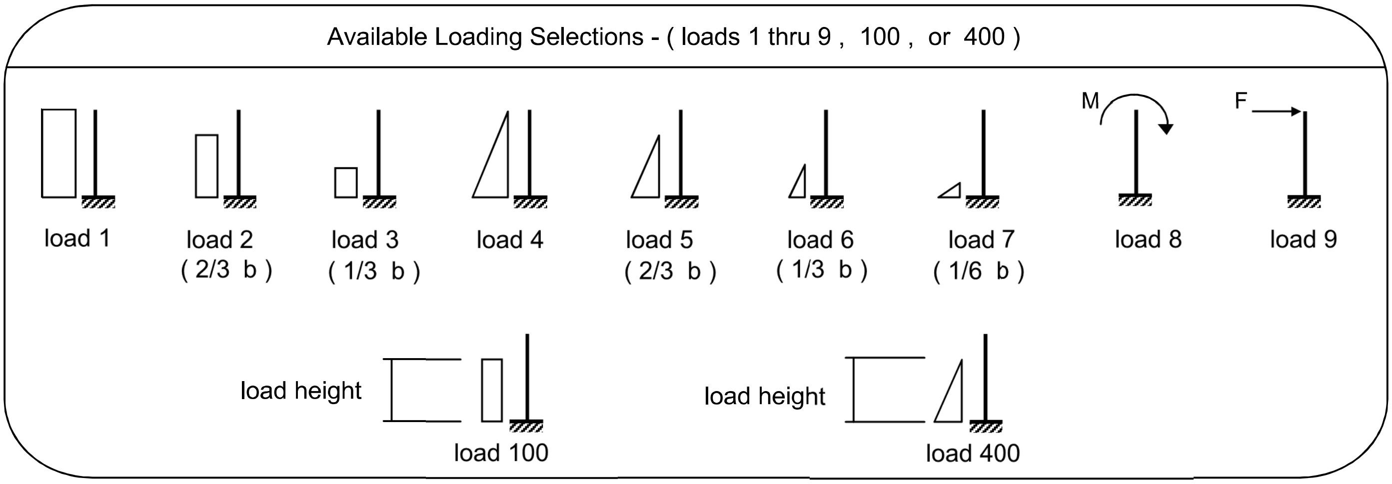
Rectangular Plate:

plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 17.5 = 35 ft
plate dimension, a = **17.5** ft
plate dimension, b = **20.5** ft

plate sides ratio, a/b = 0.8537





Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads 100 or 400	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**18.500**	**1.154**	**2.25**	**1.4**
B					
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Hydrostatic

M_x - Moment Summary

a = 17.5
b = 20.5
a / b = 0.8537

Loads: q , or M			
1.154			
Moment Coefficient Multipliers			
484.969			

Boundary Case 2

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.54
0	0.8	0.0148				7.18				7.18	16.15	0.24	0.54
0	0.6	0.0253				12.29				12.29	27.65	0.42	0.56
0	0.4	0.0264				12.78				12.78	28.76	0.44	0.58
0	0.2	0.0138				6.68				6.68	15.03	0.23	0.54
0	0	0.0000				0.00				0.00	0.00	0.00	0.54
0.2	0	0.0032				1.54				1.54	3.47	0.05	0.54
0.4	0	0.0064				3.11				3.11	7.00	0.10	0.54
0.6	0	0.0085				4.13				4.13	9.29	0.14	0.54
0.8	0	0.0097				4.70				4.70	10.58	0.16	0.54
1	0	0.0100				4.86				4.86	10.94	0.16	0.54
1	0.2	-0.0022				-1.09				-1.09	-2.45	-0.04	-0.54
1	0.4	-0.0088				-4.27				-4.27	-9.60	-0.14	-0.54
1	0.6	-0.0094				-4.55				-4.55	-10.23	-0.15	-0.54
1	0.8	-0.0057				-2.76				-2.76	-6.21	-0.09	-0.54
1	1	0.0000				0.00				0.00	0.00	0.00	0.54
0.8	1	0.0000				0.00				0.00	0.00	0.00	0.54
0.8	0.8	-0.0056				-2.71				-2.71	-6.10	-0.09	-0.54
0.8	0.6	-0.0092				-4.48				-4.48	-10.08	-0.15	-0.54
0.8	0.4	-0.0088				-4.26				-4.26	-9.60	-0.14	-0.54
0.8	0.2	-0.0024				-1.18				-1.18	-2.66	-0.04	-0.54

max negative moment, $M_{ux}(-)$ = -10.23 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.15 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 28.76 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.44 in^2/ft
minimum steel req'd = 0.58 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Hydrostatic

M_y - Moment Summary

a = 17.5
b = 20.5
a / b = 0.8537

Loads: q , or M			
1.154			
Moment Coefficient Multipliers			
484.969			

Boundary Case 2

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.54
0	0.8	0.0029				1.42				1.42	3.20	0.05	0.54
0	0.6	0.0051				2.45				2.45	5.51	0.08	0.54
0	0.4	0.0052				2.54				2.54	5.71	0.08	0.54
0	0.2	0.0028				1.34				1.34	3.01	0.04	0.54
0	0	0.0000				0.00				0.00	0.00	0.00	0.54
0.2	0	0.0158				7.68				7.68	17.28	0.25	0.54
0.4	0	0.0319				15.49				15.49	34.85	0.51	0.62
0.6	0	0.0426				20.68				20.68	46.53	0.69	0.62
0.8	0	0.0483				23.44				23.44	52.74	0.79	0.62
1	0	0.0501				24.29				24.29	54.64	0.81	0.62
1	0.2	-0.0021				-1.01				-1.01	-2.28	-0.03	-0.54
1	0.4	-0.0198				-9.59				-9.59	-21.58	-0.31	-0.54
1	0.6	-0.0185				-8.95				-8.95	-20.15	-0.29	-0.54
1	0.8	-0.0101				-4.90				-4.90	-11.02	-0.16	-0.54
1	1	0.0000				0.00				0.00	0.00	0.00	0.54
1	0.4	-0.0198				-9.59				-9.59	-21.58	-0.31	-0.54
0.8	0.4	-0.0189				-9.19				-9.19	-20.67	-0.30	-0.54
0.6	0.4	-0.0164				-7.95				-7.95	-17.88	-0.26	-0.54
0.4	0.4	-0.0116				-5.63				-5.63	-12.67	-0.18	-0.54
0.2	0.4	-0.0041				-2.01				-2.01	-4.52	-0.07	-0.54

max negative moment, $M_{uy}(-)$ = -21.58 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.31 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 54.64 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.81 in^2/ft
minimum steel req'd = 0.62 in^2/ft
Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Hydrostatic

Shear Summary

a = 17.5
b = 20.5
a / b = 0.8537

Loads: q , or M			
1.154			
Shear Coefficient Multipliers			
23.657			

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0590				-1.40				-1.40	-1.96	17.65
0	0.8	0.0958				2.27				2.27	3.17	17.65
0	0.6	0.1858				4.40				4.40	6.15	17.65
0	0.4	0.2383				5.64				5.64	7.89	17.65
0	0.2	0.1444				3.42				3.42	4.78	17.65
0	0.00	-0.0119				-0.28				-0.28	-0.39	17.65
0.2	0	0.1665				3.94				3.94	5.52	17.65
0.4	0	0.2871				6.79				6.79	9.51	17.65
0.6	0	0.3424				8.10				8.10	11.34	17.65
0.8	0	0.3652				8.64				8.64	12.09	17.65
1	0	0.3712				8.78				8.78	12.29	17.65
0.2	1	-0.0190				-0.45				-0.45	-0.63	17.65
0.4	1	0.0404				0.96				0.96	1.34	17.65
0.6	1	0.0694				1.64				1.64	2.30	17.65
0.8	1	0.0819				1.94				1.94	2.71	17.65
1	1	0.0853				2.02				2.02	2.82	17.65

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in
maximum shear, V_u = 12.29 k/ft **OK**
$\phi V_c = \phi$*2*(f 'c)$^{1/2}$*b*d = (0.75*2*(4000)ˆ½ *12*15.5)/1000 = 17.65 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

BY:	C. Che	**DATE:** Sep-17	**CLIENT** Willametter River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**JOB NO:**	10721A.10
DESIGN TASK:			Wall 1 - Hydrodynamic		

Rectangular Plate:

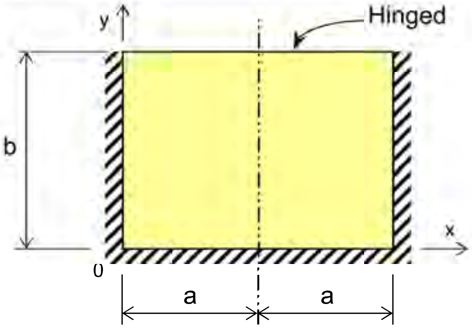
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 17.5 = 35 ft

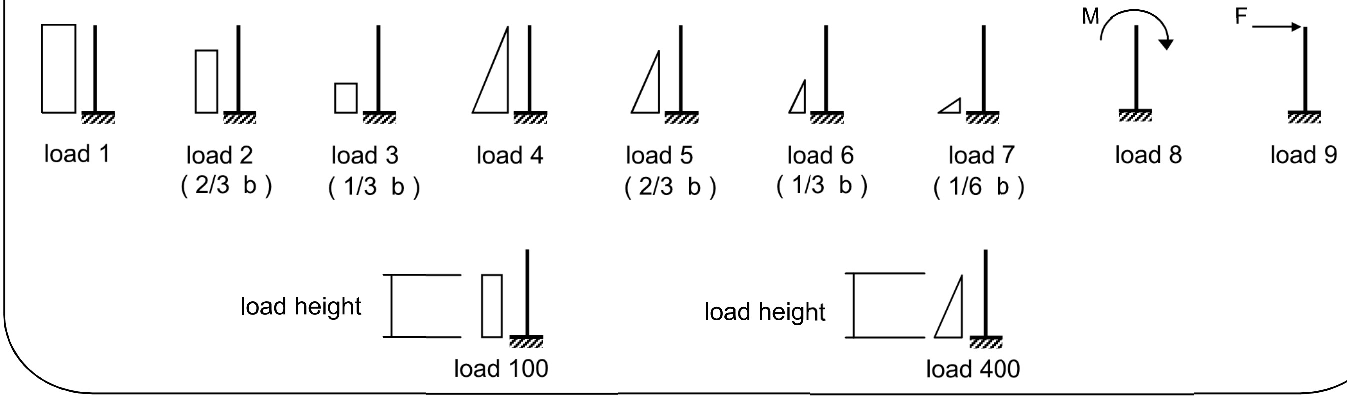
plate dimension, a = **17.5** ft

plate dimension, b = **20.5** ft

plate sides ratio, a/b = 0.8537



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	for shear
A	**400**	**18.500**	**1.154**	**1.2**	**1.2**
B	**100**	**18.500**	**0.191**	**1.4**	**1.4**
C	**400**	**18.500**	**0.208**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi

reinforcing steel strength, fy = **60** ksi

reinforcing clear cover to face of concrete = **2** in

number of curtains of reinforcing, (1 or 2) = **2**

Are bars in "x" or "y" direction closest to face of concrete ? **y**

minimum ratio of horizontal shrinkage-temperature steel = **0.00300**

minimum ratio of vertical shrinkage-temperature steel = **0.00300**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

BY:	C. Che	**DATE:**	Sep-17	**CLIENT**	Willametter River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**JOB NO:**	10721A.10
DESIGN TASK:	Wall 1 - Hydrodynamic				

M_x - Moment Summary

	Loads: q , or M				Boundary Case 2	SUMMARY
a = 17.5	1.154	0.191	0.208			
b = 20.5	Moment Coefficient Multipliers					Final Moments / Reinforcing: (d = 15")
a / b = 0.8537	484.969	80.268	87.412			

		Moment Coefficients				M_x Moments, ft-k/ft				M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0	0.8	0.0148	0.0424	0.0148		7.18	3.40	1.29		11.88	15.19	0.23	0.32
0	0.6	0.0253	0.0652	0.0253		12.29	5.23	2.21		19.73	25.17	0.38	0.51
0	0.4	0.0264	0.0580	0.0264		12.78	4.65	2.30		19.74	25.07	0.38	0.50
0	0.2	0.0138	0.0250	0.0138		6.68	2.01	1.20		9.89	12.51	0.19	0.32
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0.2	0	0.0032	0.0051	0.0032		1.54	0.41	0.28		2.23	2.81	0.04	0.32
0.4	0	0.0064	0.0114	0.0064		3.11	0.92	0.56		4.59	5.80	0.09	0.32
0.6	0	0.0085	0.0161	0.0085		4.13	1.29	0.74		6.17	7.81	0.12	0.32
0.8	0	0.0097	0.0187	0.0097		4.70	1.50	0.85		7.05	8.93	0.13	0.32
1	0	0.0100	0.0196	0.0100		4.86	1.57	0.88		7.31	9.26	0.14	0.32
1	0.2	-0.0022	-0.0033	-0.0022		-1.09	-0.27	-0.20		-1.55	-1.95	-0.03	-0.32
1	0.4	-0.0088	-0.0198	-0.0088		-4.27	-1.59	-0.77		-6.63	-8.43	-0.13	-0.32
1	0.6	-0.0094	-0.0243	-0.0094		-4.55	-1.95	-0.82		-7.31	-9.33	-0.14	-0.32
1	0.8	-0.0057	-0.0162	-0.0057		-2.76	-1.30	-0.50		-4.56	-5.83	-0.09	-0.32
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0.8	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0.8	0.8	-0.0056	-0.0159	-0.0056		-2.71	-1.27	-0.49		-4.47	-5.72	-0.09	-0.32
0.8	0.6	-0.0092	-0.0239	-0.0092		-4.48	-1.92	-0.81		-7.20	-9.19	-0.14	-0.32
0.8	0.4	-0.0088	-0.0197	-0.0088		-4.26	-1.58	-0.77		-6.61	-8.40	-0.13	-0.32
0.8	0.2	-0.0024	-0.0037	-0.0024		-1.18	-0.30	-0.21		-1.69	-2.13	-0.03	-0.32

max negative moment, $M_{ux}(-)$ = -9.33 ft-k/ft

max negative steel req'd, $A_s(-)$ = -0.14 in^2/ft

minimum steel req'd = -0.32 in^2/ft

Use

max positive moment, $M_{ux}(+)$ = 25.17 ft-k/ft

max positive steel req'd, $A_s(+)$ = 0.38 in^2/ft

minimum steel req'd = 0.51 in^2/ft

Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 1 - Hydrodynamic

M_y - Moment Summary

	Loads: q , or M			
a = 17.5	1.154	0.191	0.208	
b = 20.5	Moment Coefficient Multipliers			
a / b = 0.8537	484.969	80.268	87.412	

Boundary Case 2

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0	0.8	0.0029	0.0085	0.0029		1.42	0.68	0.26		2.36	3.02	0.04	0.32
0	0.6	0.0051	0.0130	0.0051		2.45	1.04	0.44		3.94	5.02	0.07	0.32
0	0.4	0.0052	0.0116	0.0052		2.54	0.93	0.46		3.92	4.99	0.07	0.32
0	0.2	0.0028	0.0050	0.0028		1.34	0.40	0.24		1.98	2.50	0.04	0.32
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0.2	0	0.0158	0.0267	0.0158		7.68	2.14	1.38		11.21	14.16	0.20	0.32
0.4	0	0.0319	0.0574	0.0319		15.49	4.61	2.79		22.89	28.95	0.42	0.56
0.6	0	0.0426	0.0805	0.0426		20.68	6.47	3.73		30.87	39.09	0.58	0.62
0.8	0	0.0483	0.0936	0.0483		23.44	7.51	4.22		35.18	44.56	0.66	0.62
1	0	0.0501	0.0977	0.0501		24.29	7.84	4.38		36.51	46.25	0.69	0.62
1	0.2	-0.0021	0.0052	-0.0021		-1.01	0.42	-0.18		-0.78	-0.88	-0.01	-0.32
1	0.4	-0.0198	-0.0404	-0.0198		-9.59	-3.25	-1.73		-14.56	-18.47	-0.27	-0.36
1	0.6	-0.0185	-0.0509	-0.0185		-8.95	-4.09	-1.61		-14.66	-18.73	-0.27	-0.36
1	0.8	-0.0101	-0.0339	-0.0101		-4.90	-2.72	-0.88		-8.50	-10.92	-0.16	-0.32
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
1	0.4	-0.0198	-0.0404	-0.0198		-9.59	-3.25	-1.73		-14.56	-18.47	-0.27	-0.36
0.8	0.4	-0.0189	-0.0386	-0.0189		-9.19	-3.10	-1.66		-13.94	-17.68	-0.26	-0.34
0.6	0.4	-0.0164	-0.0330	-0.0164		-7.95	-2.65	-1.43		-12.03	-15.25	-0.22	-0.32
0.4	0.4	-0.0116	-0.0227	-0.0116		-5.63	-1.82	-1.01		-8.47	-10.73	-0.15	-0.32
0.2	0.4	-0.0041	-0.0073	-0.0041		-2.01	-0.58	-0.36		-2.96	-3.74	-0.05	-0.32

max negative moment, $M_{uy}(-)$ = -18.73 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.27 in^2/ft
minimum steel req'd = -0.36 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 46.25 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.69 in^2/ft
minimum steel req'd = 0.62 in^2/ft
Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 1 - Hydrodynamic

Shear Summary

a = 17.5 b = 20.5 a / b = 0.8537		Loads: q , or M				Boundary Case 2				SUMMARY		
		1.154	0.191	0.208						Final Shears		
		Shear Coefficient Multipliers										
		23.657	3.916	4.264								
		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0590	-0.1470	-0.0590		-1.40	-0.58	-0.25		-2.22	-2.83	17.65
0	0.8	0.0958	0.3409	0.0958		2.27	1.33	0.41		4.01	5.16	17.65
0	0.6	0.1858	0.5259	0.1858		4.40	2.06	0.79		7.25	9.27	17.65
0	0.4	0.2383	0.4856	0.2383		5.64	1.90	1.02		8.55	10.85	17.65
0	0.2	0.1444	0.1742	0.1444		3.42	0.68	0.62		4.71	5.91	17.65
0	0.00	-0.0119	-0.0566	-0.0119		-0.28	-0.22	-0.05		-0.55	-0.72	17.65
0.2	0	0.1665	0.1843	0.1665		3.94	0.72	0.71		5.37	6.73	17.65
0.4	0	0.2871	0.4128	0.2871		6.79	1.62	1.22		9.63	12.13	17.65
0.6	0	0.3424	0.5340	0.3424		8.10	2.09	1.46		11.65	14.69	17.65
0.8	0	0.3652	0.5885	0.3652		8.64	2.30	1.56		12.50	15.77	17.65
1	0	0.3712	0.6037	0.3712		8.78	2.36	1.58		12.73	16.06	17.65
0.2	1	-0.0190	0.0244	-0.0190		-0.45	0.10	-0.08		-0.44	-0.52	17.65
0.4	1	0.0404	0.1915	0.0404		0.96	0.75	0.17		1.88	2.44	17.65
0.6	1	0.0694	0.2681	0.0694		1.64	1.05	0.30		2.99	3.86	17.65
0.8	1	0.0819	0.2998	0.0819		1.94	1.17	0.35		3.46	4.46	17.65
1	1	0.0853	0.3082	0.0853		2.02	1.21	0.36		3.59	4.62	17.65

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in
maximum shear, V_u = 16.06 k/ft **OK**
$\phi V_c = \phi*2*(f'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*15.5)/1000 = 17.65 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

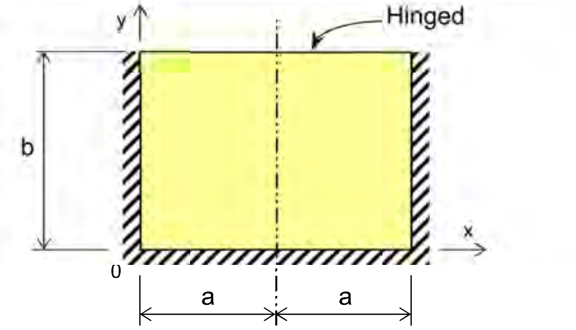
carollo
Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Soil Static

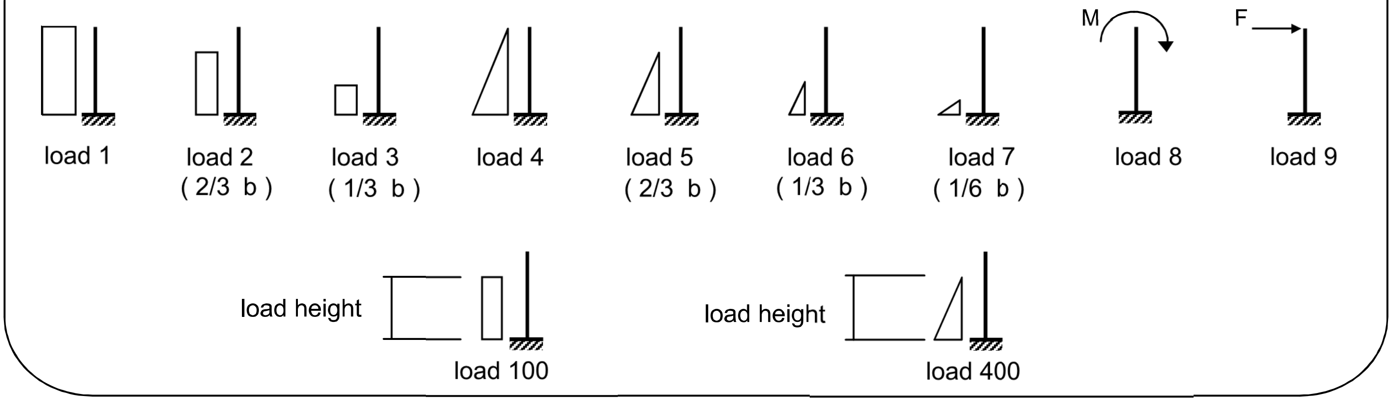
Rectangular Plate:
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 17.5 = 35 ft
plate dimension, a = **17.5** ft
plate dimension, b = **20.5** ft

plate sides ratio, a/b = 0.8537



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	for shear
A	**4**		**1.128**	**2.25**	**1.6**
B	**1**		**0.100**	**2.25**	**1.6**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**JOB NO:**	10721A.00
DESIGN TASK:	Wall 1 - Soil Static				

M_x - Moment Summary

a = 17.5
b = 20.5
a / b = 0.8537

Loads: q , or M			
1.128	0.100		
Moment Coefficient Multipliers			
474.042	42.025		

Boundary Case 2

SUMMARY

Reinforcing: (d = 15")

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0	0.8	0.0185	0.0492			8.77	2.07			10.83	24.38	0.37	0.54
0	0.6	0.0304	0.0701			14.42	2.95			17.37	39.08	0.60	0.60
0	0.4	0.0300	0.0595			14.20	2.50			16.70	37.58	0.57	0.60
0	0.2	0.0149	0.0252			7.07	1.06			8.14	18.30	0.27	0.54
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0.2	0	0.0034	0.0051			1.60	0.22			1.82	4.09	0.06	0.54
0.4	0	0.0069	0.0116			3.29	0.49			3.78	8.50	0.13	0.54
0.6	0	0.0093	0.0165			4.42	0.69			5.11	11.49	0.17	0.54
0.8	0	0.0107	0.0192			5.06	0.81			5.87	13.20	0.20	0.54
1	0	0.0111	0.0201			5.25	0.84			6.10	13.71	0.21	0.54
1	0.2	-0.0023	-0.0033			-1.10	-0.14			-1.23	-2.77	-0.04	-0.54
1	0.4	-0.0100	-0.0204			-4.76	-0.86			-5.62	-12.65	-0.19	-0.54
1	0.6	-0.0113	-0.0261			-5.35	-1.10			-6.45	-14.50	-0.22	-0.54
1	0.8	-0.0071	-0.0188			-3.37	-0.79			-4.16	-9.35	-0.14	-0.54
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0.8	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0.8	0.8	-0.0070	-0.0184			-3.30	-0.77			-4.08	-9.18	-0.14	-0.54
0.8	0.6	-0.0111	-0.0257			-5.28	-1.08			-6.36	-14.30	-0.21	-0.54
0.8	0.4	-0.0100	-0.0202			-4.76	-0.85			-5.61	-12.63	-0.19	-0.54
0.8	0.2	-0.0025	-0.0037			-1.19	-0.15			-1.35	-3.03	-0.05	-0.54

max negative moment, $M_{ux}(-)$ = -14.50 ft-k/ft

max negative steel req'd, $A_s(-)$ = -0.22 in^2/ft

minimum steel req'd = -0.54 in^2/ft

Use

max positive moment, $M_{ux}(+)$ = 39.08 ft-k/ft

max positive steel req'd, $A_s(+)$ = 0.60 in^2/ft

minimum steel req'd = 0.60 in^2/ft

Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Soil Static

M_y - Moment Summary

a = 17.5
b = 20.5
a / b = 0.8537

Loads: q , or M			
1.128	0.100		
Moment Coefficient Multipliers			
474.042	42.025		

Boundary Case 2

SUMMARY

Final Moments

Reinforcing: (d = 15.5")

		Moment Coefficients				M_y Moments, ft-k/ft				M_y	M_{uy}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0	0.8	0.0037	0.0098			1.74	0.41			2.15	4.84	0.07	0.54
0	0.6	0.0061	0.0140			2.88	0.59			3.47	7.81	0.11	0.54
0	0.4	0.0060	0.0119			2.82	0.50			3.32	7.48	0.11	0.54
0	0.2	0.0030	0.0050			1.41	0.21			1.62	3.64	0.05	0.54
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0.2	0	0.0168	0.0258			7.96	1.08			9.04	20.35	0.30	0.54
0.4	0	0.0346	0.0582			16.38	2.44			18.82	42.35	0.63	0.62
0.6	0	0.0467	0.0822			22.15	3.46			25.60	57.60	0.86	0.62
0.8	0	0.0533	0.0959			25.27	4.03			29.30	65.92	0.99	0.62
1	0	0.0553	0.1002			26.23	4.21			30.44	68.49	1.03	0.62
1	0.2	-0.0009	0.0068			-0.43	0.29			-0.14	-0.32	0.00	-0.54
1	0.4	-0.0219	-0.0396			-10.37	-1.67			-12.04	-27.09	-0.40	-0.54
1	0.6	-0.0227	-0.0545			-10.78	-2.29			-13.07	-29.42	-0.43	-0.57
1	0.8	-0.0135	-0.0426			-6.38	-1.79			-8.17	-18.38	-0.27	-0.54
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
1	0.4	-0.0219	-0.0396			-10.37	-1.67			-12.04	-27.09	-0.40	-0.54
0.8	0.4	-0.0209	-0.0378			-9.93	-1.59			-11.52	-25.91	-0.38	-0.54
0.6	0.4	-0.0180	-0.0320			-8.54	-1.35			-9.88	-22.23	-0.32	-0.54
0.4	0.4	-0.0127	-0.0216			-6.00	-0.91			-6.90	-15.53	-0.23	-0.54
0.2	0.4	-0.0044	-0.0063			-2.07	-0.27			-2.34	-5.26	-0.08	-0.54

max negative moment, $M_{uy}(-)$ = -29.42 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.43 in^2/ft
minimum steel req'd = -0.57 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 68.49 ft-k/ft
max positive steel req'd, $A_s(+)$ = 1.03 in^2/ft
minimum steel req'd = 0.62 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Soil Static

Shear Summary

a = 17.5
b = 20.5
a / b = 0.8537

Loads: q , or M			
1.128	0.100		
Shear Coefficient Multipliers			
23.124	2.050		

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0732	-0.1571			-1.69	-0.32			-2.01	-3.22	17.65
0	0.8	0.1311	0.4490			3.03	0.92			3.95	6.32	17.65
0	0.6	0.2317	0.5559			5.36	1.14			6.50	10.40	17.65
0	0.4	0.2626	0.4734			6.07	0.97			7.04	11.27	17.65
0	0.2	0.1442	0.1684			3.34	0.35			3.68	5.89	17.65
0	0.00	-0.0167	-0.0577			-0.39	-0.12			-0.50	-0.81	17.65
0.2	0	0.1660	0.1790			3.84	0.37			4.21	6.73	17.65
0.4	0	0.2981	0.4110			6.89	0.84			7.74	12.38	17.65
0.6	0	0.3610	0.5369			8.35	1.10			9.45	15.12	17.65
0.8	0	0.3876	0.5946			8.96	1.22			10.18	16.29	17.65
1	0	0.3948	0.6108			9.13	1.25			10.38	16.61	17.65
0.2	1	-0.0171	0.0788			-0.40	0.16			-0.23	-0.37	17.65
0.4	1	0.0567	0.2702			1.31	0.55			1.87	2.99	17.65
0.6	1	0.0919	0.3549			2.13	0.73			2.85	4.56	17.65
0.8	1	0.1068	0.3894			2.47	0.80			3.27	5.23	17.65
1	1	0.1109	0.3985			2.56	0.82			3.38	5.41	17.65

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in
maximum shear, V_u = 16.61 k/ft **OK**
$\phi V_c = \phi*2*(f\,'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*15.5)/1000 = 17.65 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

BY: C. Che	**DATE:** Aug-17	**CLIENT**	Willamette River WTP	**SHEET:**	
CHKD:	**DESCRIPTION:**		Area 8 - Washwater Basin PS	**JOB NO:**	10721A.00
DESIGN TASK:			Wall 1 - Soil EQ		

Rectangular Plate:

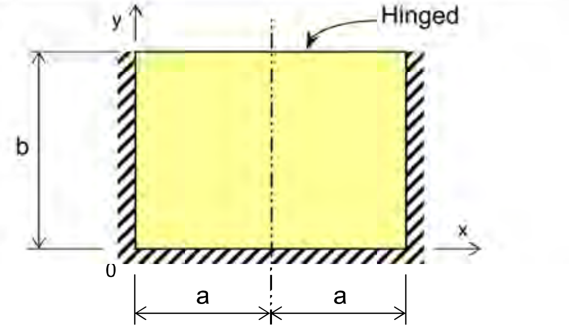
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 17.5 = 35 ft

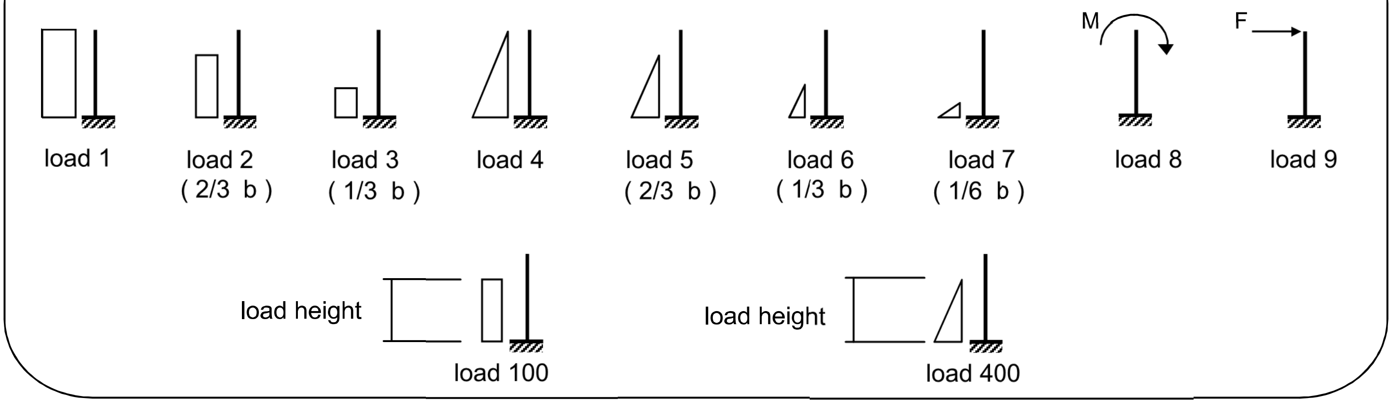
plate dimension, a = **17.5** ft

plate dimension, b = **20.5** ft

plate sides ratio, a/b = 0.8537



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**4**		**1.128**	**1.6**	**1.6**
B	**1**		**0.524**	**1.4**	**1.4**
C	**4**		**-0.497**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi

reinforcing steel strength, fy = **60** ksi

reinforcing clear cover to face of concrete = **2** in

number of curtains of reinforcing, (1 or 2) = **2**

Are bars in "x" or "y" direction closest to face of concrete ? **y**

minimum ratio of horizontal shrinkage-temperature steel = **0.00500**

minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 8 - Washwater Basin PS	**JOB NO:**	10721A.00
DESIGN TASK:					Wall 1 - Soil EQ		

M_x - Moment Summary

a = 17.5
b = 20.5
a / b = 0.8537

	A	B	C	D
Loads: q , or M	1.128	0.524	-0.497	
Moment Coefficient Multipliers	474.042	220.211	-208.864	

Boundary Case 2

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15")	
										M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0	0.8	0.0185	0.0492	0.0185		8.77	10.84	-3.86		15.74	23.79	0.36	0.54
0	0.6	0.0304	0.0701	0.0304		14.42	15.43	-6.36		23.50	35.79	0.54	0.60
0	0.4	0.0300	0.0595	0.0300		14.20	13.10	-6.26		21.05	32.31	0.49	0.60
0	0.2	0.0149	0.0252	0.0149		7.07	5.56	-3.12		9.52	14.74	0.22	0.54
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0.2	0	0.0034	0.0051	0.0034		1.60	1.13	-0.71		2.03	3.16	0.05	0.54
0.4	0	0.0069	0.0116	0.0069		3.29	2.55	-1.45		4.39	6.81	0.10	0.54
0.6	0	0.0093	0.0165	0.0093		4.42	3.63	-1.95		6.10	9.42	0.14	0.54
0.8	0	0.0107	0.0192	0.0107		5.06	4.22	-2.23		7.06	10.89	0.16	0.54
1	0	0.0111	0.0201	0.0111		5.25	4.42	-2.31		7.36	11.36	0.17	0.54
1	0.2	-0.0023	-0.0033	-0.0023		-1.10	-0.72	0.48		-1.33	-2.08	-0.03	-0.54
1	0.4	-0.0100	-0.0204	-0.0100		-4.76	-4.50	2.10		-7.16	-10.98	-0.16	-0.54
1	0.6	-0.0113	-0.0261	-0.0113		-5.35	-5.74	2.36		-8.73	-13.30	-0.20	-0.54
1	0.8	-0.0071	-0.0188	-0.0071		-3.37	-4.14	1.48		-6.02	-9.10	-0.14	-0.54
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0.8	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0.8	0.8	-0.0070	-0.0184	-0.0070		-3.30	-4.06	1.46		-5.91	-8.93	-0.13	-0.54
0.8	0.6	-0.0111	-0.0257	-0.0111		-5.28	-5.65	2.33		-8.60	-13.10	-0.20	-0.54
0.8	0.4	-0.0100	-0.0202	-0.0100		-4.76	-4.45	2.10		-7.11	-10.91	-0.16	-0.54
0.8	0.2	-0.0025	-0.0037	-0.0025		-1.19	-0.81	0.53		-1.48	-2.31	-0.03	-0.54

max negative moment, $M_{ux}(-)$ = -13.30 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.20 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 35.79 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.54 in^2/ft
minimum steel req'd = 0.60 in^2/ft
Use

carollo
Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 1 - Soil EQ

M_y - Moment Summary

a = 17.5
b = 20.5
a / b = 0.8537

	A	B	C	D
Loads: q , or M	1.128	0.524	-0.497	
Moment Coefficient Multipliers	474.042	220.211	-208.864	

Boundary Case 2

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0	0.8	0.0037	0.0098	0.0037		1.74	2.17	-0.77		3.14	4.75	0.07	0.54
0	0.6	0.0061	0.0140	0.0061		2.88	3.09	-1.27		4.70	7.16	0.10	0.54
0	0.4	0.0060	0.0119	0.0060		2.82	2.62	-1.24		4.20	6.44	0.09	0.54
0	0.2	0.0030	0.0050	0.0030		1.41	1.10	-0.62		1.89	2.93	0.04	0.54
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0.2	0	0.0168	0.0258	0.0168		7.96	5.68	-3.51		10.13	15.78	0.23	0.54
0.4	0	0.0346	0.0582	0.0346		16.38	12.81	-7.22		21.97	34.04	0.50	0.62
0.6	0	0.0467	0.0822	0.0467		22.15	18.11	-9.76		30.49	47.12	0.70	0.62
0.8	0	0.0533	0.0959	0.0533		25.27	21.11	-11.13		35.25	54.40	0.81	0.62
1	0	0.0553	0.1002	0.0553		26.23	22.07	-11.56		36.74	56.68	0.85	0.62
1	0.2	-0.0009	0.0068	-0.0009		-0.43	1.50	0.19		1.26	1.68	0.02	0.54
1	0.4	-0.0219	-0.0396	-0.0219		-10.37	-8.73	4.57		-14.53	-22.42	-0.33	-0.54
1	0.6	-0.0227	-0.0545	-0.0227		-10.78	-12.01	4.75		-18.04	-27.42	-0.40	-0.54
1	0.8	-0.0135	-0.0426	-0.0135		-6.38	-9.38	2.81		-12.95	-19.41	-0.28	-0.54
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
1	0.4	-0.0219	-0.0396	-0.0219		-10.37	-8.73	4.57		-14.53	-22.42	-0.33	-0.54
0.8	0.4	-0.0209	-0.0378	-0.0209		-9.93	-8.32	4.37		-13.87	-21.41	-0.31	-0.54
0.6	0.4	-0.0180	-0.0320	-0.0180		-8.54	-7.06	3.76		-11.83	-18.27	-0.27	-0.54
0.4	0.4	-0.0127	-0.0216	-0.0127		-6.00	-4.75	2.64		-8.10	-12.54	-0.18	-0.54
0.2	0.4	-0.0044	-0.0063	-0.0044		-2.07	-1.39	0.91		-2.55	-3.99	-0.06	-0.54

max negative moment, $M_{uy}(-)$ = -27.42 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.40 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 56.68 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.85 in^2/ft
minimum steel req'd = 0.62 in^2/ft
Use

carollo
Engineers...Working Wonders With Water ™

BY: C. Che	**DATE:** Aug-17	**CLIENT**	Willamette River WTP	**SHEET:**	
CHKD:	**DESCRIPTION:**		Area 8 - Washwater Basin PS	**JOB NO:**	10721A.00
DESIGN TASK:			Wall 1 - Soil EQ		

Shear Summary

a = 17.5
b = 20.5
a / b = 0.8537

Loads: q , or M: 1.128 | 0.524 | -0.497

Shear Coefficient Multipliers: 23.124 | 10.742 | -10.189

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c	
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft	
0	1	-0.0732	-0.1571	-0.0732		-1.69	-1.69	0.75		-2.63	-4.03	17.65	
0	0.8	0.1311	0.4490	0.1311		3.03	4.82	-1.34		6.52	9.73	17.65	
0	0.6	0.2317	0.5559	0.2317		5.36	5.97	-2.36		8.97	13.63	17.65	
0	0.4	0.2626	0.4734	0.2626		6.07	5.09	-2.68		8.48	13.09	17.65	
0	0.2	0.1442	0.1684	0.1442		3.34	1.81	-1.47		3.67	5.81	17.65	
0	0.00	-0.0167	-0.0577	-0.0167		-0.39	-0.62	0.17		-0.84	-1.25	17.65	
0.2	0	0.1660	0.1790	0.1660		3.84	1.92	-1.69		4.07	6.47	17.65	
0.4	0	0.2981	0.4110	0.2981		6.89	4.42	-3.04		8.27	12.96	17.65	
0.6	0	0.3610	0.5369	0.3610		8.35	5.77	-3.68		10.44	16.28	17.65	
0.8	0	0.3876	0.5946	0.3876		8.96	6.39	-3.95		11.40	17.75	17.65	NG
1	0	0.3948	0.6108	0.3948		9.13	6.56	-4.02		11.67	18.16	17.65	NG
0.2	1	-0.0171	0.0788	-0.0171		-0.40	0.85	0.17		0.62	0.80	17.65	
0.4	1	0.0567	0.2702	0.0567		1.31	2.90	-0.58		3.64	5.35	17.65	
0.6	1	0.0919	0.3549	0.0919		2.13	3.81	-0.94		5.00	7.43	17.65	
0.8	1	0.1068	0.3894	0.1068		2.47	4.18	-1.09		5.56	8.28	17.65	
1	1	0.1109	0.3985	0.1109		2.56	4.28	-1.13		5.71	8.51	17.65	

Ok for phi=1.0

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in

maximum shear, V_u = 18.16 k/ft

$\phi V_c = \phi*2*(f'c)^{1/2}*b*d$ = (0.75*2*(4000)^½ *12*15.5)/1000 = 17.65 k/ft

SHEAR NOT SATISFIED ! , CHANGE PLATE THICKNESS, or CHECK SHEAR AT DISTANCE "d".

Vn=23.5-kips for phi=1.0, Shear OK

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Area 8 - Washwater Basin
Wall 2 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.61	20.15	32.44	55.00	***0.59***	5.53	23.53	***0.23***	***<- OK***
1.2F+1.4E	1.00	37.57	37.57	55.00	***0.68***	7.80	23.53	***0.33***	***<- OK***
1.6(H+L)	1.41	45.07	63.55	55.00	***1.16***	9.89	23.53	***0.42***	***<- NG***
1.6H+1.4E	1.00	78.20	78.20	55.00	***1.42***	18.57	23.53	***0.79***	***<- NG***

Vertical Span

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	V_u (kip)	V_n (kip)	***DCR***	
1.4F	1.12	31.22	34.97	66.00	***0.53***	10.33	23.53	***0.44***	***<- OK***
1.2F+1.4E	1.00	46.72	46.72	66.00	***0.71***	14.10	23.53	***0.60***	***<- OK***
1.6(H+L)	1.00	52.10	52.10	66.00	***0.79***	15.32	23.53	***0.65***	***<- OK***
1.6H+1.4E	1.00	69.97	69.97	66.00	***1.06***	18.19	23.53	***0.77***	***<- NG***

Vertical to Slab Transition - Slab Top Bar

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	
1.4F	1.61	31.22	50.26	39.50	***1.27***	***<- NG***
1.2F+1.4E	1.00	46.72	46.72	39.50	***1.18***	***<- NG***

Vertical to Slab Transition - Slab Bottom Bar

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	
1.6(H+L)	1.00	52.10	52.10	53.00	***0.98***	***<- OK***
1.6H+1.4E	1.00	69.97	69.97	53.00	***1.32***	***<- NG***

Engineers...Working Wonders With Water ™

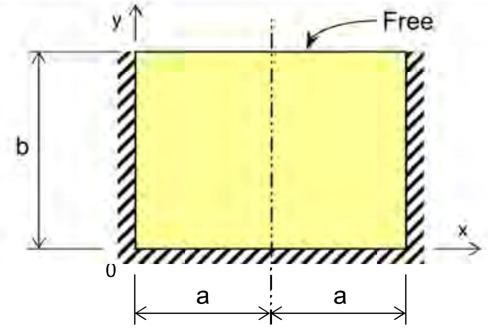
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Hydrostatic

Rectangular Plate:

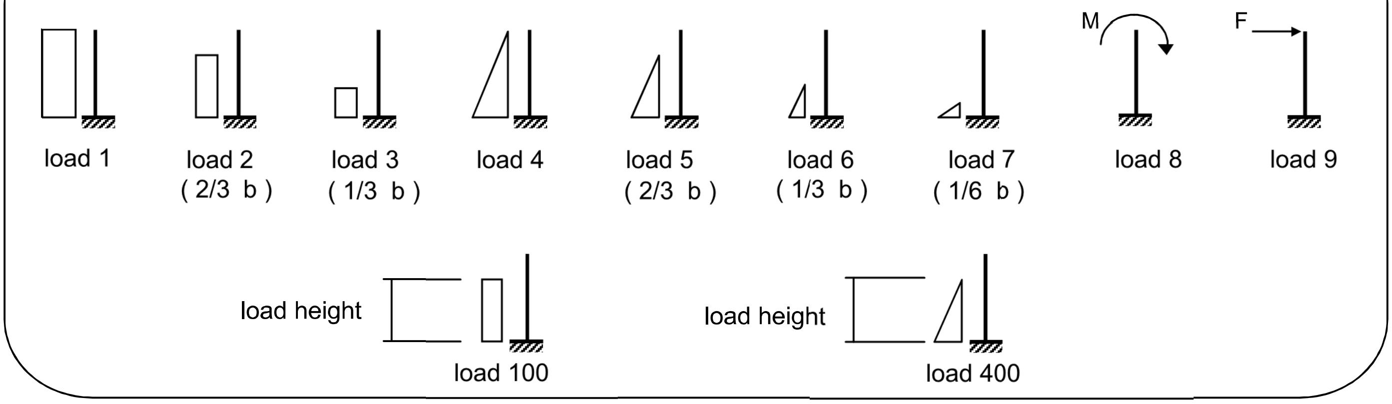
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 17.5 = 35 ft
plate dimension, a = **17.5** ft
plate dimension, b = **18** ft

plate sides ratio, a/b = 0.9722



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads 100 or 400	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	 for shear
A	**400**	**16.000**	**0.999**	**2.25**	**1.4**
B					
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Hydrostatic

M_x - Moment Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F: 0.999
Moment Coefficient Multipliers: 323.676

Boundary Case 1

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0445				14.39				14.39	32.37	0.49	0.60
0	0.8	0.0431				13.96				13.96	31.42	0.48	0.60
0	0.6	0.0392				12.70				12.70	28.57	0.43	0.58
0	0.4	0.0307				9.93				9.93	22.33	0.34	0.54
0	0.2	0.0137				4.45				4.45	10.01	0.15	0.54
0	0	0.0000				0.00				0.00	0.00	0.00	0.54
0.2	0	0.0039				1.26				1.26	2.84	0.04	0.54
0.4	0	0.0081				2.63				2.63	5.93	0.09	0.54
0.6	0	0.0113				3.67				3.67	8.26	0.12	0.54
0.8	0	0.0132				4.26				4.26	9.60	0.14	0.54
1	0	0.0138				4.46				4.46	10.03	0.15	0.54
1	0.2	-0.0005				-0.17				-0.17	-0.37	-0.01	-0.54
1	0.4	-0.0102				-3.32				-3.32	-7.46	-0.11	-0.54
1	0.6	-0.0154				-5.00				-5.00	-11.25	-0.17	-0.54
1	0.8	-0.0181				-5.85				-5.85	-13.16	-0.20	-0.54
1	1	-0.0200				-6.48				-6.48	-14.58	-0.22	-0.54
0.8	1	-0.0182				-5.89				-5.89	-13.24	-0.20	-0.54
0.8	0.8	-0.0166				-5.37				-5.37	-12.09	-0.18	-0.54
0.8	0.6	-0.0145				-4.70				-4.70	-10.57	-0.16	-0.54
0.8	0.4	-0.0099				-3.21				-3.21	-7.23	-0.11	-0.54
0.8	0.2	-0.0008				-0.25				-0.25	-0.56	-0.01	-0.54

max negative moment, $M_{ux}(-)$ = -14.58 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.22 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 32.37 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.49 in^2/ft
minimum steel req'd = 0.60 in^2/ft
Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Hydrostatic

M_y - Moment Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F: 0.999
Moment Coefficient Multipliers: 323.676

Boundary Case 1

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.54
0	0.8	0.0086				2.78				2.78	6.26	0.09	0.54
0	0.6	0.0079				2.55				2.55	5.73	0.08	0.54
0	0.4	0.0061				1.98				1.98	4.46	0.06	0.54
0	0.2	0.0028				0.90				0.90	2.03	0.03	0.54
0	0	0.0000				0.00				0.00	0.00	0.00	0.54
0.2	0	0.0194				6.28				6.28	14.14	0.20	0.54
0.4	0	0.0408				13.20				13.20	29.70	0.43	0.58
0.6	0	0.0565				18.29				18.29	41.15	0.61	0.62
0.8	0	0.0658				21.30				21.30	47.93	0.71	0.62
1	0	0.0689				22.30				22.30	50.16	0.75	0.62
1	0.2	0.0102				3.31				3.31	7.44	0.11	0.54
1	0.4	-0.0119				-3.84				-3.84	-8.64	-0.12	-0.54
1	0.6	-0.0131				-4.25				-4.25	-9.56	-0.14	-0.54
1	0.8	-0.0068				-2.20				-2.20	-4.94	-0.07	-0.54
1	1	0.0000				0.00				0.00	0.00	0.00	0.54
1	0.4	-0.0119				-3.84				-3.84	-8.64	-0.12	-0.54
0.8	0.4	-0.0116				-3.77				-3.77	-8.48	-0.12	-0.54
0.6	0.4	-0.0107				-3.46				-3.46	-7.78	-0.11	-0.54
0.4	0.4	-0.0082				-2.65				-2.65	-5.95	-0.09	-0.54
0.2	0.4	-0.0027				-0.88				-0.88	-1.99	-0.03	-0.54

max negative moment, $M_{uy}(-)$ = -9.56 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.14 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 50.16 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.75 in^2/ft
minimum steel req'd = 0.62 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Hydrostatic

Shear Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F: 0.999

Shear Coefficient Multipliers: 17.982

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.1194				2.15				2.15	3.00	17.65
0	0.8	0.1780				3.20				3.20	4.48	17.65
0	0.6	0.1915				3.44				3.44	4.82	17.65
0	0.4	0.2195				3.95				3.95	5.53	17.65
0	0.2	0.1212				2.18				2.18	3.05	17.65
0	0.00	-0.0156				-0.28				-0.28	-0.39	17.65
0.2	0	0.1706				3.07				3.07	4.29	17.65
0.4	0	0.3002				5.40				5.40	7.56	17.65
0.6	0	0.3679				6.62				6.62	9.26	17.65
0.8	0	0.4007				7.21				7.21	10.09	17.65
1	0	0.4105				7.38				7.38	10.33	17.65

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in
maximum shear, V_u = 10.33 k/ft **OK**
$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d$ = (0.75*2*(4000)ˆ½ *12*15.5)/1000 = 17.65 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water™

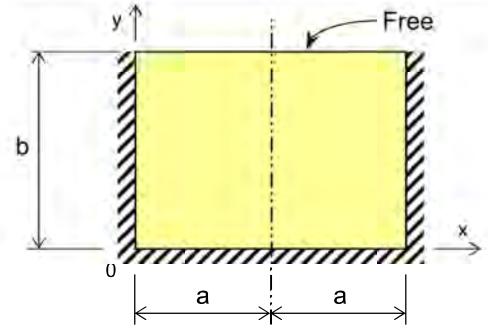
BY: C. Che **DATE:** Sep-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

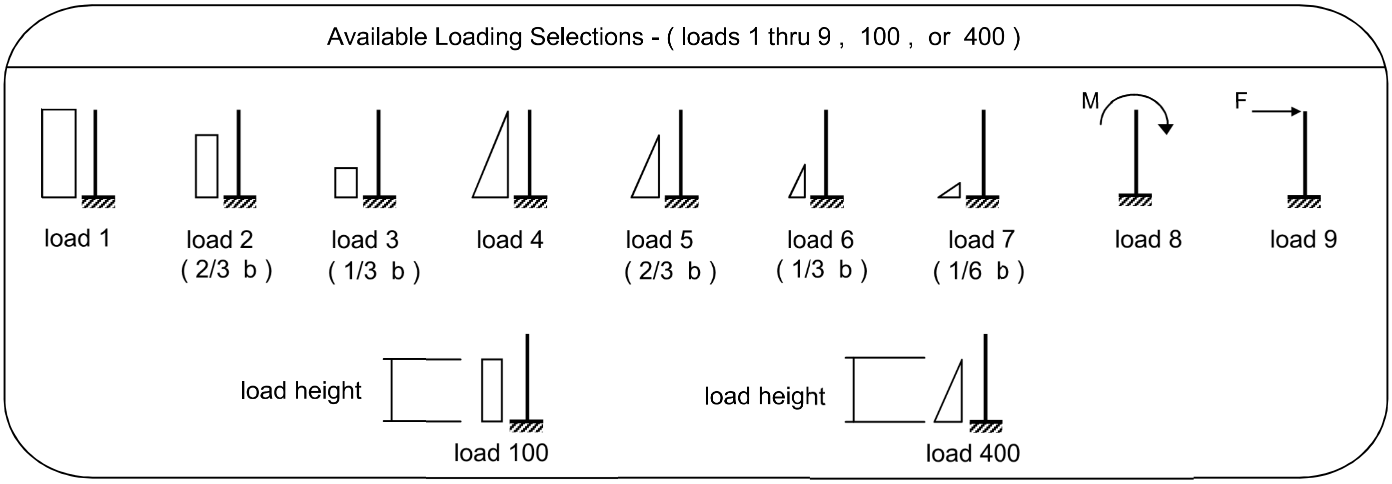
Rectangular Plate:

plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 17.5 = 35 ft
plate dimension, a = **17.5** ft
plate dimension, b = **18** ft

plate sides ratio, a/b = 0.9722





Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**16.000**	**0.999**	**1.2**	**1.2**
B	**100**	**16.000**	**0.228**	**1.4**	**1.4**
C	**400**	**16.000**	**0.083**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00300**
minimum ratio of vertical shrinkage-temperature steel = **0.00300**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

BY:	C. Che	**DATE:**	Sep-17	**CLIENT**	Willametter River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 8 - Washwater Basin PS	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 2 - Hydrodynamic		

M_x - Moment Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F			
0.999	0.228	0.083	
Moment Coefficient Multipliers			
323.676	73.872	26.892	

Boundary Case 1

SUMMARY

Final Moments

Reinforcing: (d = 15")

		Moment Coefficients				M_x Moments, ft-k/ft				M_x	M_{ux}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0445	0.1801	0.0445		14.39	13.31	1.20		28.89	37.57	0.57	0.60
0	0.8	0.0431	0.1560	0.0431		13.96	11.52	1.16		26.64	34.51	0.52	0.60
0	0.6	0.0392	0.1225	0.0392		12.70	9.05	1.05		22.80	29.38	0.44	0.59
0	0.4	0.0307	0.0791	0.0307		9.93	5.85	0.82		16.60	21.25	0.32	0.43
0	0.2	0.0137	0.0281	0.0137		4.45	2.08	0.37		6.90	8.77	0.13	0.32
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0.2	0	0.0039	0.0068	0.0039		1.26	0.50	0.10		1.87	2.36	0.04	0.32
0.4	0	0.0081	0.0172	0.0081		2.63	1.27	0.22		4.12	5.24	0.08	0.32
0.6	0	0.0113	0.0260	0.0113		3.67	1.92	0.31		5.90	7.53	0.11	0.32
0.8	0	0.0132	0.0317	0.0132		4.26	2.34	0.35		6.96	8.89	0.13	0.32
1	0	0.0138	0.0336	0.0138		4.46	2.48	0.37		7.31	9.34	0.14	0.32
1	0.2	-0.0005	0.0021	-0.0005		-0.17	0.15	-0.01		-0.03	-0.01	0.00	-0.32
1	0.4	-0.0102	-0.0273	-0.0102		-3.32	-2.01	-0.28		-5.60	-7.18	-0.11	-0.32
1	0.6	-0.0154	-0.0490	-0.0154		-5.00	-3.62	-0.42		-9.03	-11.65	-0.17	-0.32
1	0.8	-0.0181	-0.0630	-0.0181		-5.85	-4.65	-0.49		-10.99	-14.21	-0.21	-0.32
1	1	-0.0200	-0.0736	-0.0200		-6.48	-5.44	-0.54		-12.45	-16.14	-0.24	-0.32
0.8	1	-0.0182	-0.0674	-0.0182		-5.89	-4.98	-0.49		-11.35	-14.72	-0.22	-0.32
0.8	0.8	-0.0166	-0.0579	-0.0166		-5.37	-4.28	-0.45		-10.10	-13.06	-0.20	-0.32
0.8	0.6	-0.0145	-0.0456	-0.0145		-4.70	-3.37	-0.39		-8.46	-10.90	-0.16	-0.32
0.8	0.4	-0.0099	-0.0258	-0.0099		-3.21	-1.90	-0.27		-5.39	-6.90	-0.10	-0.32
0.8	0.2	-0.0008	0.0016	-0.0008		-0.25	0.12	-0.02		-0.15	-0.16	0.00	-0.32

max negative moment, $M_{ux}(-)$ = -16.14 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.24 in^2/ft
minimum steel req'd = -0.32 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 37.57 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.57 in^2/ft
minimum steel req'd = 0.60 in^2/ft
Use

carollo
Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

M_y - Moment Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F			
0.999	0.228	0.083	
Moment Coefficient Multipliers			
323.676	73.872	26.892	

Boundary Case 1

		Moment Coefficients				M_y Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 15.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0	0.8	0.0086	0.0312	0.0086		2.78	2.30	0.23		5.32	6.89	0.10	0.32
0	0.6	0.0079	0.0245	0.0079		2.55	1.81	0.21		4.56	5.88	0.08	0.32
0	0.4	0.0061	0.0158	0.0061		1.98	1.17	0.16		3.32	4.25	0.06	0.32
0	0.2	0.0028	0.0056	0.0028		0.90	0.42	0.07		1.39	1.77	0.03	0.32
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
0.2	0	0.0194	0.0339	0.0194		6.28	2.51	0.52		9.31	11.78	0.17	0.32
0.4	0	0.0408	0.0859	0.0408		13.20	6.35	1.10		20.64	26.26	0.38	0.51
0.6	0	0.0565	0.1303	0.0565		18.29	9.63	1.52		29.43	37.55	0.55	0.62
0.8	0	0.0658	0.1584	0.0658		21.30	11.70	1.77		34.78	44.42	0.66	0.62
1	0	0.0689	0.1680	0.0689		22.30	12.41	1.85		36.56	46.72	0.69	0.62
1	0.2	0.0102	0.0507	0.0102		3.31	3.74	0.27		7.32	9.59	0.14	0.32
1	0.4	-0.0119	-0.0101	-0.0119		-3.84	-0.75	-0.32		-4.91	-6.10	-0.09	-0.32
1	0.6	-0.0131	-0.0294	-0.0131		-4.25	-2.17	-0.35		-6.77	-8.63	-0.12	-0.32
1	0.8	-0.0068	-0.0199	-0.0068		-2.20	-1.47	-0.18		-3.85	-4.95	-0.07	-0.32
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.32
1	0.4	-0.0119	-0.0101	-0.0119		-3.84	-0.75	-0.32		-4.91	-6.10	-0.09	-0.32
0.8	0.4	-0.0116	-0.0102	-0.0116		-3.77	-0.75	-0.31		-4.84	-6.02	-0.09	-0.32
0.6	0.4	-0.0107	-0.0098	-0.0107		-3.46	-0.72	-0.29		-4.47	-5.57	-0.08	-0.32
0.4	0.4	-0.0082	-0.0069	-0.0082		-2.65	-0.51	-0.22		-3.38	-4.20	-0.06	-0.32
0.2	0.4	-0.0027	0.0009	-0.0027		-0.88	0.07	-0.07		-0.89	-1.07	-0.02	-0.32

max negative moment, $M_{uy}(-)$ = -8.63 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.12 in^2/ft
minimum steel req'd = -0.32 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 46.72 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.69 in^2/ft
minimum steel req'd = 0.62 in^2/ft
Use

BY: C. Che **DATE:** Sep-17 **CLIENT** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 2 - Hydrodynamic

Shear Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F			
0.999	0.228	0.083	
Shear Coefficient Multipliers			
17.982	4.104	1.494	

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.1194	0.7365	0.1194		2.15	3.02	0.18		5.35	7.06	17.65
0	0.8	0.1780	0.6762	0.1780		3.20	2.78	0.27		6.24	8.10	17.65
0	0.6	0.1915	0.5684	0.1915		3.44	2.33	0.29		6.06	7.80	17.65
0	0.4	0.2195	0.4327	0.2195		3.95	1.78	0.33		6.05	7.68	17.65
0	0.2	0.1212	0.0884	0.1212		2.18	0.36	0.18		2.72	3.38	17.65
0	0.00	-0.0156	-0.0805	-0.0156		-0.28	-0.33	-0.02		-0.63	-0.83	17.65
0.2	0	0.1706	0.1490	0.1706		3.07	0.61	0.25		3.93	4.89	17.65
0.4	0	0.3002	0.4390	0.3002		5.40	1.80	0.45		7.65	9.63	17.65
0.6	0	0.3679	0.6285	0.3679		6.62	2.58	0.55		9.75	12.32	17.65
0.8	0	0.4007	0.7304	0.4007		7.21	3.00	0.60		10.80	13.68	17.65
1	0	0.4105	0.7622	0.4105		7.38	3.13	0.61		11.12	14.10	17.65

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in
maximum shear, V_u = 14.10 k/ft **OK**
$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d =$ (0.75*2*(4000)ˆ½ *12*15.5)/1000 = 17.65 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water™

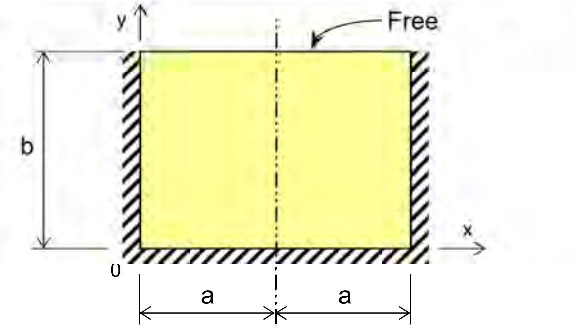
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Soil Static

Rectangular Plate:

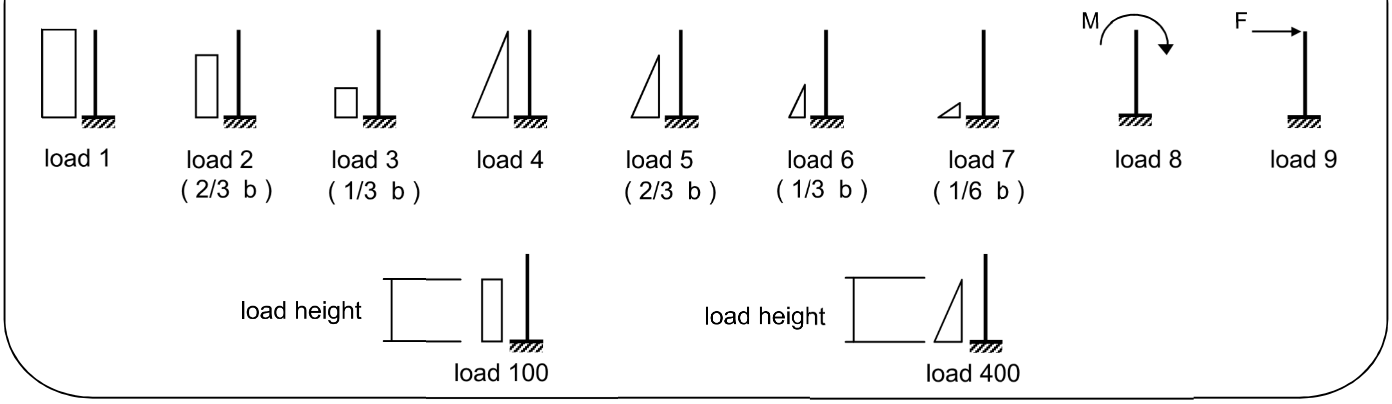
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 17.5 = 35 ft
plate dimension, a = **17.5** ft
plate dimension, b = **18** ft

plate sides ratio, a/b = 0.9722



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	concrete load factors for shear
A	**4**		**0.990**	**2.25**	**1.6**
B	**1**		**0.100**	**2.25**	**1.6**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

BY:	C. Che	**DATE:** Aug-17	**CLIENT** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**JOB NO:**	10721A.00
DESIGN TASK:			Wall 2 - Soil Static		

M_x - Moment Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F			
0.990	0.100		
Moment Coefficient Multipliers			
320.760	32.400		

Boundary Case 1

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0622	0.2537			19.95	8.22			28.17	63.38	0.99	0.60
0	0.8	0.0586	0.2092			18.79	6.78			25.57	57.52	0.89	0.60
0	0.6	0.0507	0.1517			16.27	4.91			21.19	47.67	0.73	0.60
0	0.4	0.0370	0.0905			11.88	2.93			14.81	33.33	0.51	0.60
0	0.2	0.0155	0.0302			4.97	0.98			5.95	13.39	0.20	0.54
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0.2	0	0.0042	0.0070			1.35	0.23			1.58	3.55	0.05	0.54
0.4	0	0.0092	0.0189			2.97	0.61			3.58	8.05	0.12	0.54
0.6	0	0.0132	0.0297			4.24	0.96			5.21	11.71	0.18	0.54
0.8	0	0.0156	0.0367			5.00	1.19			6.18	13.92	0.21	0.54
1	0	0.0164	0.0391			5.25	1.27			6.51	14.66	0.22	0.54
1	0.2	-0.0001	0.0036			-0.03	0.12			0.08	0.19	0.00	0.54
1	0.4	-0.0124	-0.0315			-3.99	-1.02			-5.01	-11.28	-0.17	-0.54
1	0.6	-0.0201	-0.0609			-6.45	-1.97			-8.42	-18.95	-0.28	-0.54
1	0.8	-0.0243	-0.0831			-7.78	-2.69			-10.48	-23.57	-0.36	-0.54
1	1	-0.0272	-0.0995			-8.72	-3.22			-11.94	-26.87	-0.41	-0.54
0.8	1	-0.0247	-0.0915			-7.94	-2.96			-10.90	-24.53	-0.37	-0.54
0.8	0.8	-0.0223	-0.0764			-7.16	-2.48			-9.64	-21.68	-0.33	-0.54
0.8	0.6	-0.0189	-0.0563			-6.05	-1.82			-7.87	-17.72	-0.27	-0.54
0.8	0.4	-0.0120	-0.0294			-3.85	-0.95			-4.80	-10.80	-0.16	-0.54
0.8	0.2	-0.0004	0.0031			-0.12	0.10			-0.02	-0.04	0.00	-0.54

max negative moment, $M_{ux}(-)$ = -26.87 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.41 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 63.38 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.99 in^2/ft
minimum steel req'd = 0.60 in^2/ft
Use

BY:	C. Che	**DATE:** Aug-17	**CLIENT** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**JOB NO:**	10721A.00
DESIGN TASK:			Wall 2 - Soil Static		

M_y - Moment Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F			
0.990	0.100		
Moment Coefficient Multipliers			
320.760	32.400		

Boundary Case 1

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0	0.8	0.0117	0.0418			3.75	1.35			5.11	11.49	0.17	0.54
0	0.6	0.0101	0.0303			3.25	0.98			4.24	9.53	0.14	0.54
0	0.4	0.0074	0.0181			2.36	0.59			2.95	6.64	0.10	0.54
0	0.2	0.0031	0.0061			1.00	0.20			1.20	2.70	0.04	0.54
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
0.2	0	0.0211	0.0350			6.76	1.13			7.89	17.76	0.26	0.54
0.4	0	0.0464	0.0948			14.89	3.07			17.96	40.41	0.60	0.62
0.6	0	0.0660	0.1485			21.16	4.81			25.97	58.44	0.87	0.62
0.8	0	0.0778	0.1834			24.95	5.94			30.89	69.50	1.05	0.62
1	0	0.0818	0.1954			26.23	6.33			32.56	73.26	1.11	0.62
1	0.2	0.0159	0.0687			5.10	2.23			7.33	16.49	0.24	0.54
1	0.4	-0.0113	0.0028			-3.61	0.09			-3.52	-7.92	-0.11	-0.54
1	0.6	-0.0159	-0.0243			-5.08	-0.79			-5.87	-13.21	-0.19	-0.54
1	0.8	-0.0093	-0.0240			-2.98	-0.78			-3.76	-8.46	-0.12	-0.54
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.54
1	0.4	-0.0113	0.0028			-3.61	0.09			-3.52	-7.92	-0.11	-0.54
0.8	0.4	-0.0111	0.0022			-3.56	0.07			-3.49	-7.85	-0.11	-0.54
0.6	0.4	-0.0102	0.0012			-3.27	0.04			-3.23	-7.28	-0.10	-0.54
0.4	0.4	-0.0077	0.0018			-2.46	0.06			-2.40	-5.41	-0.08	-0.54
0.2	0.4	-0.0020	0.0065			-0.65	0.21			-0.44	-0.99	-0.01	-0.54

max negative moment, $M_{uy}(-)$ = -13.21 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.19 in^2/ft
minimum steel req'd = -0.54 in^2/ft
Use

max positive moment, $M_{uy}(+)$ = 73.26 ft-k/ft
max positive steel req'd, $A_s(+)$ = 1.11 in^2/ft
minimum steel req'd = 0.62 in^2/ft
Use

BY:	C. Che	**DATE:** Aug-17	**CLIENT** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 8 - Washwater Basin PS	**JOB NO:**	10721A.00
DESIGN TASK:			Wall 2 - Soil Static		

Shear Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F			
0.990	0.100		
Shear Coefficient Multipliers			
17.820	1.800		

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.1894	1.1771			3.38	2.12			5.49	8.79	17.65
0	0.8	0.2520	0.9404			4.49	1.69			6.18	9.89	17.65
0	0.6	0.2481	0.6236			4.42	1.12			5.54	8.87	17.65
0	0.4	0.2426	0.4028			4.32	0.73			5.05	8.08	17.65
0	0.2	0.1129	0.0509			2.01	0.09			2.10	3.37	17.65
0	0.00	-0.0238	-0.0916			-0.42	-0.16			-0.59	-0.94	17.65
0.2	0	0.1644	0.1118			2.93	0.20			3.13	5.01	17.65
0.4	0	0.3145	0.4335			5.60	0.78			6.38	10.21	17.65
0.6	0	0.3985	0.6610			7.10	1.19			8.29	13.27	17.65
0.8	0	0.4407	0.7883			7.85	1.42			9.27	14.84	17.65
1	0	0.4535	0.8288			8.08	1.49			9.57	15.32	17.65

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in
maximum shear, V_u = 15.32 k/ft **OK**
$\phi V_c = \phi * 2 * (f\,'c)^{1/2} * b * d =$ (0.75*2*(4000)ˆ½ *12*15.5)/1000 = 17.65 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

carollo
Engineers...Working Wonders With Water™

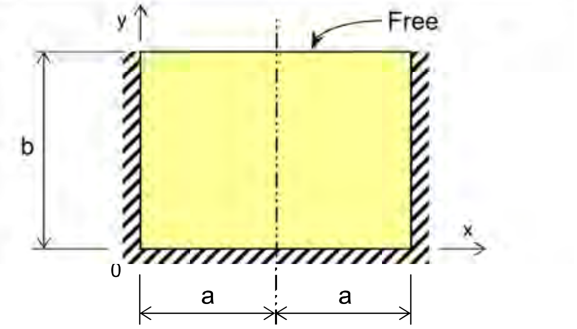
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Soil EQ

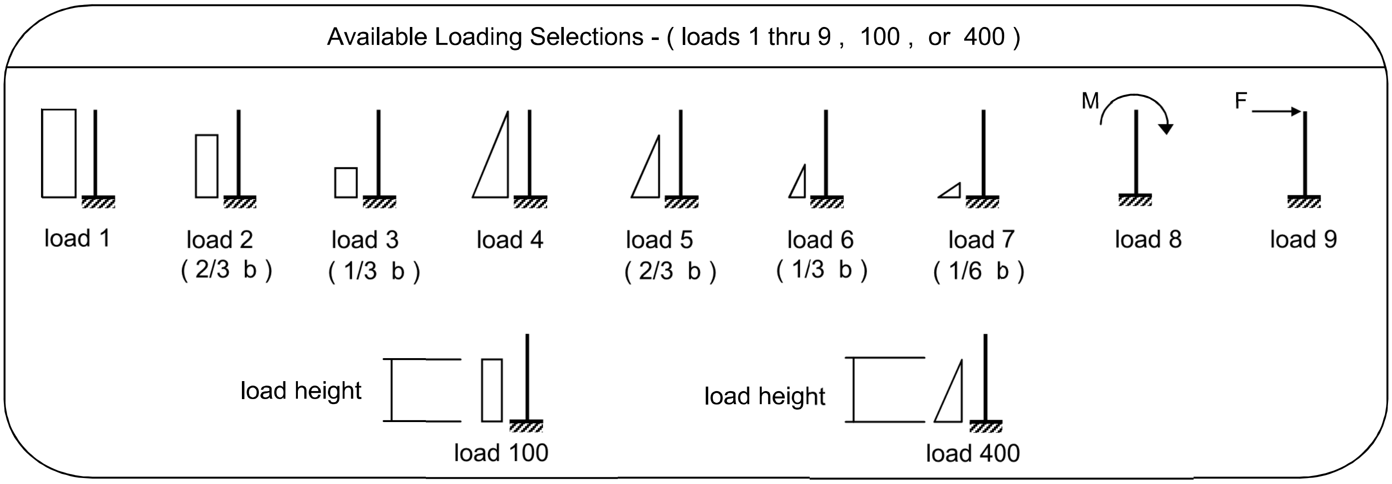
Rectangular Plate:

plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 17.5 = 35 ft
plate dimension, a = **17.5** ft
plate dimension, b = **18** ft

plate sides ratio, a/b = 0.9722




Available Loading Selections - (loads 1 thru 9 , 100 , or 400)

Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	concrete load factors for shear
A	**4**		**0.990**	**1.6**	**1.6**
B	**1**		**0.524**	**1.4**	**1.4**
C	**4**		**-0.497**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **18** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00500**
minimum ratio of vertical shrinkage-temperature steel = **0.00500**

bar locations	d (in)	d' (in)
Mx bending	15"	3"
My bending	15.5"	2.5"

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Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Soil EQ

M_x - Moment Summary

a = 17.5
b = 18
a / b = 0.9722

Loads: q , M , or F			
0.990	0.524	-0.497	
Moment Coefficient Multipliers			
320.760	169.776	-161.028	

Boundary Case 1

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 15")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0622	0.2537	0.0622		19.95	43.07	-10.01		53.01	78.20	1.23	0.60
0	0.8	0.0586	0.2092	0.0586		18.79	35.52	-9.43		44.87	66.58	1.04	0.60
0	0.6	0.0507	0.1517	0.0507		16.27	25.75	-8.17		33.85	50.65	0.78	0.60
0	0.4	0.0370	0.0905	0.0370		11.88	15.36	-5.96		21.28	32.16	0.49	0.60
0	0.2	0.0155	0.0302	0.0155		4.97	5.13	-2.50		7.60	11.64	0.17	0.54
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0.2	0	0.0042	0.0070	0.0042		1.35	1.19	-0.68		1.86	2.88	0.04	0.54
0.4	0	0.0092	0.0189	0.0092		2.97	3.21	-1.49		4.69	7.16	0.11	0.54
0.6	0	0.0132	0.0297	0.0132		4.24	5.04	-2.13		7.15	10.86	0.16	0.54
0.8	0	0.0156	0.0367	0.0156		5.00	6.23	-2.51		8.72	13.21	0.20	0.54
1	0	0.0164	0.0391	0.0164		5.25	6.64	-2.63		9.25	14.00	0.21	0.54
1	0.2	-0.0001	0.0036	-0.0001		-0.03	0.61	0.02		0.60	0.83	0.01	0.54
1	0.4	-0.0124	-0.0315	-0.0124		-3.99	-5.36	2.00		-7.34	-11.08	-0.17	-0.54
1	0.6	-0.0201	-0.0609	-0.0201		-6.45	-10.34	3.24		-13.56	-20.27	-0.30	-0.54
1	0.8	-0.0243	-0.0831	-0.0243		-7.78	-14.12	3.91		-17.99	-26.75	-0.40	-0.54
1	1	-0.0272	-0.0995	-0.0272		-8.72	-16.89	4.38		-21.23	-31.46	-0.48	-0.60
0.8	1	-0.0247	-0.0915	-0.0247		-7.94	-15.53	3.99		-19.48	-28.86	-0.44	-0.58
0.8	0.8	-0.0223	-0.0764	-0.0223		-7.16	-12.98	3.59		-16.54	-24.59	-0.37	-0.54
0.8	0.6	-0.0189	-0.0563	-0.0189		-6.05	-9.56	3.04		-12.57	-18.81	-0.28	-0.54
0.8	0.4	-0.0120	-0.0294	-0.0120		-3.85	-5.00	1.93		-6.91	-10.45	-0.16	-0.54
0.8	0.2	-0.0004	0.0031	-0.0004		-0.12	0.53	0.06		0.47	0.63	0.01	0.54

max negative moment, $M_{ux}(-)$ = -31.46 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.48 in^2/ft
minimum steel req'd = -0.60 in^2/ft
Use

max positive moment, $M_{ux}(+)$ = 78.20 ft-k/ft
max positive steel req'd, $A_s(+)$ = 1.23 in^2/ft
minimum steel req'd = 0.60 in^2/ft
Use

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Soil EQ

M_y - Moment Summary

		Loads: q , M , or F				Boundary Case 1				SUMMARY			
a =	17.5	0.990	0.524	-0.497									
b =	18	Moment Coefficient Multipliers								Final Moments		Reinforcing: (d = 15.5")	
a / b =	0.9722	320.760	169.776	-161.028									
		Moment Coefficients				M_y Moments, ft-k/ft				M_y	M_{uy}	$A_{s(req'd)}$	$A_{s(min)}$
x / a	y / b	A	B	C	D	A	B	C	D	ft-k/ft	ft-k/ft	in^2/ft	in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0	0.8	0.0117	0.0418	0.0117		3.75	7.10	-1.88		8.97	13.31	0.19	0.54
0	0.6	0.0101	0.0303	0.0101		3.25	5.14	-1.63		6.76	10.12	0.15	0.54
0	0.4	0.0074	0.0181	0.0074		2.36	3.07	-1.19		4.25	6.42	0.09	0.54
0	0.2	0.0031	0.0061	0.0031		1.00	1.03	-0.50		1.53	2.34	0.03	0.54
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
0.2	0	0.0211	0.0350	0.0211		6.76	5.94	-3.39		9.30	14.38	0.21	0.54
0.4	0	0.0464	0.0948	0.0464		14.89	16.09	-7.48		23.50	35.88	0.53	0.62
0.6	0	0.0660	0.1485	0.0660		21.16	25.21	-10.62		35.74	54.27	0.81	0.62
0.8	0	0.0778	0.1834	0.0778		24.95	31.14	-12.52		43.56	65.98	0.99	0.62
1	0	0.0818	0.1954	0.0818		26.23	33.17	-13.17		46.23	69.97	1.06	0.62
1	0.2	0.0159	0.0687	0.0159		5.10	11.66	-2.56		14.20	20.91	0.30	0.54
1	0.4	-0.0113	0.0028	-0.0113		-3.61	0.47	1.81		-1.32	-2.58	-0.04	-0.54
1	0.6	-0.0159	-0.0243	-0.0159		-5.08	-4.13	2.55		-6.66	-10.34	-0.15	-0.54
1	0.8	-0.0093	-0.0240	-0.0093		-2.98	-4.08	1.50		-5.56	-8.38	-0.12	-0.54
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.54
1	0.4	-0.0113	0.0028	-0.0113		-3.61	0.47	1.81		-1.32	-2.58	-0.04	-0.54
0.8	0.4	-0.0111	0.0022	-0.0111		-3.56	0.37	1.79		-1.40	-2.67	-0.04	-0.54
0.6	0.4	-0.0102	0.0012	-0.0102		-3.27	0.21	1.64		-1.42	-2.65	-0.04	-0.54
0.4	0.4	-0.0077	0.0018	-0.0077		-2.46	0.31	1.24		-0.92	-1.78	-0.03	-0.54
0.2	0.4	-0.0020	0.0065	-0.0020		-0.65	1.10	0.33		0.77	0.95	0.01	0.54

max negative moment, $M_{uy}(-)$ = -10.34 ft-k/ft

max negative steel req'd, $A_s(-)$ = -0.15 in^2/ft

minimum steel req'd = -0.54 in^2/ft

Use

max positive moment, $M_{uy}(+)$ = 69.97 ft-k/ft

max positive steel req'd, $A_s(+)$ = 1.06 in^2/ft

minimum steel req'd = 0.62 in^2/ft

Use

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.00
DESIGN TASK: Wall 2 - Soil EQ

Shear Summary

a = 17.5
b = 18
a / b = 0.9722

	A	B	C	D
Loads: q , M , or F	0.990	0.524	-0.497	
Shear Coefficient Multipliers	17.820	9.432	-8.946	

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c	
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft	
0	1	0.1894	1.1771	0.1894		3.38	11.10	-1.69		12.78	18.57	17.65	NG Ok for phi=1.0
0	0.8	0.2520	0.9404	0.2520		4.49	8.87	-2.25		11.11	16.45	17.65	
0	0.6	0.2481	0.6236	0.2481		4.42	5.88	-2.22		8.08	12.20	17.65	
0	0.4	0.2426	0.4028	0.2426		4.32	3.80	-2.17		5.95	9.20	17.65	
0	0.2	0.1129	0.0509	0.1129		2.01	0.48	-1.01		1.48	2.48	17.65	
0	0.00	-0.0238	-0.0916	-0.0238		-0.42	-0.86	0.21		-1.08	-1.59	17.65	
0.2	0	0.1644	0.1118	0.1644		2.93	1.05	-1.47		2.51	4.11	17.65	
0.4	0	0.3145	0.4335	0.3145		5.60	4.09	-2.81		6.88	10.75	17.65	
0.6	0	0.3985	0.6610	0.3985		7.10	6.23	-3.57		9.77	15.10	17.65	
0.8	0	0.4407	0.7883	0.4407		7.85	7.43	-3.94		11.35	17.45	17.65	
1	0	0.4535	0.8288	0.4535		8.08	7.82	-4.06		11.84	18.19	17.65	NG Ok for phi=1.0

Concrete strength reduction factor for shear, ϕ = 0.75

d = 15.5 in
maximum shear, V_u = 18.57 k/ft
$\phi V_c = \phi*2*(f'c)^{1/2}*b*d$ = (0.75*2*(4000)^½ *12*15.5)/1000 = 17.65 k/ft

SHEAR NOT SATISFIED ! , CHANGE PLATE THICKNESS, or CHECK SHEAR AT DISTANCE "d".

Vn=23.5-kips for phi=1.0, Shear OK

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

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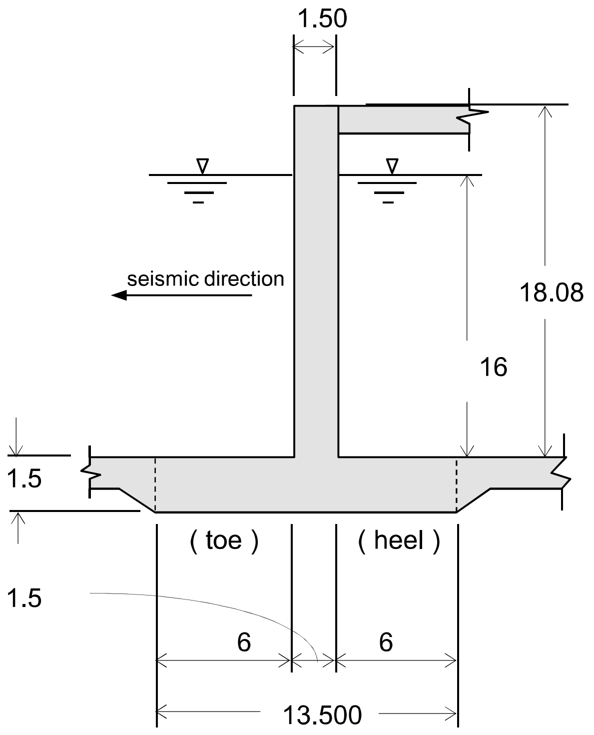
BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willametter River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 8 - Washwater Basin PS	**JOB NO:**	10721A.10
DESIGN TASK:					Wall 3 - Hydrodynamic (Water 2-Sides)		

Hydrodynamic analysis of an interior wall with equal water each side per ASCE 7-10 and the 2012 IBC code:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B =	1	ft
tank inside length in direction of seismic, L =	**28.25**	ft
inside serpentine wall thickness, t_w =	**18**	inch
wall height to underside of roof, H_w =	**18**	ft
roof thickness, tr =	**1**	inch
liquid height, H_L =	**16**	ft
liquid specific gravity =	**1**	
liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ =	0.0624	k/ft^3
acceleration due to gravity, g =	32.17	ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ =	0.00194	$k\text{-}sec^2/ft^4$
foundation footing thickness, t_f =	1.5	ft
foundation projection toe side, l_t =	6	ft
foundation projection heel side, l_h =	6	ft
allowable soil bearing pressure static =	**2**	ksf
allowable soil bearing pressure seismic =	**2.67**	ksf
yield strength of reinforcement, f_y =	**60**	ksi
concrete strength, f'_c =	**4**	ksi
concrete density, γ_c =	0.150	k/ft^3
concrete modulus of elasticity, E_c =	3605.0	ksi
concrete mass density, $\rho_c = \gamma_c / g$ =	0.004663	$k\text{-}sec^2/ft^4$

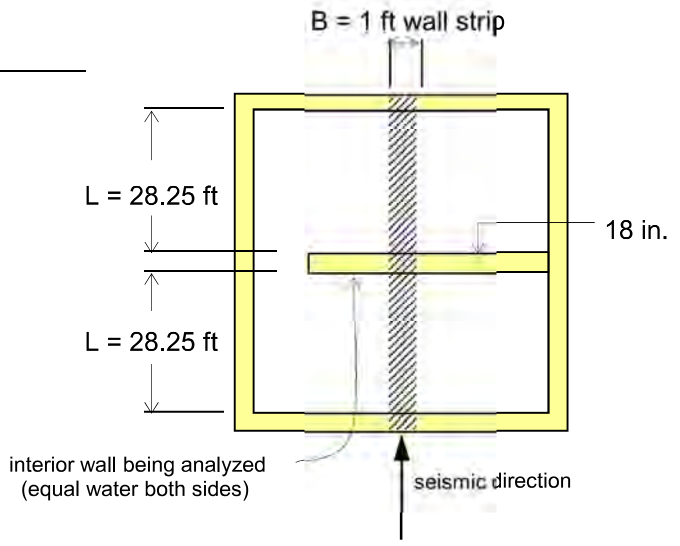


Interior Wall Section

(wall fixity = pinned at roof & fixed at floor)

Seismic data from the IBC code:	
Structure Risk Category =	**3**
Seismic importance factor, I =	**1.25**
Response modification factor, R_i =	**3**
Response modification factor, R_c =	**1.5**

Note:
Hydrodynamic seismic forces on the interior wall will be the sum of half the impulsive and convective forces from water on <u>each</u> side of the wall.



Interior Wall Plan

BY: C. Che **DATE:** Sep-17 **CLIENT:** Willametter River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 8 - Washwater Basin PS **JOB NO:** 10721A.10
DESIGN TASK: Wall 3 - Hydrodynamic (Water 2-Sides)

Weights:

unit 1-ft width wall mass, W_w = (18/12) * (18) * 0.15 = 4.05 kip
wall c.g. relative to base, h_w = 18 / 2 = 9.000 ft

unit width liquid mass, W_L = 28.25*1*16*0.0624 = 28.20 kip

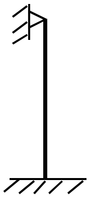
Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Note: Hydrodynamic seismic forces on the interior wall will be the sum of half the impulsive and convective forces from water on each side of the wall.

1). wall stiffness and dynamic property:

Note: Wi and hi are impulsive component variables calculated on page 3.



wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.12589 k-sec^2/ft^2
liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.26100 k-sec^2/ft^2
centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 6.976 ft
wall fixity condition is pinned at roof & fixed at floor:
wall stiffness is determined using a unit mass load located at the centroidal distance h.
wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 3808.79 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (3808.79 / (0.1259 + 0.261))\hat{}½ = 99.21943 \text{ rad/sec}$$

period of vibration of the wall plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2*π / 99.21943 = 0.0633 sec

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 *g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = 9.8051 \qquad \omega_c = \frac{\lambda}{\sqrt{L}} = \quad 9.8051/(28.25)\hat{}½ = 1.8448 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2*π / 1.8448 = 3.4059 sec
Long transition period (from map figure 22-12 ASCE 7), T_L = **16** sec
design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.2889 *g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021 \text{ , but } \le 1.0 = 0.7312$$

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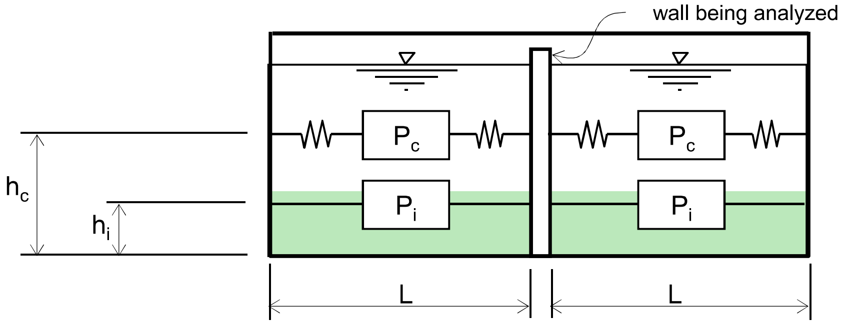
DESIGN TASK:					Wall 3 - Hydrodynamic (Water 2-Sides)		



Dynamic Model

$L =$ 28.25 ft
$B =$ 1 ft
$H_L =$ 16 ft
$W_L =$ 28.2 kip

$L / H_L =$ 1.76563
$H_L / L =$ 0.56637

3). lateral fluid impulsive force:

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) = \quad 16.79 \text{ kip}$$

hi (EBP) = HL * 0.375 = 16 * 0.375 = 6 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 11.438 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_i}\right)W_i = \quad (\ 0.611 * 1.25 / 3) * 16.79 = \quad 4.27 \text{ kip}$$

impulsive force moment excluding bottom pressure , $M_{i(EBP)} = P_i{*}h_{i(EBP)} =$ 4.27 * 6 = 25.62 ft-k

impulsive force moment including bottom pressure , $M_{i(IBP)} = P_i{*}h_{i(IBP)} =$ 4.27 * 11.438 = 48.84 ft-k

4). lateral fluid convective force:

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) = \quad 12.43 \text{ kip}$$

$$h_{c\ (EBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) = \quad 9.619 \text{ ft}$$

$$h_{c\ (IBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) = \quad 12.721 \text{ ft}$$

$$\text{convective force, } P_c = \left(\frac{S_{ac}\ I}{R_c}\right)W_c = \quad (\ 0.2889 * 1.25 / 1.5) * 12.43 = \quad 2.99 \text{ kip}$$

convective force moment excluding bottom pressure , $M_{c(EBP)} = P_c{*}h_{c(EBP)} =$ 2.99 * 9.619 = 28.76 ft-k

convective force moment including bottom pressure , $M_{c(IBP)} = P_c{*}h_{c(IBP)} =$ 2.99 * 12.721 = 38.04 ft-k

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DESIGN TASK:					Wall 3 - Hydrodynamic (Water 2-Sides)		

5). <u>lateral inertia force of the accelerating wall:</u>

mass of a unit 1-ft width wall, W_w = 4.05 kip

wall c.g. relative to base, h_w = 9.000 ft

wall inertia force, $P_w = \left(\frac{S_{ai}\ \text{I}\ \varepsilon}{R_i}\right)W_w =$ (0.611 * 1.25 * 0.7312 / 3) * 4.05 = 0.75 kip

wall inertia force moment, $M_w = P_w * h_w =$ 0.75 * 9 = 6.75 ft-k

6). <u>total base shear:</u>

$$V = \sqrt{(P_i + P_w)^2 + P_c^2}$$

V = ((4.27 + 0.75)² + (2.99)²)^½ = 5.84 kip

7). <u>total moment at the base excluding bottom pressure (EBP):</u>

$$M_b = \sqrt{(M_i + M_w)^2 + M_c^2}$$

M_b = ((25.62 + 6.75)² + (28.76)²)^½ = 43.30 ft-k

8). <u>total moment at the base including bottom pressure (IBP):</u>

$$M_o = \sqrt{(M_i + M_w)^2 + M_c^2}$$

M_o = ((48.84 + 6.75)² + (38.04)²)^½ = 67.36 ft-k

9). <u>maximum wave slosh height displacement:</u> (see ASCE-10, 15.7.6.1 notes c and d)

(Risk Category = 3) I = 1.25 ,use TL = 4 ,Sd1 = 0.656 ,Tc = 3.4059

S_{ac} = 1.5 * Sd1 / Tc = 0.2889 *g

$d_{(max)} = 0.42\ (\ L\ )(\ S_{ac}\ \ \text{I}\ ) =$ 0.42 * (28.25) * (0.2889 * 1.25) = 4.28 ft

(minimum freeboard see table 15.7-3 of ASCE 7) , d(min) = 0.7 * d(max) = 3 ft

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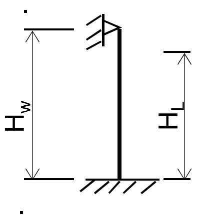
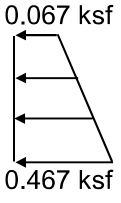
DESIGN TASK:					Wall 3 - Hydrodynamic (Water 2-Sides)		

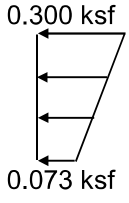
10). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



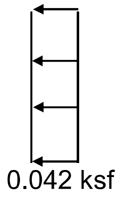
H_w = 18
H_L = 16



impulsive



convective



wall inertia

impulsive: Note: this accounts for the impulsive pressure on each side of the wall.

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{B\ H_L^2} =$$

P_i = 4.27 kip
h_i = 6 ft
at y = H_L, p_{iy} = 0.067 ksf
at base y = 0, p_{iy} = 0.467 ksf

convective: Note: this accounts for the convective pressure on each side of the wall.

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{B\ H_L^2} =$$

P_c = 2.99 kip
h_c = 9.619 ft
at y = H_L, p_{cy} = 0.300 ksf
at base y = 0, p_{cy} = 0.073 ksf

wall inertia:

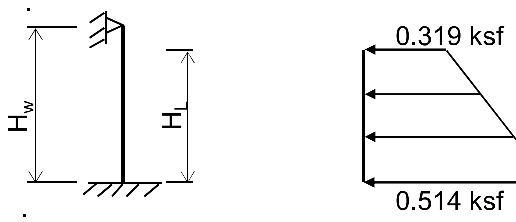
$$p_{wy} = \frac{S_{ai}\ I\ \varepsilon\ \gamma_c\ (t_w/12)}{R_i} =$$

p_{wy} = 0.1861 * γ_c * t_w
at y = H_w, p_{wy} = 0.042 ksf
at base y = 0, p_{wy} = 0.042 ksf

combine the effects of the hydrodynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2} =$$

at y = H_w, p_y = 0.319 ksf
at base y = 0, p_y = 0.514 ksf



(unfactored = 0.319 / 1.4 = 0.228 ksf)

(unfactored = 0.514 / 1.4 = 0.367 ksf)

resultant dynamic pressures

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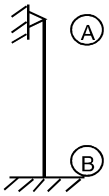
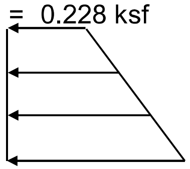
11). wall design pressures for hydrodynamic seismic:

wall height, H_w = 18 ft

liquid height, H_L = 16 ft



unfactored load = 0.228 ksf



unfactored load = 0.367 ksf

unfactored resultant dynamic pressures

load factor applied to dynamic shear = 1.4

load factor applied to dynamic moment = 1.4

factored shear, Vu = 1.4*(dynamic shear)

factored moment, Mu = 1.4*(dynamic moment)

WALL REACTIONS for HYDROSTATIC + SEISMIC		
Reactions, Shears, and Moments	**(kips/ft and ft-kips/ft)**	
Location	unfactored loads Hydrodynamic	factored loads Static + Dynamic
shear reaction at Ⓐ	1.302	1.822
moment at Ⓐ	0.000	0.000
shear reaction at Ⓑ	3.458	4.842
moment at Ⓑ	-11.687	-16.362
distance from base, y	y = **11.000**	
shear at distance y	-0.053	-0.074
moment at distance y	6.080	8.512

"y" is any arbitrary distance above the base in which to investigate moment and shears.
(max positive moment occurs at a "y" where shear = zero)

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DESIGN TASK: Wall 3 - Hydrodynamic (Water 2-Sides)

tank wall thickness, t_w = 18 inch
depth to wall tension steel, d = **15.69** inch
wall bar clear cover = **2** inch
curtains of rebar in the wall (1 or 2 ?) = **2**

wall min vert temp. / shrinkage steel ratio = **0.00250**
wall min horz temp. / shrinkage steel ratio = **0.00250**

concrete strength, f'_c = 4 ksi
strength of reinforcement, fy = 60 ksi
wall design width, b = 12 inch
tank wall thickness, t_w = 18 inch
φ, Bending = 0.9
φ for shear is dependent upon the load factors used. See code. (typically 0.85 or 0.75), φ, Shear = **1**

*** **WALL VERTICAL REINFORCEMENT REQUIRED** ***

Wall Locations		Load Case	Wall Shear factored V_u k/ft	Wall Shear factored ϕV_c k/ft	Wall Moment service M ft-k/ft	Wall Moment factored M_u ft-k/ft	A_s required in^2/ft	A_s min in^2/ft
top of wall	heel side	seismic	1.822	23.816	0.000	0.000	0.00	0.27
bottom of wall	heel side	seismic	4.842	23.816	-11.687	-16.362	0.23	0.31
distance y = 11-ft from the base	toe side	seismic	-0.074	23.816	6.080	8.512	0.12	0.27

WALL SHEAR OKAY!!

*** **WALL VERTICAL & HORIZONTAL STEEL PROVIDED** ***

Wall Locations		load case	M (ft-k/ft)	M_u (ft-k/ft)	A_s or $A_{(min)}$ (required) (in^2/ft)	bar number size	bar spacing (in.)	A_s (provided) (in^2/ft)
top of wall	heel side	seismic	0.000	0.000	0.27	**5**	**12**	0.31
bottom of wall	heel side	seismic	-11.687	-16.362	0.31	**5**	**12**	0.31
distance y = 11-ft from the base	toe side	seismic	6.080	8.512	0.27	**5**	**12**	0.31
Horizontal reinforcement required each face A_s = ρ*b*tw / (number of curtains)					0.27	**5**	**12**	0.31

** Note: Crack control is not a requirement for the seismic load case.

WALL MOMENT OKAY!!

Area 8 - Washwater Basin
Wall 4 - Moment & Shear

Horizontal Span

	S_d	M_{ux} (k-ft)	S_d*M_{ux} (k-ft)	M_n (k-ft)	***DCR***	SQX_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.61	21.10	33.97	55.00	***0.62***	59	126	***0.46***	***<- OK***
1.2F+1.4E	1.00	36.40	36.40	55.00	***0.66***	95	126	***0.75***	***<- OK***
1.6(H+L)	1.41	46.20	65.14	55.00	***1.18***	118	126	***0.93***	***<- NG***
1.6H+1.4E	1.00	84.20	84.20	55.00	***1.53***	210	126	***1.66***	***<- NG***

Vertical Span

	S_d	M_{uy} (k-ft)	S_d*M_{uy} (k-ft)	M_n (k-ft)	***DCR***	SQY_u (psi)	SQ_n (psi)	***DCR***	
1.4F	1.12	30.40	34.05	88.50	***0.38***	59	126	***0.46***	***<- OK***
1.2F+1.4E	1.00	46.10	46.10	88.50	***0.52***	76	126	***0.60***	***<- OK***
1.6(H+L)	1.00	52.40	52.40	88.50	***0.59***	76	126	***0.60***	***<- OK***
1.6H+1.4E	1.00	83.80	83.80	88.50	***0.95***	127	126	***1.00***	***<- NG***

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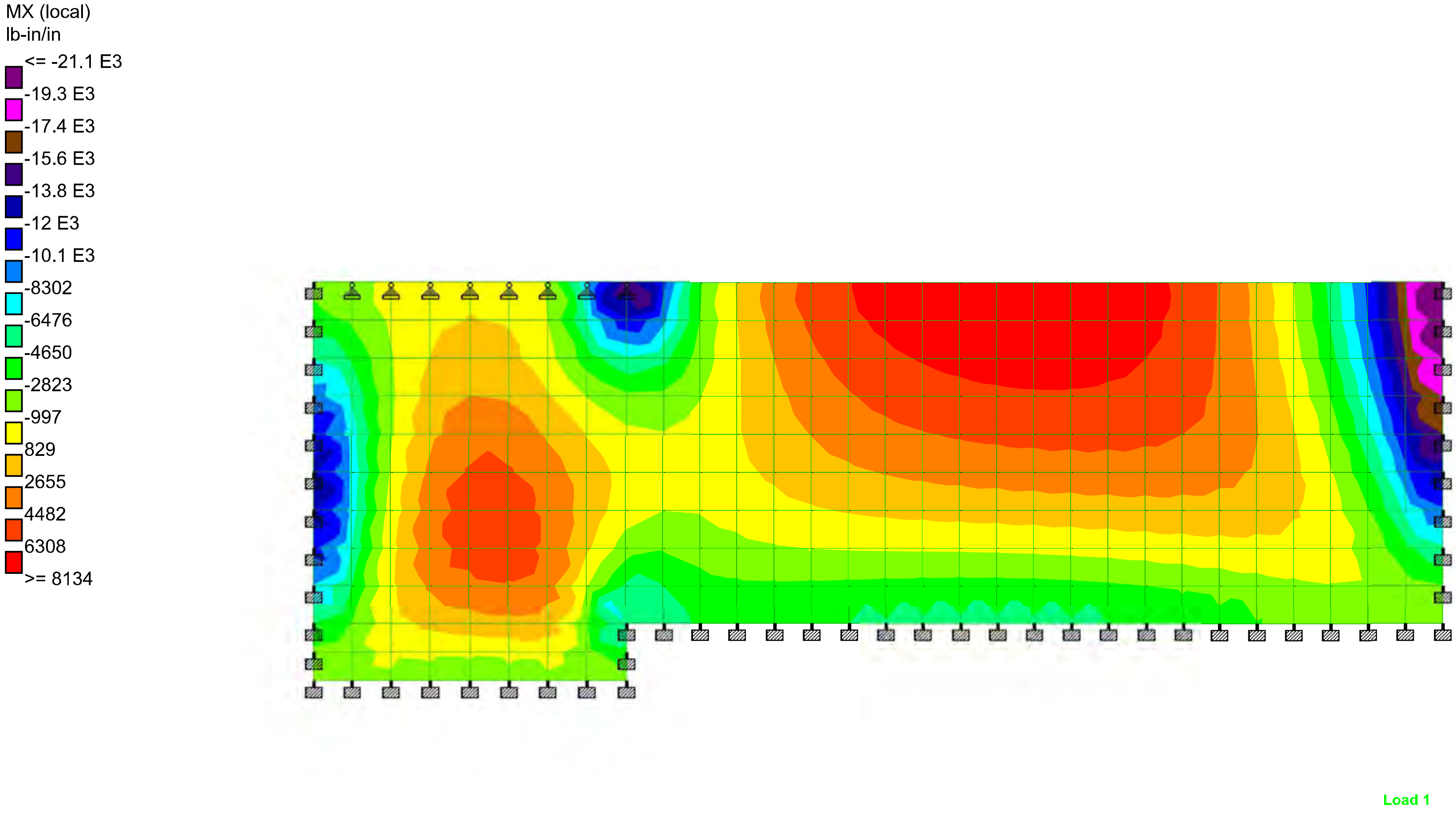
	Part Wall 4		
Job Title Area 8 - Washwater Basin	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 10-Aug-2017 12:10	



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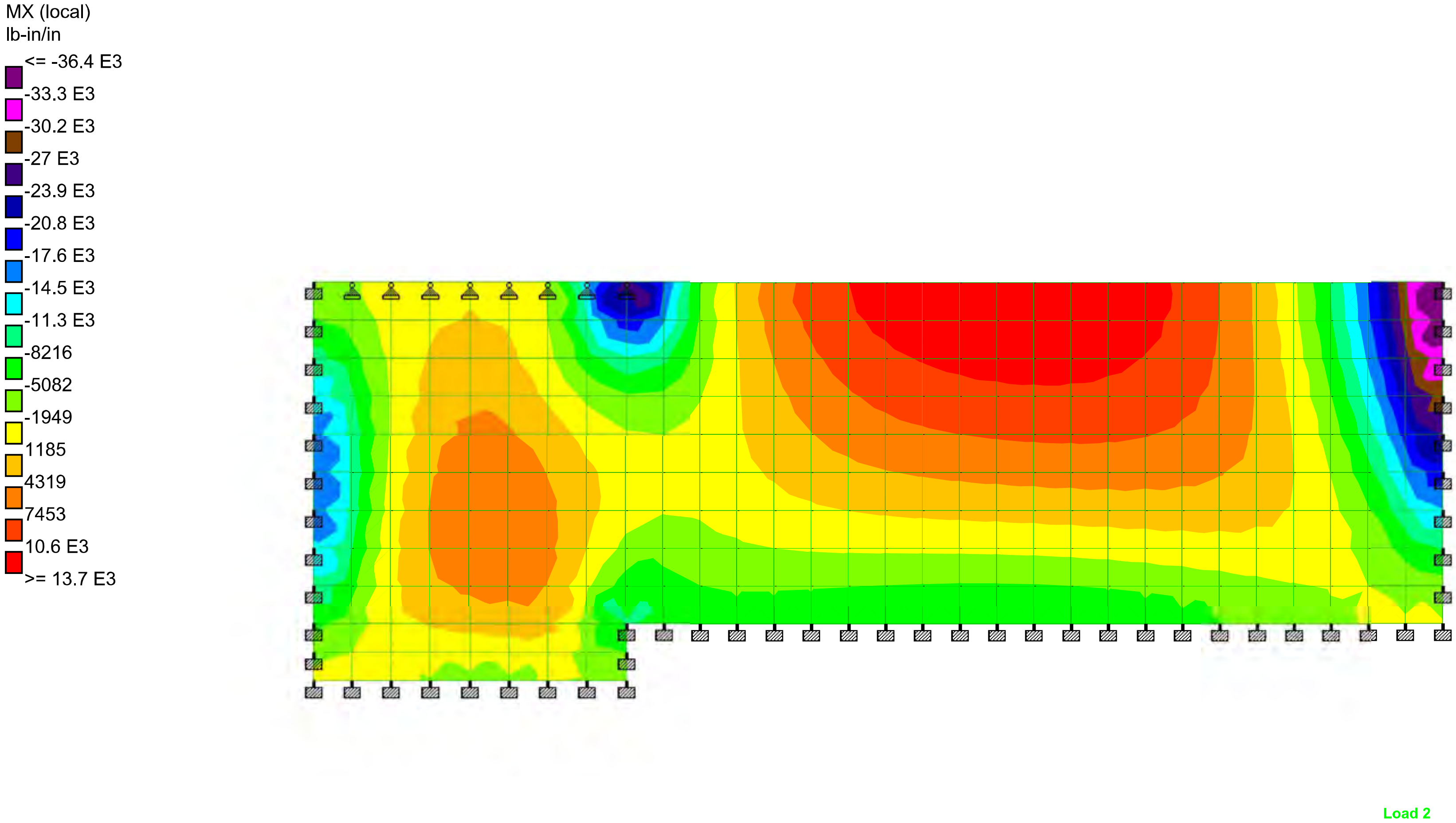
Client Willametter River WTP	File Wall 4.std	Date/Time 15-Sep-2017 11:53	



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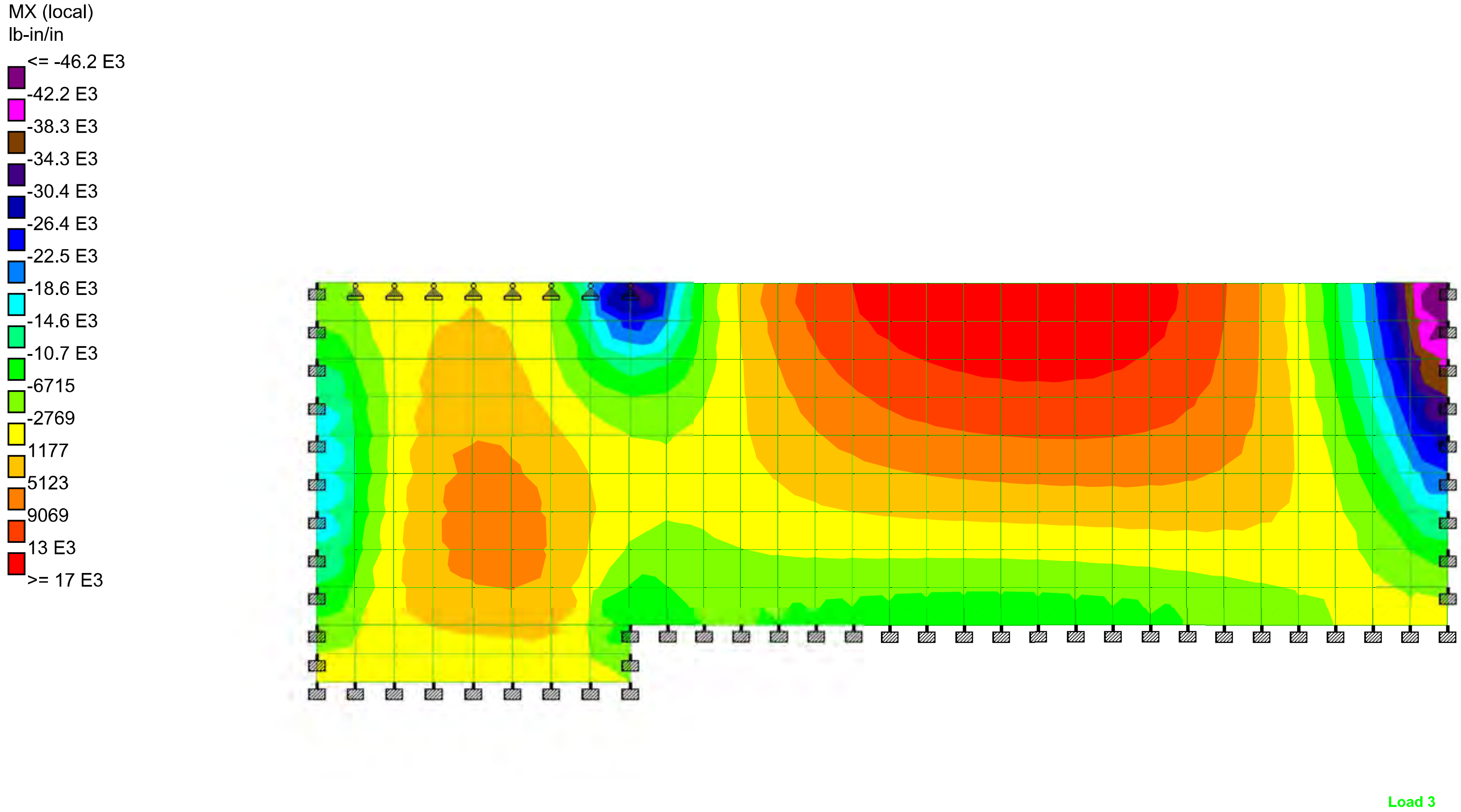

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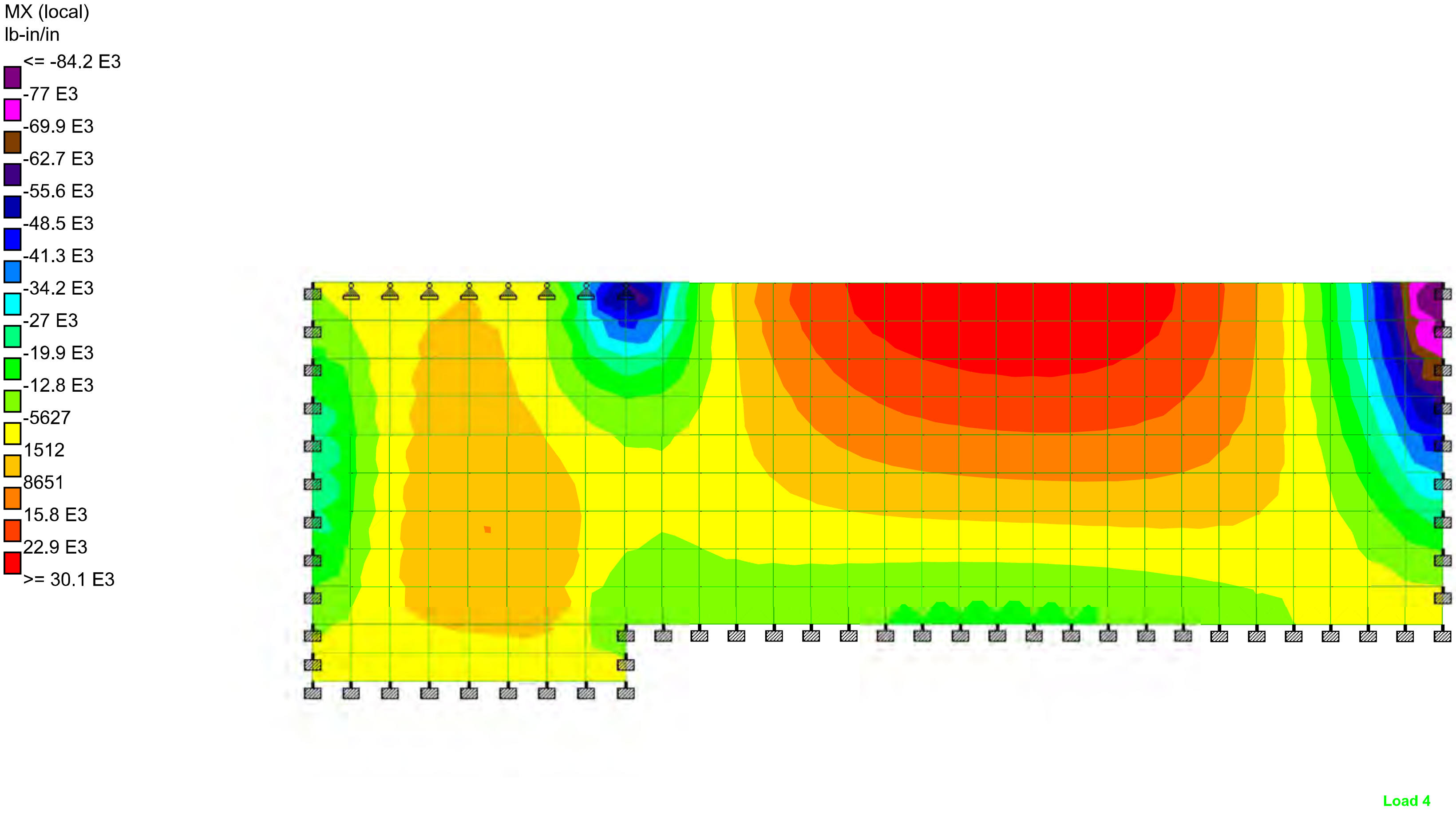

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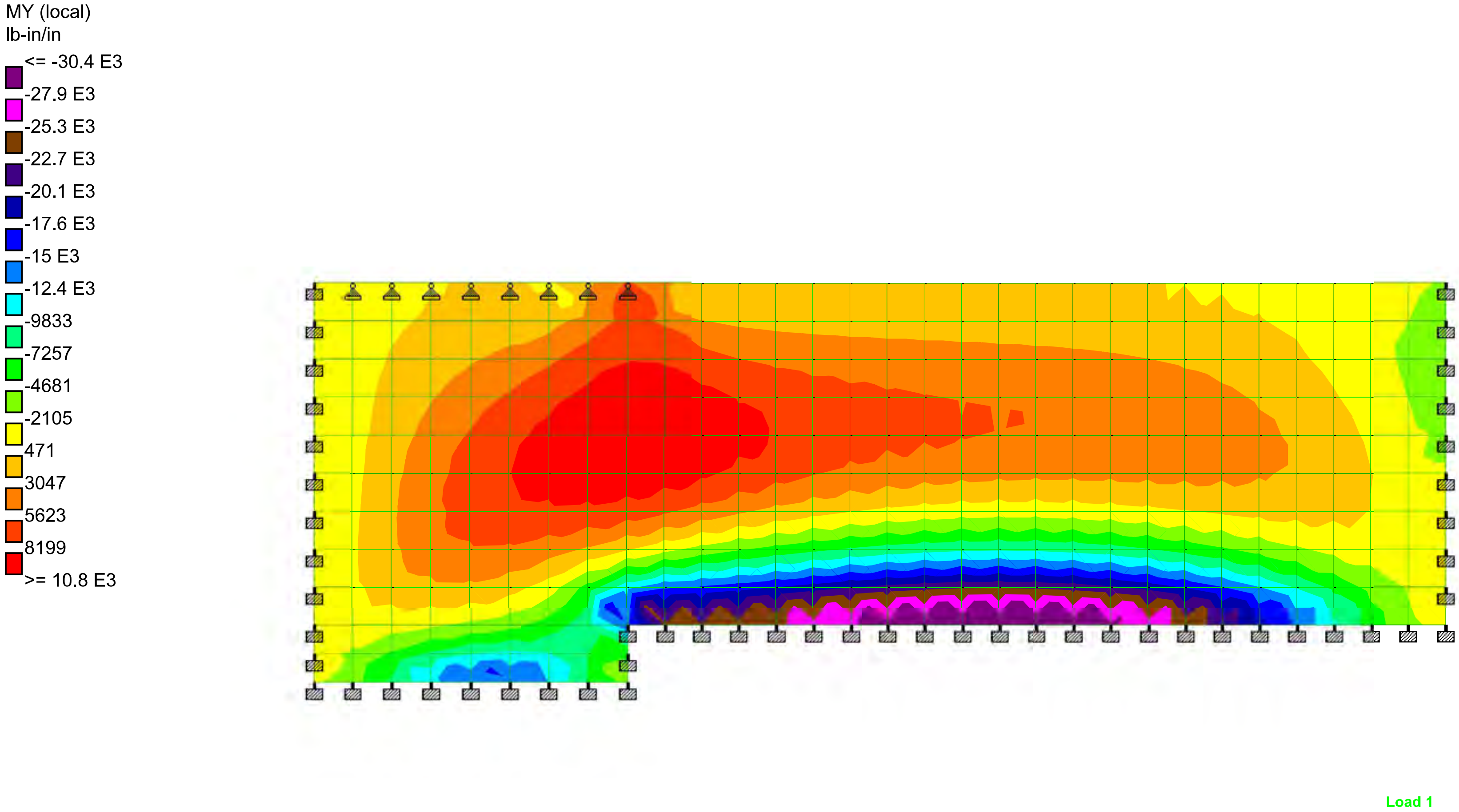

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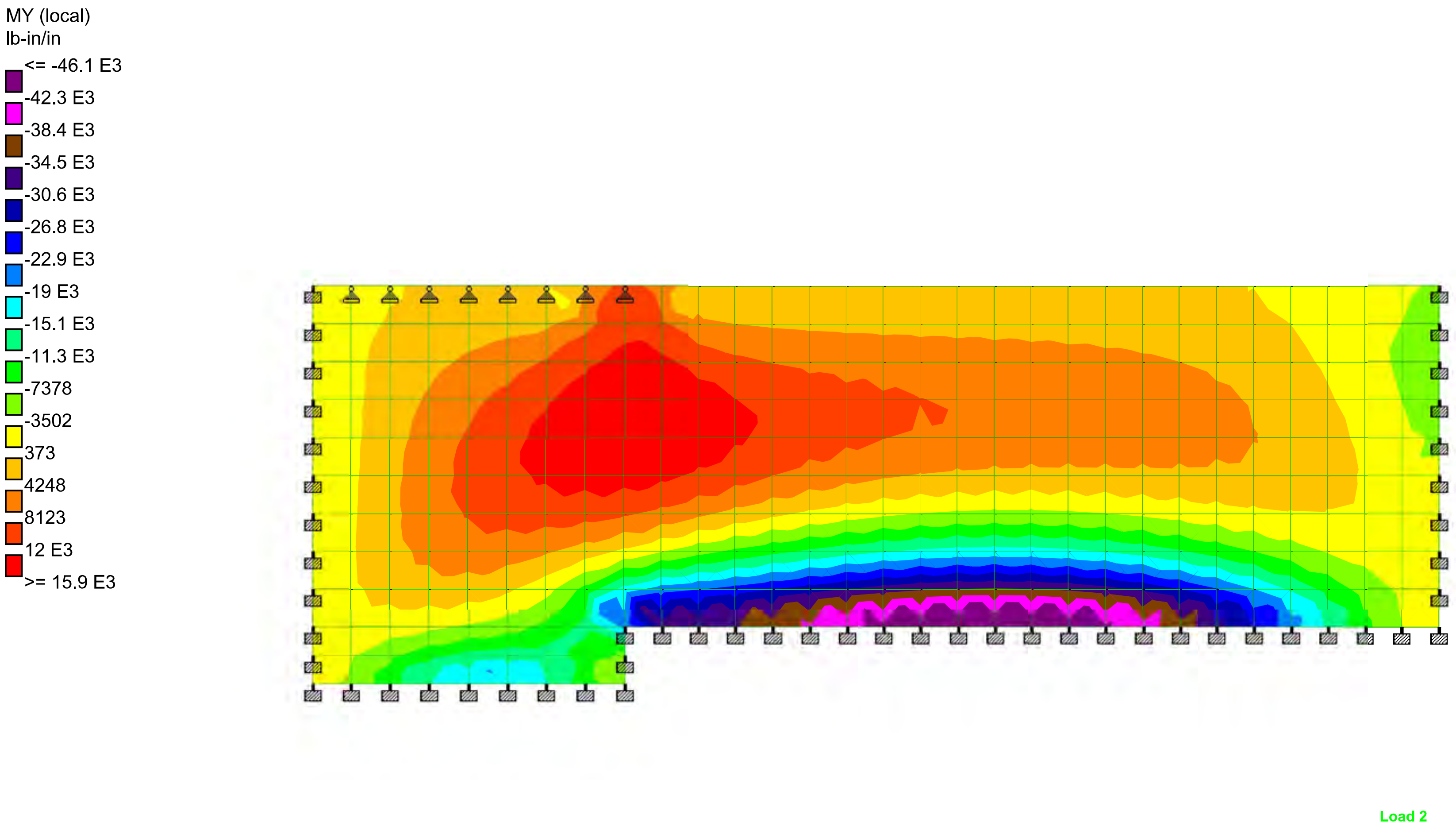

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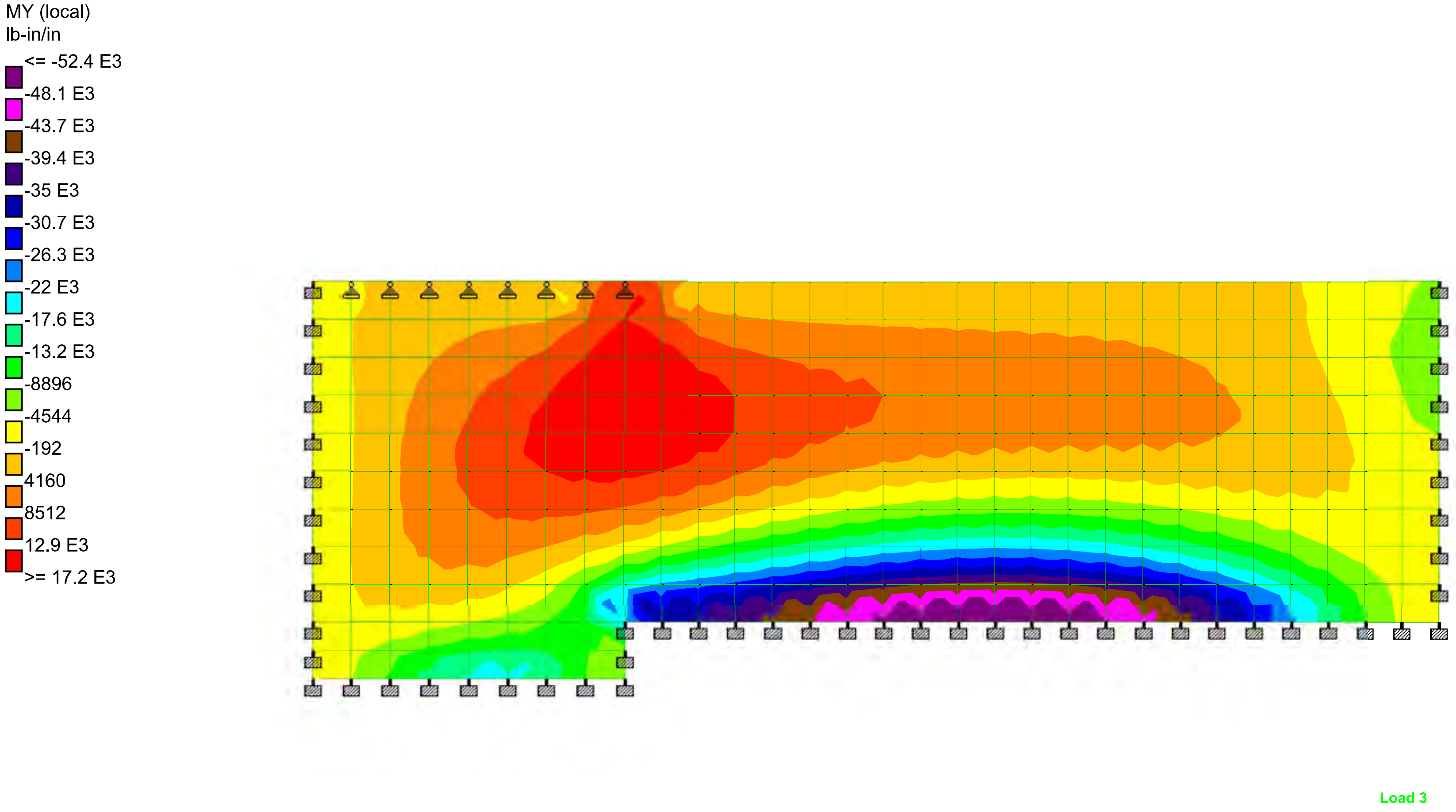
	Part Wall 4		
Job Title Area 8 - Washwater Basin	Ref		
Load Case: 1.6(H+L)	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 10-Aug-2017 12:10	



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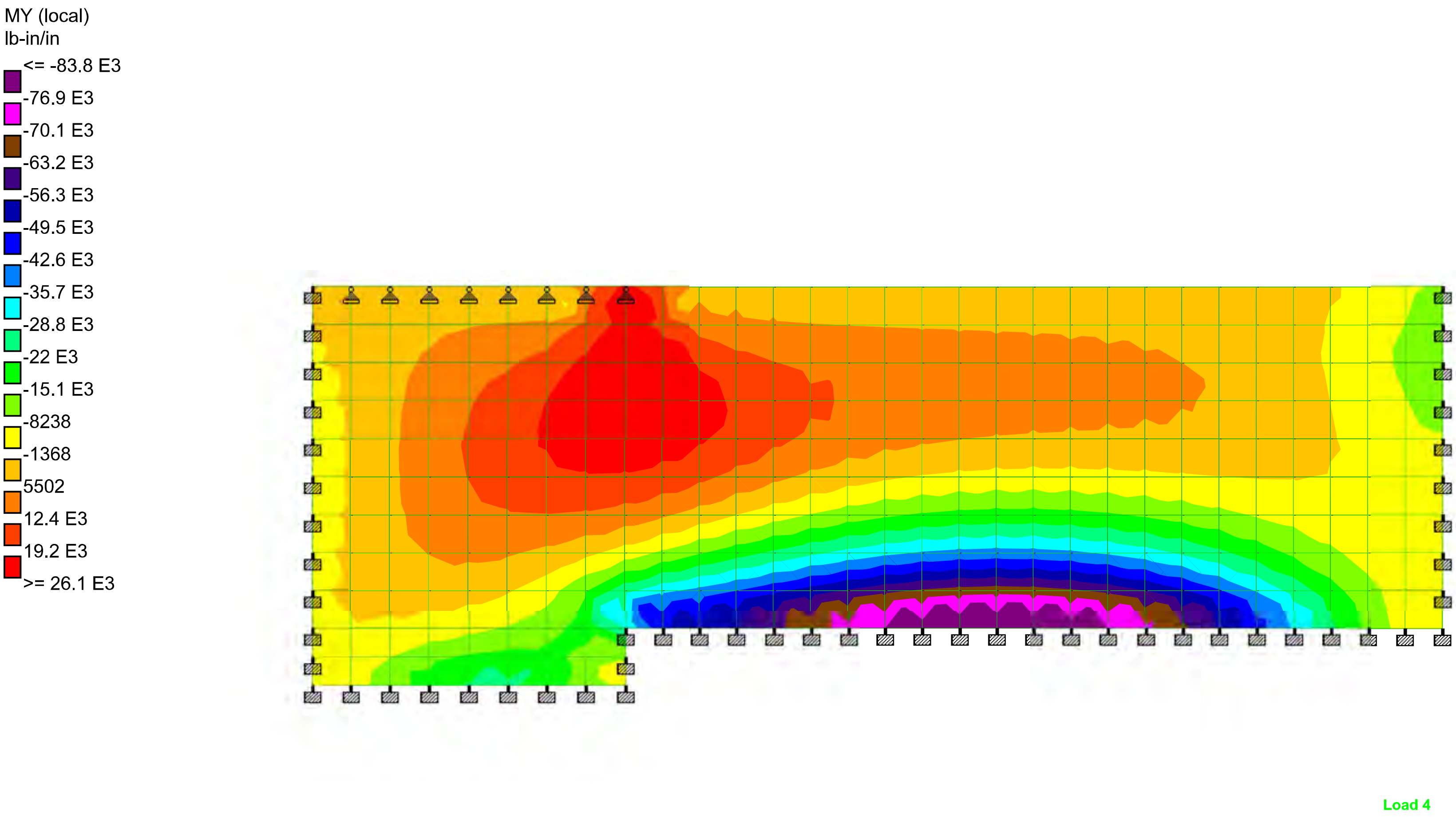
Part	Wall 4				
Ref					
By		Date	04-Aug-17	Chd	
File	Wall 4.std	Date/Time	10-Aug-2017 12:10		

Job Title Area 8 - Washwater Basin

Load Case: 1.6H+1.4E

Client Willametter River WTP



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		Ref		
		By	Date 04-Aug-17	Chd
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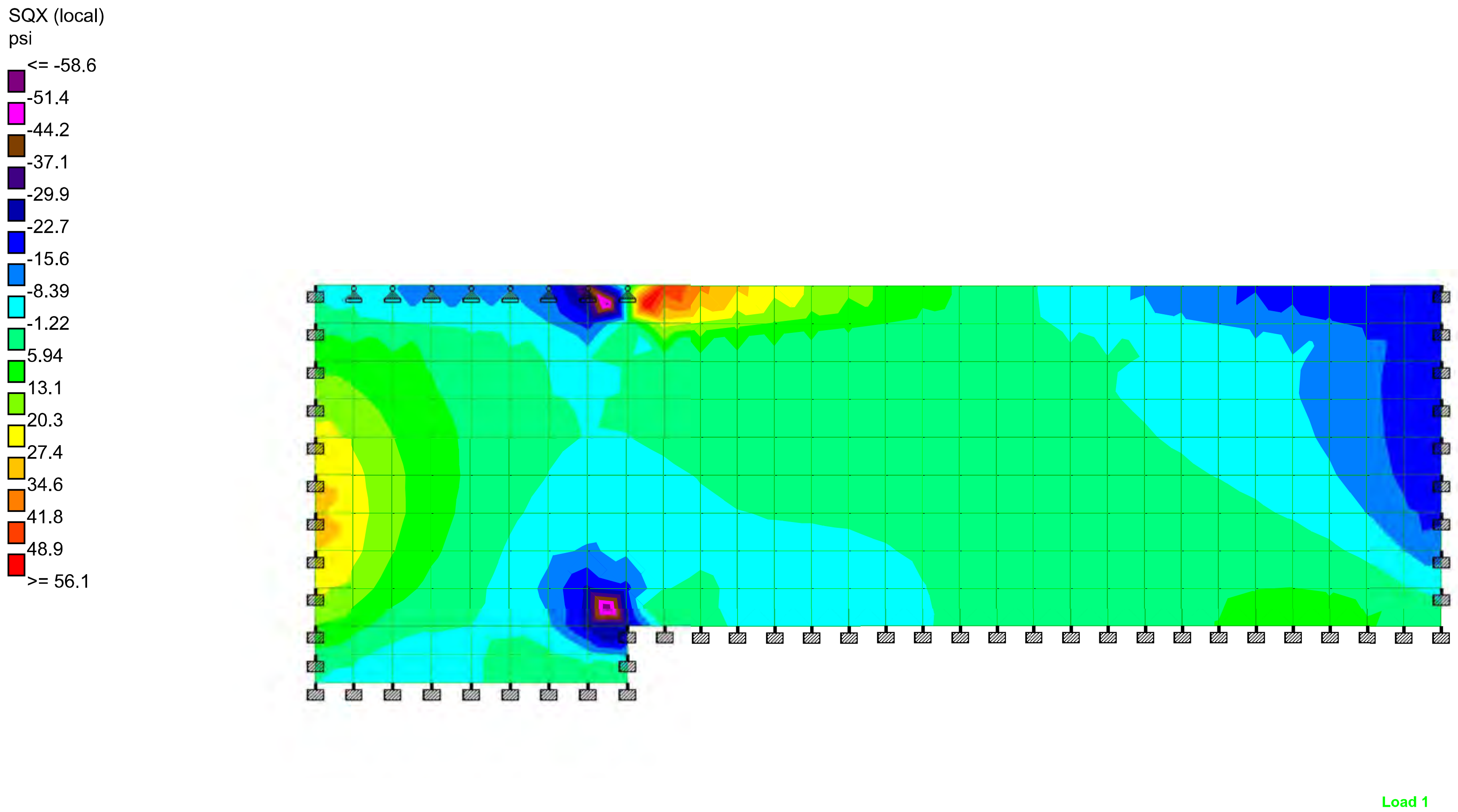

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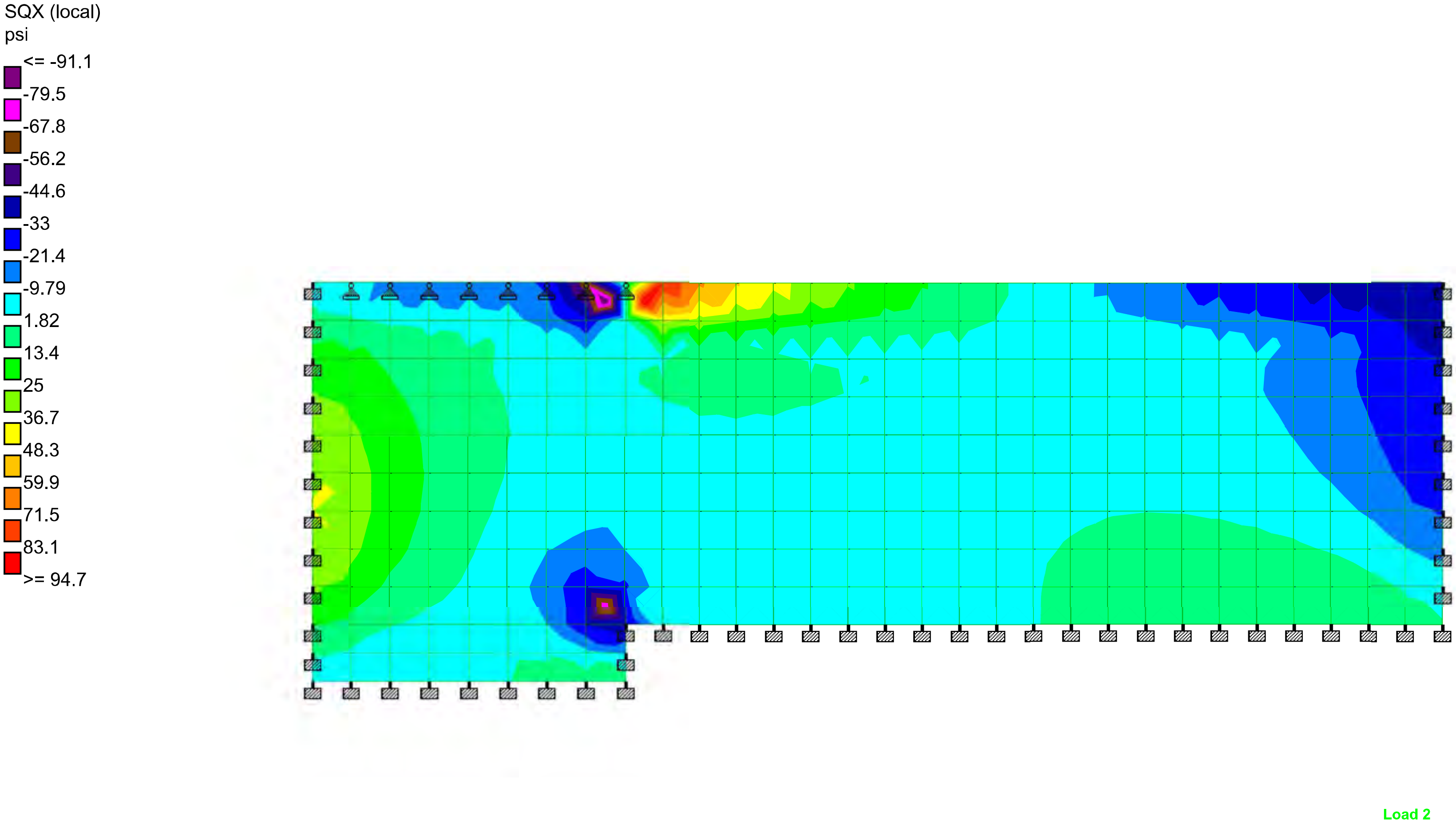

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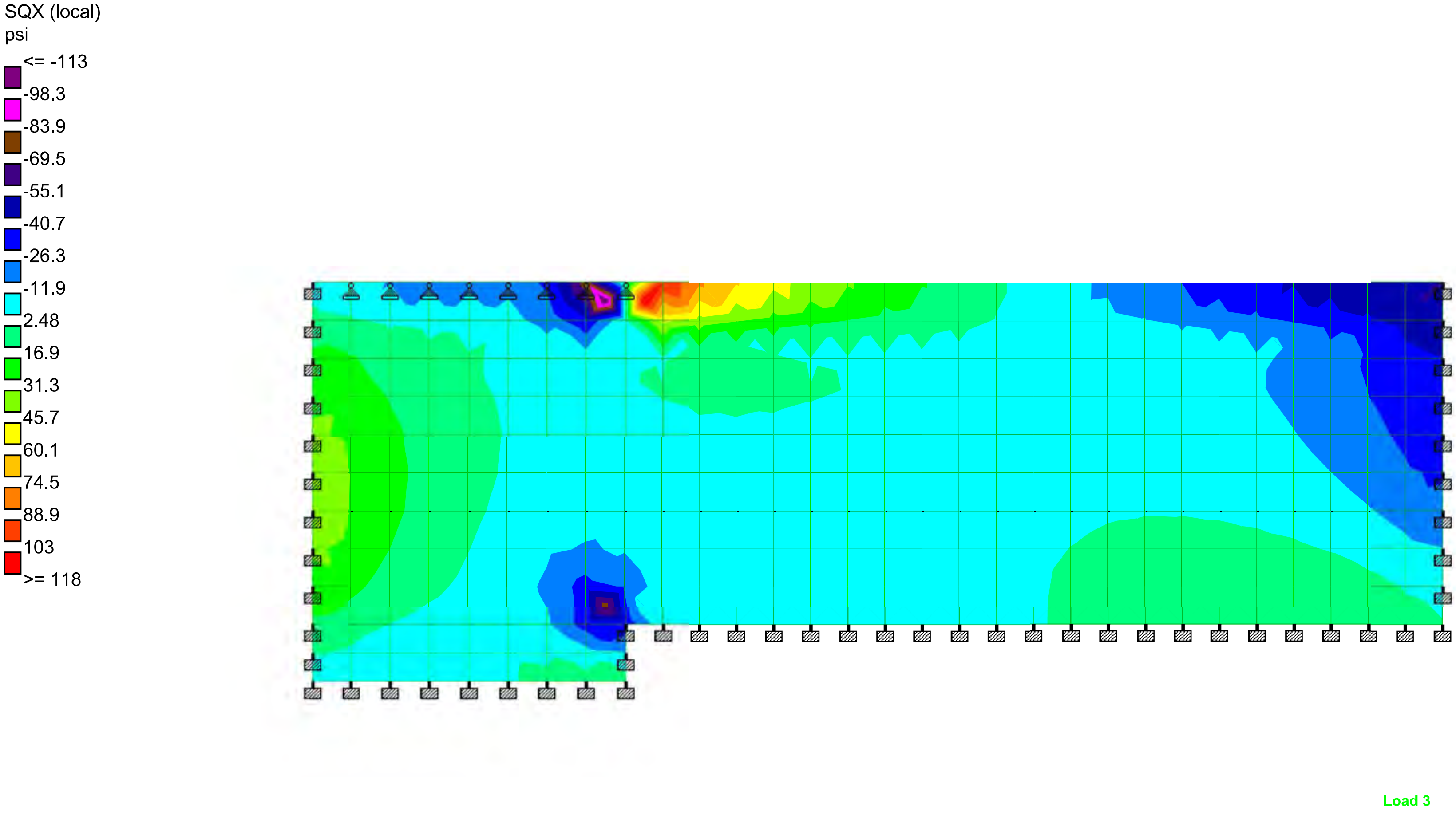
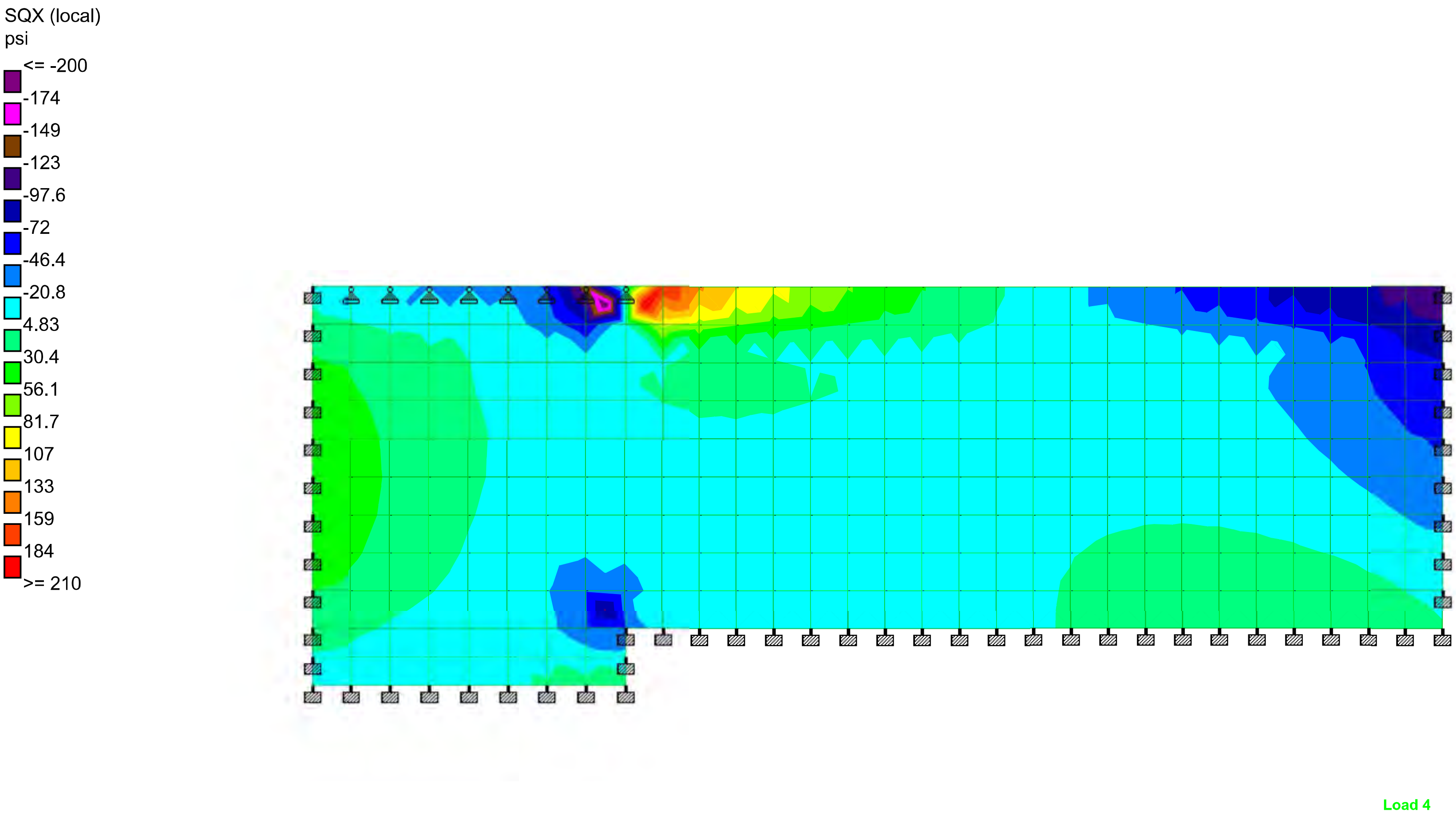
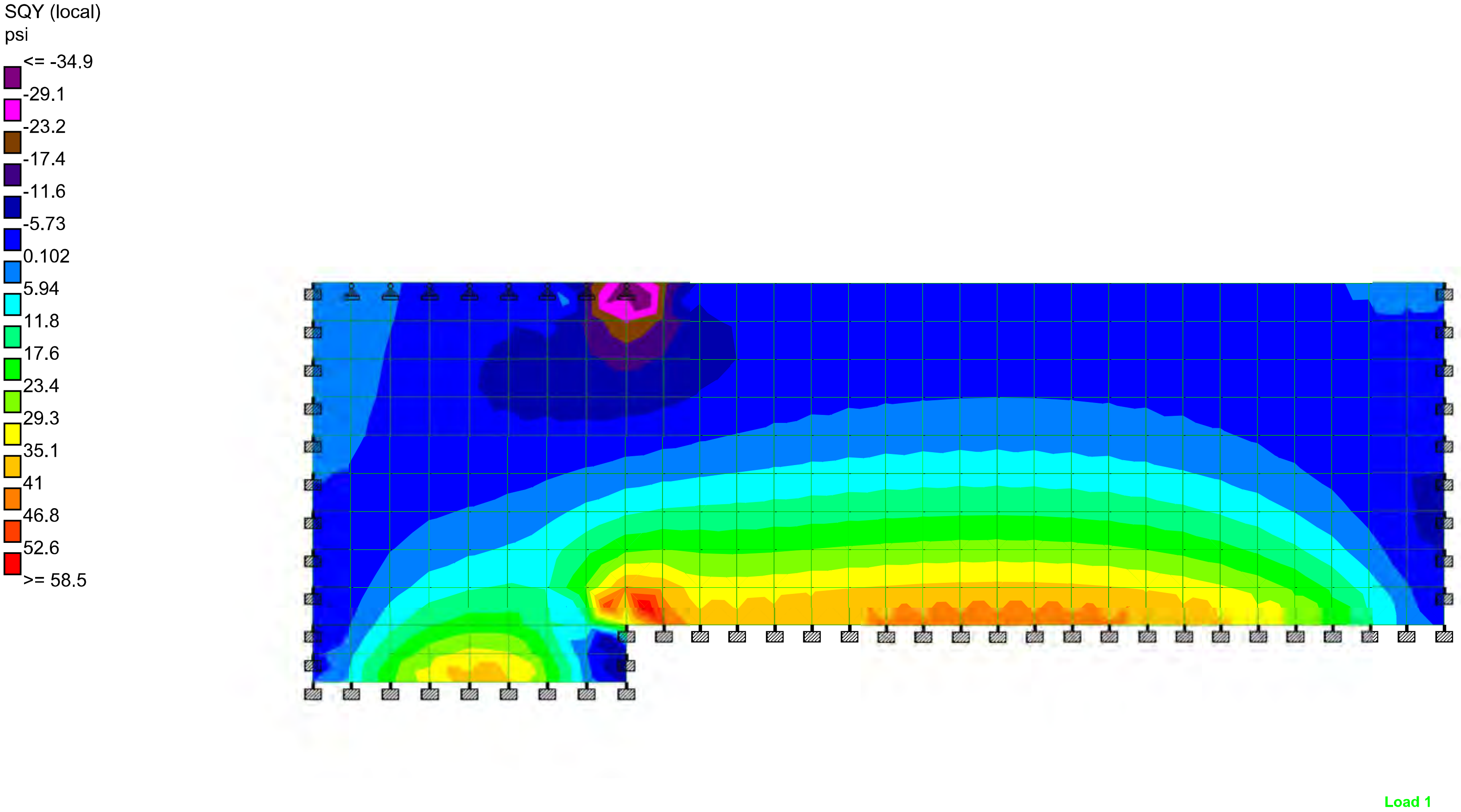
Client Willametter River WTP	File Wall 4.std	Date/Time 10-Aug-2017 12:10	



Software licensed to Carollo Engineers	Job No **10721A.00**		Sheet No **1**	Rev
	Part Wall 4			
Job Title Area 8 - Washwater Basin	Ref			
Load Case: 1.6H+1.4E	By	Date 04-Aug-17	Chd	
Client Willametter River WTP	File Wall 4.std		Date/Time 10-Aug-2017 12:10	

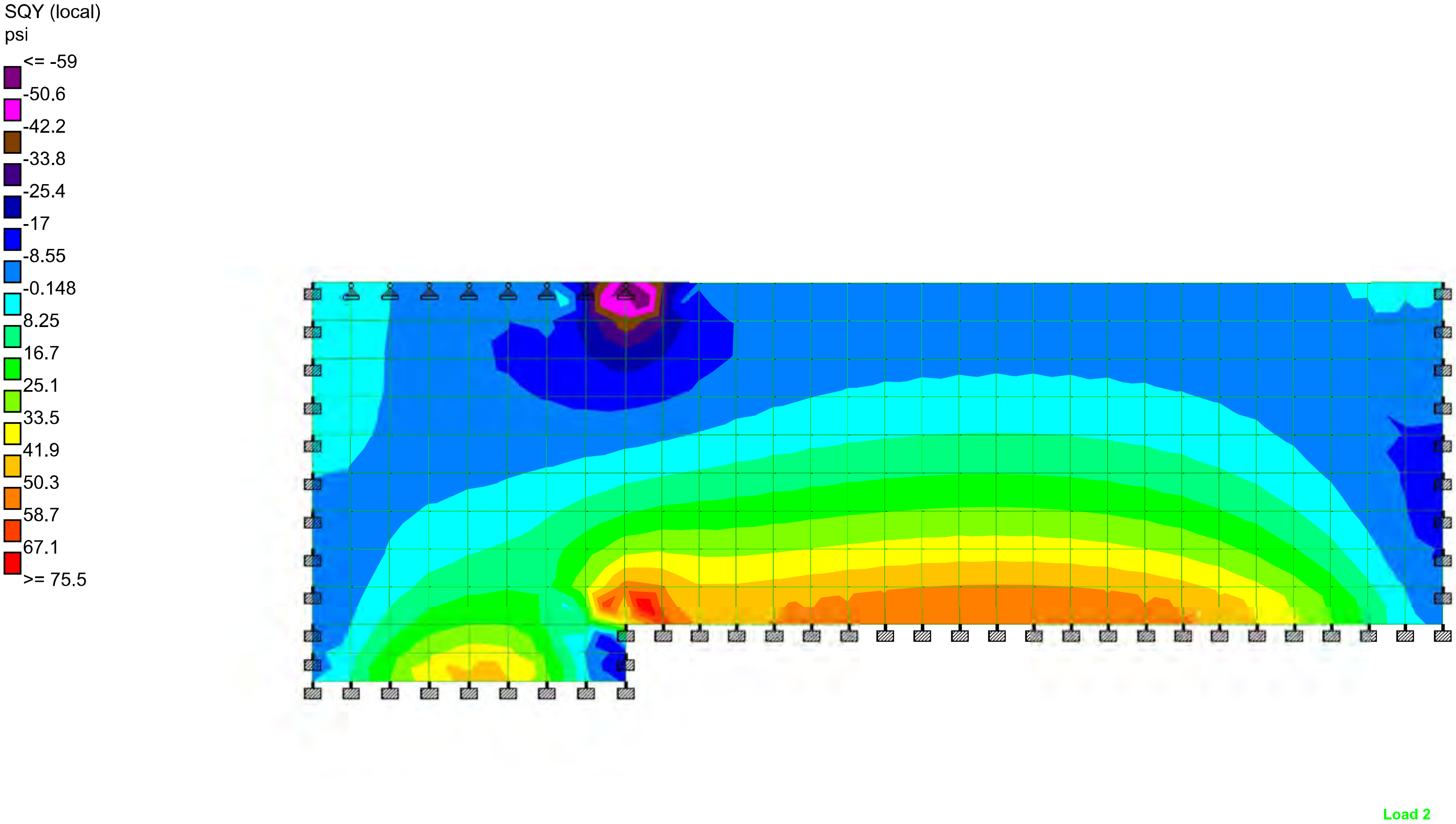


Software licensed to Carollo Engineers	Job No 10721A.00	Sheet No 1	Rev
	Part Wall 4		
Job Title Area 8 - Washwater Basin	Ref		
Load Case: 1.4F	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 10-Aug-2017 12:10	

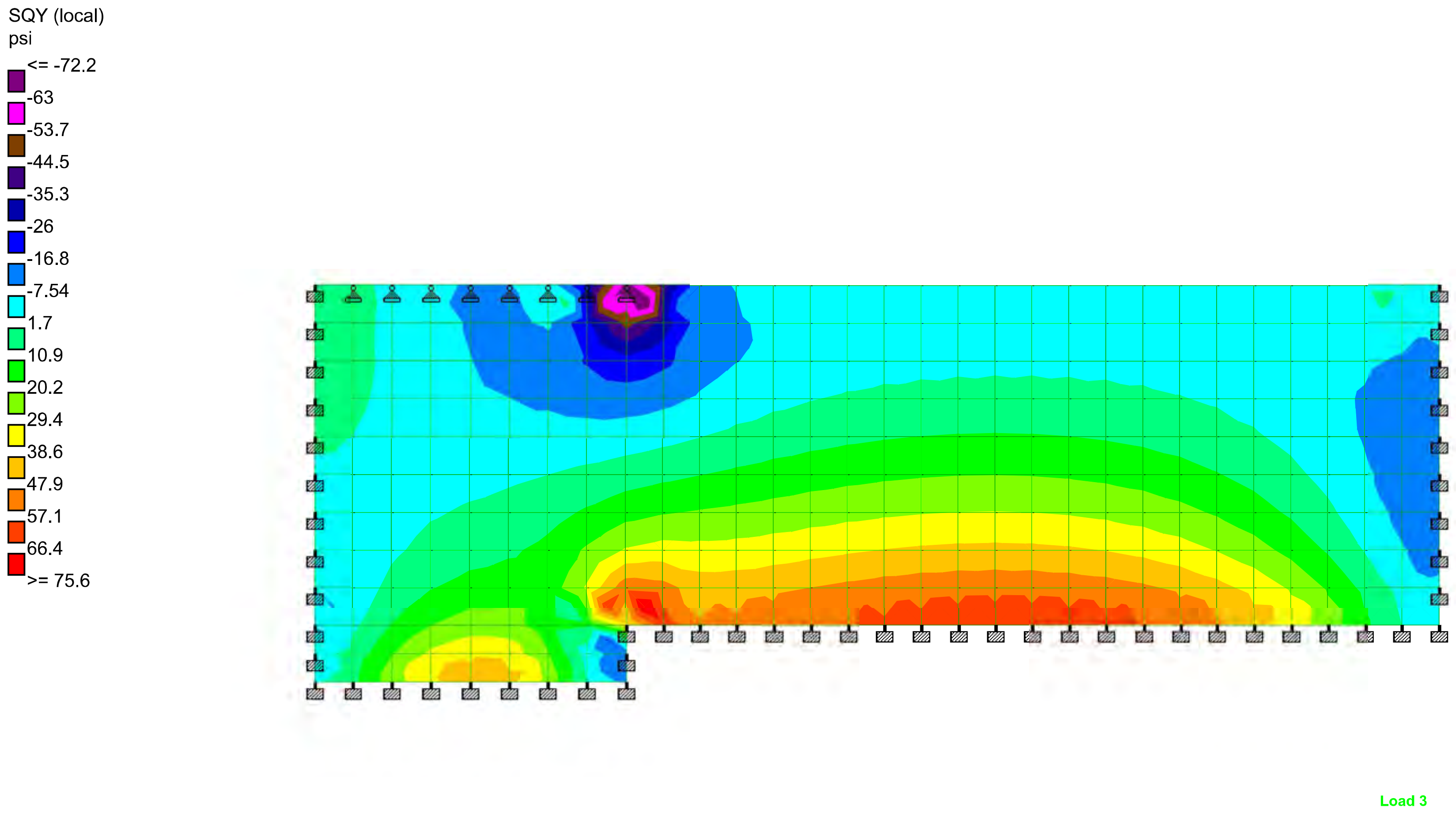


STAAD.Pro V8i (SELECTseries 6) 20.07.11.82

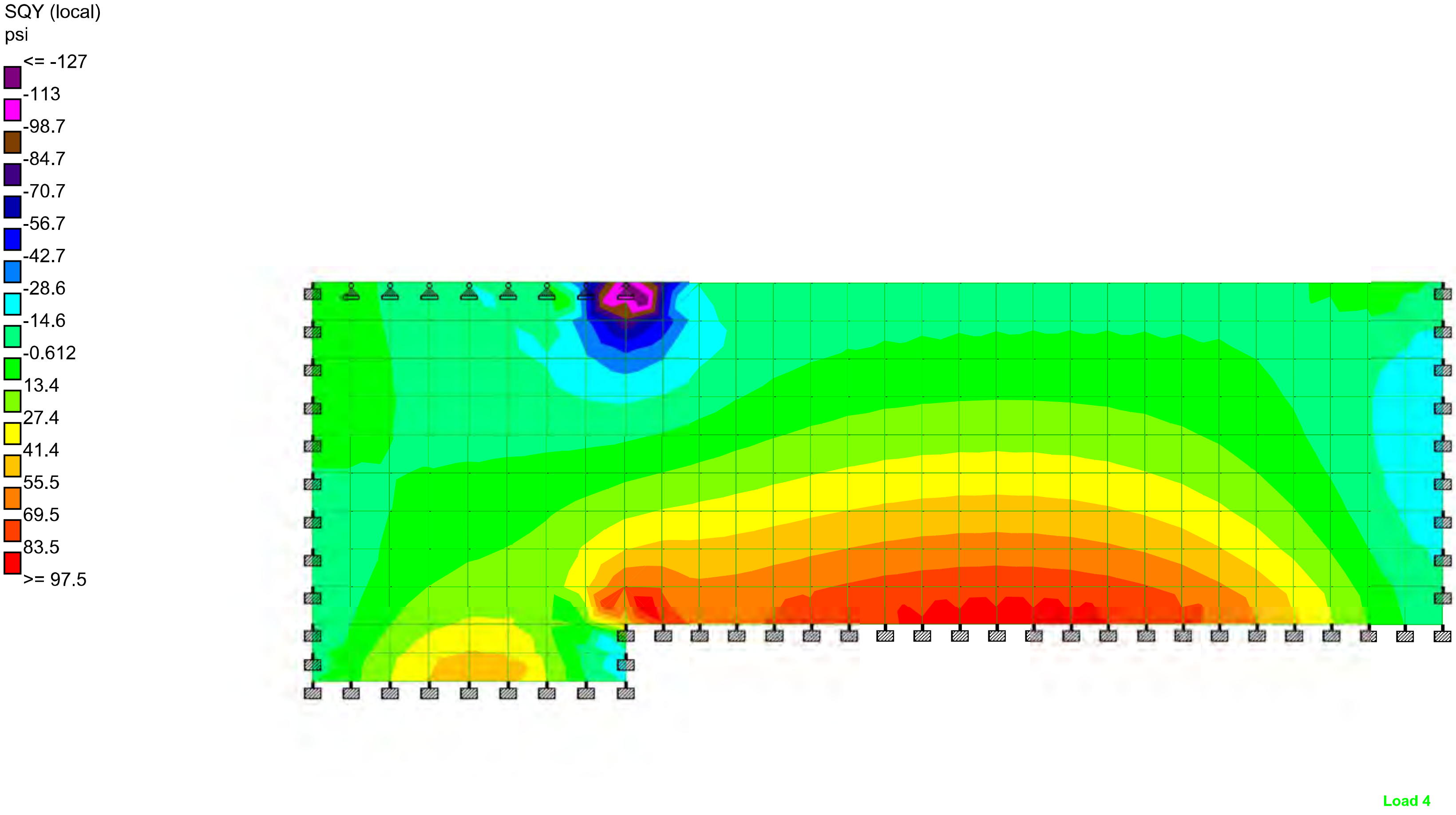
Software licensed to Carollo Engineers CONNECTED User: Caleb Che	Job No 10721A.00	Sheet No 1	Rev
	Part Wall 4		
Job Title Area 8 - Washwater Basin Load Case: 1.2F+1.4E	Ref		
	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 15-Sep-2017 11:53	



Software licensed to Carollo Engineers	Job No 10721A.00	Sheet No 1	Rev
	Part Wall 4		
Job Title Area 8 - Washwater Basin	Ref		
Load Case: 1.6(H+L)	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 10-Aug-2017 12:10	



Software licensed to Carollo Engineers	Job No 10721A.00	Sheet No 1	Rev
	Part Wall 4		
Job Title Area 8 - Washwater Basin Load Case: 1.6H+1.4E	Ref		
	By	Date 04-Aug-17	Chd
Client Willametter River WTP	File Wall 4.std	Date/Time 10-Aug-2017 12:10	



Area 9 - High Service Pump Station
ASCE 41 Evaluation

BY JAD	DATE 5/18/15	SUBJECT WILLAMETTE RIVER WTP	SHEET NO. ___ OF ___
CHKD. BY	DATE	FINISHED WATER P.S.	JOB NO. 9865A.00

TIER I CHECKLISTS

16.1.2IO

VERTICAL IRREGULARITY:

NC – ◦ WEST WALL HAS NO SHEAR WALL BELOW. CHECK RESERVOIR SLAB FOR ADEQUATE SHEAR CAPACITY.

◦ INTERIOR WALL IS DISCONTINUOUS. CHECK RESERVOIR SLAB FOR ADEQUATE SHEAR CAPACITY. ALSO, CHECK COLUMN FOR ADDITIONAL OVERTURNING FORCE.

PERFORM ANALYSIS PER SEC. 5.2.4.

OVERTURNING:

$\ell_{min_{SW}} = 29.2$ FT

$h_{BLDG} = 22.33$ FT

$29.2/22.33 = 1.31 > 0.267$ OK

16.10IO

SHEAR STRESS CHECK: (E-W CHECK ONLY)

$V_j = (0.611)\,W_j$

$W_j = 691$ k

$A_W = (8 \text{ in.})(352 \text{ in.} + 388 \text{ in.} + 274 \text{ in.} + 250 \text{ in.}) = 10{,}112 \text{ in.}^2$

$$V_j^{AVG\ E-W} = \frac{(0.611)(691 \text{ k})}{(2.0)(10{,}112 \text{ in.}^2)} = 0.021 \text{ ksi} \quad \text{OK}$$

REINFORCING STL:

$$\text{VERT 8'' WALL} \quad A_{ST_V} = \frac{(0.88 \text{ in.}^2)}{(12 \text{ in.})(8 \text{ in.})} = 0.0092 > 0.0012$$

BY JAD DATE 5/19/15 SUBJECT WILLAMETTE RIVER WTP FINISHED WATER P.S. SHEET NO. ___ OF ___

CHKD. BY ___ DATE ___ JOB NO. 9865A.00

HORZ 8" WALL $A_{ST_H} = \frac{(0.31\ in^2)}{(8\ in)(12\ in)} = 0.0032 > 0.0020$ OK

WALL ANCHORAGE: (PER SEC. 4.3.5.7)

$T_c = \psi S_{XS} W_p A_p$

$T_c = 1.8(0.611) W_p A_p$

$A_{P\ WEST\ WALL} = [3.33\ FT + 2.33\ FT + 22\ FT/2](7.33\ FT) = 122\ FT^2$

$A_{P\ NORTH\ WALL} = [2.33\ FT + 22\ FT/2](2.0\ FT) = 26.7\ FT^2$

$T_{c\ WEST\ WALL\ max} = 1.8(0.611)(122\ FT^2)(8/12\ FT)(150\ PSF) = 13{,}418\ LB$

$T_{c\ NORTH\ WALL} = 1.8(0.611)(26.7\ FT^2)(8/12\ FT)(150\ PSF) = 2{,}936\ LB$

$T_{c\ TYP\ WEST\ WALL} = 1.8(0.611)(95.8\ FT^2)(100\ PSF) = 10{,}542\ LB$

⟹ DETAILS ABOUT JOIST SEATS AND LEDGER ANCHORAGE ARE MISSING FROM THE DRAWINGS.

ASSUMING 3/4" ∅ × 6" EMBED W/ EPOXY @ 24" O.C. @ LEDGER ANGLES

NO ADHESIVE ANCHOR MEETS APPENDIX D BUT STRENGTH IS OK.

ASSUMING (2) 3/4" ∅ × 8" EMBED ANCHOR BOLTS @ JOIST BEARING SEATS. CHECK CONDITION W/ 5.75-FT JOIST SPACING.

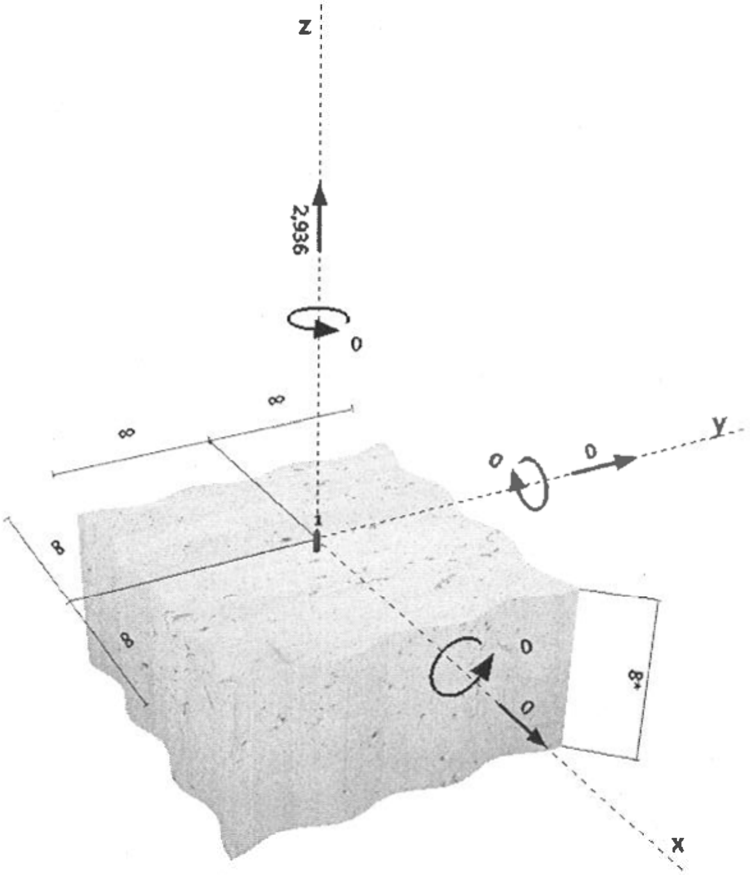
DCR = 1.55 > 1.0 NG

Specifier's comments:

1 Input data

Anchor type and diameter:	**HIT-RE 500-SD + HAS B7 3/4**
Effective embedment depth:	$h_{ef,act}$ = 6.000 in. ($h_{ef,limit}$ = - in.)
Material:	ASTM A 193 Grade B7
Evaluation Service Report:	ESR-2322
Issued I Valid:	2/1/2014 | 4/1/2016
Proof:	Design method ACI 318-11 / Chem
Stand-off Installation:	- (Recommended plate thickness: not calculated)
Profile:	no profile
Base material:	cracked concrete, 4000, f_c' = 4000 psi; h = 8.000 in., Temp. short/long: 32/32 °F
Installation:	hammer drilled hole, Installation condition: Dry
Reinforcement:	tension: condition A, shear: condition A; no supplemental splitting reinforcement present edge reinforcement: > No. 4 bar
Seismic loads (cat. C, D, E, or F)	Tension load: yes (D.3.3.4.3 (a)) Shear load: yes (D.3.3.5.3 (a))

Geometry [in.] & Loading [lb, in.lb]



Company:	Carollo Engineers	Page:	2
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Area 09 / Ledger Anchr
Phone I Fax:	|	Date:	5/19/2015
E-Mail:			

2 Load case/Resulting anchor forces

Load case: Design loads

Anchor reactions [lb]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	2936	0	0	0

max. concrete compressive strain: - [‰]
max. concrete compressive stress: - [psi]
resulting tension force in (x/y)=(0.000/0.000): 0 [lb]
resulting compression force in (x/y)=(0.000/0.000): 0 [lb]

3 Tension load

	Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status
Steel Strength*	2936	50172	6	OK
Bond Strength**	2936	9189	32	not recommended^A
Sustained Tension Load Bond Strength*	N/A	N/A	N/A	N/A
Concrete Breakout Strength**	2936	15802	19	not recommended^A

* anchor having the highest loading **anchor group (anchors in tension)

^A When D.3.3.4.3 (a) is selected for seismic design, the design steel strength must be the governing design strength having the highest utilization.

3.1 Steel Strength

N_{sa} = ESR value refer to ICC-ES ESR-2322
$\phi N_{steel} \geq N_{ua}$ ACI 318-11 Table D.4.1.1

Variables

n	$A_{se,N}$ [in.^{2}]	f_{uta} [psi]
1	0.33	125000

Calculations

N_{sa} [lb]
41810

Results

N_{sa} [lb]	ϕ_{steel}	ϕN_{sa} [lb]	N_{ua} [lb]
41810	1.200	50172	2936

3.2 Bond Strength

$N_a = \left(\frac{A_{Na}}{A_{Na0}}\right) \psi_{ed,Na}\, \psi_{cp,Na}\, N_{ba}$ ACI 318-11 Eq. (D-18)

$\phi\, N_a \geq N_{ua}$ ACI 318-11 Table D.4.1.1

A_{Na} = see ACI 318-11, Part D.5.5.1, Fig. RD.5.5.1(b)

$A_{Na0} = (2\, c_{Na})^2$ ACI 318-11 Eq. (D-20)

$c_{Na} = 10\, d_a \sqrt{\frac{\tau_{uncr}}{1100}}$ ACI 318-11 Eq. (D-21)

$\psi_{ec,Na} = \left(\frac{1}{1 + \frac{e_N}{c_{Na}}}\right) \leq 1.0$ ACI 318-11 Eq. (D-23)

$\psi_{ed,Na} = 0.7 + 0.3\left(\frac{c_{a,min}}{c_{Na}}\right) \leq 1.0$ ACI 318-11 Eq. (D-25)

$\psi_{cp,Na} = \mathrm{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}}\right) \leq 1.0$ ACI 318-11 Eq. (D-27)

$N_{ba} = \lambda_a \cdot \tau_{k,c} \cdot \alpha_{N,seis} \cdot \kappa_{bond} \cdot \pi \cdot d_a \cdot h_{ef}$ ACI 318-11 Eq. (D-22)

Variables

$\tau_{k,c,uncr}$ [psi]	d_a [in.]	h_{ef} [in.]	$c_{a,min}$ [in.]	$\tau_{k,c}$ [psi]
2065	0.750	6.000	∞	1000

$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	c_{ac} [in.]	κ_{bond}	λ_a	$\alpha_{N,seis}$
0.000	0.000	14.703	1.00	1.000	0.650

Calculations

c_{Na} [in.]	A_{Na} [in.^{2}]	A_{Na0} [in.^{2}]	$\psi_{ed,Na}$
10.230	418.58	418.58	1.000

$\psi_{ec1,Na}$	$\psi_{ec2,Na}$	$\psi_{cp,Na}$	N_{ba} [lb]
1.000	1.000	1.000	9189

Results

N_a [lb]	ϕ_{bond}	$\phi_{seismic}$	$\phi\, N_a$ [lb]	N_{ua} [lb]
9189	1.000	1.000	9189	2936

3.3 Concrete Breakout Strength

$N_{cb} = \left(\frac{A_{Nc}}{A_{Nc0}}\right) \psi_{ed,N}\, \psi_{c,N}\, \psi_{cp,N}\, N_b$ ACI 318-11 Eq. (D-3)

$\phi\, N_{cb} \geq N_{ua}$ ACI 318-11 Table D.4.1.1

A_{Nc} see ACI 318-11, Part D.5.2.1, Fig. RD.5.2.1(b)

$A_{Nc0} = 9\, h_{ef}^2$ ACI 318-11 Eq. (D-5)

$\psi_{ec,N} = \left(\frac{1}{1 + \frac{2\, e_N}{3\, h_{ef}}}\right) \leq 1.0$ ACI 318-11 Eq. (D-8)

$\psi_{ed,N} = 0.7 + 0.3 \left(\frac{c_{a,min}}{1.5h_{ef}}\right) \leq 1.0$ ACI 318-11 Eq. (D-10)

$\psi_{cp,N} = \mathrm{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{1.5h_{ef}}{c_{ac}}\right) \leq 1.0$ ACI 318-11 Eq. (D-12)

$N_b = k_c\, \lambda_a \sqrt{f'_c}\, h_{ef}^{1.5}$ ACI 318-11 Eq. (D-6)

Variables

h_{ef} [in.]	$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	$c_{a,min}$ [in.]	$\psi_{c,N}$
6.000	0.000	0.000	∞	1.000

c_{ac} [in.]	k_c	λ_a	f'_c [psi]
14.703	17	1.000	4000

Calculations

A_{Nc} [in.^{2}]	A_{Nc0} [in.^{2}]	$\psi_{ec1,N}$	$\psi_{ec2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]
324.00	324.00	1.000	1.000	1.000	1.000	15802

Results

N_{cb} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi\, N_{cb}$ [lb]	N_{ua} [lb]
15802	1.000	1.000	15802	2936

Company:	Carollo Engineers	Page:	5
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Area 09 / Ledger Anchr
Phone I Fax:	|	Date:	5/19/2015
E-Mail:			

4 Shear load

	Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_V = V_{ua}/\phi V_n$	Status
Steel Strength*	N/A	N/A	N/A	N/A
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout Strength (Bond Strength controls)*	N/A	N/A	N/A	N/A
Concrete edge failure in direction **	N/A	N/A	N/A	N/A

* anchor having the highest loading **anchor group (relevant anchors)

5 Warnings

- Load re-distributions on the anchors due to elastic deformations of the anchor plate are not considered. The anchor plate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the loading! Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Condition A applies when supplementary reinforcement is used. The Φ factor is increased for non-steel Design Strengths except Pullout Strength and Pryout strength. Condition B applies when supplementary reinforcement is not used and for Pullout Strength and Pryout Strength. Refer to your local standard.
- Design Strengths of adhesive anchor systems are influenced by the cleaning method. Refer to the INSTRUCTIONS FOR USE given in the Evaluation Service Report for cleaning and installation instructions
- Checking the transfer of loads into the base material and the shear resistance are required in accordance with ACI 318 or the relevant standard!
- An anchor design approach for structures assigned to Seismic Design Category C, D, E or F is given in ACI 318-11 Appendix D, Part D.3.3.4.3 (a) that requires the governing design strength of an anchor or group of anchors be limited by ductile steel failure. If this is NOT the case, the connection design (tension) shall satisfy the provisions of Part D.3.3.4.3 (b), Part D.3.3.4.3 (c), or Part D.3.3.4.3 (d). The connection design (shear) shall satisfy the provisions of Part D.3.3.5.3 (a), Part D.3.3.5.3 (b), or Part D.3.3.5.3 (c).
- Part D.3.3.4.3 (b) / part D.3.3.5.3 (a) requires that the attachment the anchors are connecting to the structure be designed to undergo ductile yielding at a load level corresponding to anchor forces no greater than the controlling design strength. Part D.3.3.4.3 (c) / part D.3.3.5.3 (b) waives the ductility requirements and requires that the anchors shall be designed for the maximum tension / shear that can be transmitted to the anchors by a non-yielding attachment. Part D.3.3.4.3 (d) / part D.3.3.5.3 (c) waives the ductility requirements and requires the design strength of the anchors to equal or exceed the maximum tension / shear obtained from design load combinations that include E, with E increased by Ω_0.
- Installation of Hilti adhesive anchor systems shall be performed by personnel trained to install Hilti adhesive anchors. Reference ACI 318-11, Part D.9.1

Fastening does not meet the design criteria!

6 Installation data

Anchor plate, steel: -
Profile: -
Hole diameter in the fixture: -
Plate thickness (input): -
Recommended plate thickness: -
Cleaning: Premium cleaning of the drilled hole is required

Anchor type and diameter: HIT-RE 500-SD + HAS B7 3/4
Installation torque: 1200.000 in.lb
Hole diameter in the base material: 0.875 in.
Hole depth in the base material: 6.000 in.
Minimum thickness of the base material: 7.750 in.

Coordinates Anchor in.

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	0.000	0.000	-	-	-	-

7 Remarks; Your Cooperation Duties

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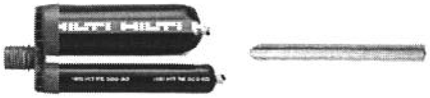
Company:	Carollo Engineers	Page:	1
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Area 09
Phone I Fax:	|	Date:	5/21/2015
E-Mail:			

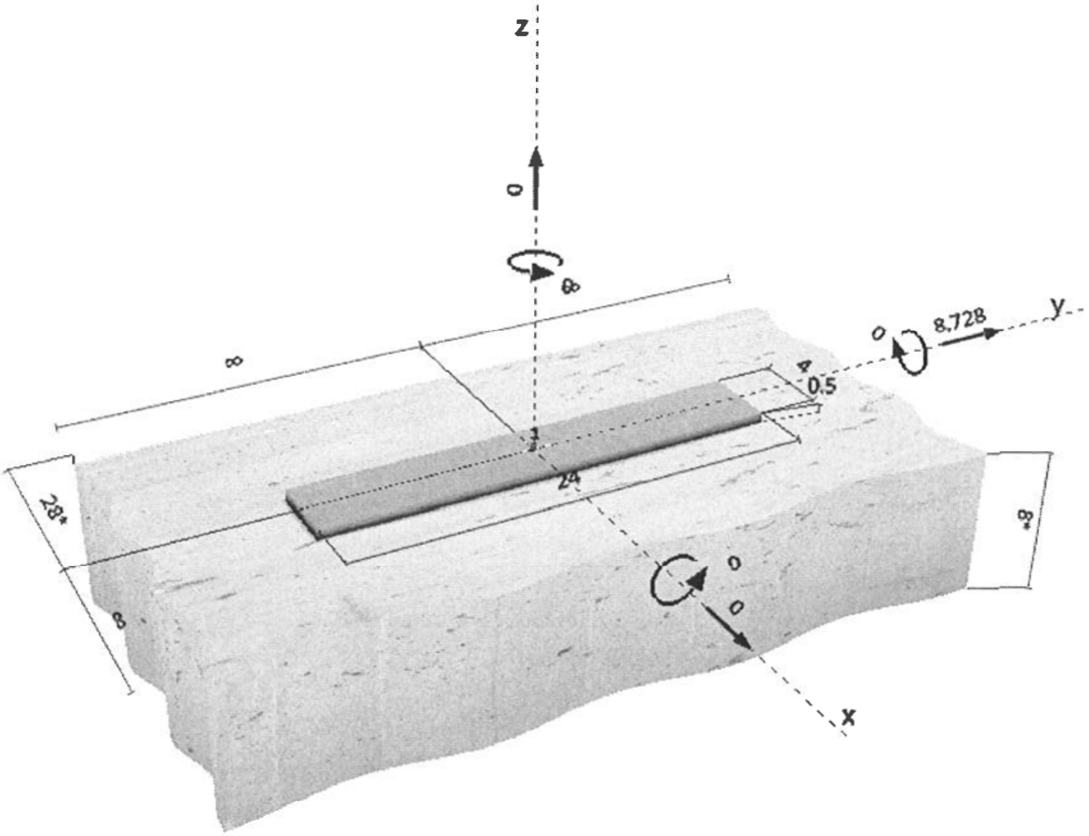
Specifier's comments: Ledger Anchors / Diaphragm Boundary

1 Input data



Anchor type and diameter:	**HIT-RE 500-SD + HAS B7 3/4**
Effective embedment depth:	$h_{ef,act}$ = 6.000 in. ($h_{ef,limit}$ = - in.)
Material:	ASTM A 193 Grade B7
Evaluation Service Report:	ESR-2322
Issued I Valid:	2/1/2014 | 4/1/2016
Proof:	Design method ACI 318-11 / Chem
Stand-off installation:	e_b = 0.000 in. (no stand-off); t = 0.500 in.
Anchor plate:	l_x x l_y x t = 4.000 in. x 24.000 in. x 0.500 in.; (Recommended plate thickness: not calculated)
Profile:	no profile
Base material:	cracked concrete, 4000, f_c' = 4000 psi; h = 8.000 in., Temp. short/long: 32/32 °F
Installation:	hammer drilled hole, Installation condition: Dry
Reinforcement:	tension: condition B, shear: condition B; no supplemental splitting reinforcement present edge reinforcement: none or < No. 4 bar
Seismic loads (cat. C, D, E, or F)	Tension load: yes (D.3.3.4.3 (a)) Shear load: yes (D.3.3.5.3 (c))

Geometry [in.] & Loading [lb, in.lb]



2 Load case/Resulting anchor forces

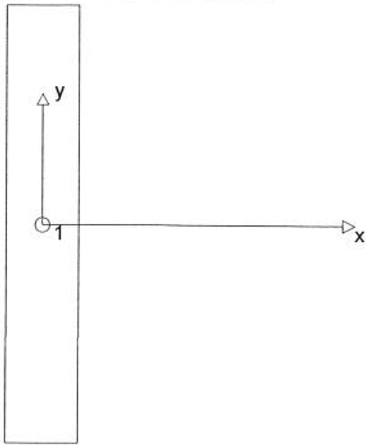
Load case: Design loads

Anchor reactions [lb]

Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	0	8728	0	8728

max. concrete compressive strain: - [‰]
max. concrete compressive stress: - [psi]
resulting tension force in (x/y)=(0.000/0.000): 0 [lb]
resulting compression force in (x/y)=(0.000/0.000): 0 [lb]



3 Tension load

	Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status
Steel Strength*	N/A	N/A	N/A	N/A
Bond Strength**	N/A	N/A	N/A	N/A
Sustained Tension Load Bond Strength*	N/A	N/A	N/A	N/A
Concrete Breakout Strength**	N/A	N/A	N/A	N/A

* anchor having the highest loading **anchor group (anchors in tension)

4 Shear load

	Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_V = V_{ua}/\phi V_n$	Status
Steel Strength*	8728	11414	77	OK
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout Strength (Bond Strength controls)**	8728	12865	68	OK
Concrete edge failure in direction x-**	8728	51530	17	OK

* anchor having the highest loading **anchor group (relevant anchors)

4.1 Steel Strength

$V_{sa} = \alpha_{V,seis} (n\ 0.6\ A_{se,V}\ f_{uta})$ refer to ICC-ES ESR-2322

$\phi\ V_{steel} \geq V_{ua}$ ACI 318-11 Table D.4.1.1

Variables

n	$A_{se,V}$ [in.^{2}]	f_{uta} [psi]	$\alpha_{V,seis}$	$(n\ 0.6\ A_{se,V}\ f_{uta})$ [lb]
1	0.33	125000	0.700	25085

Calculations

$V_{sa,eq}$ [lb]
17560

Results

$V_{sa,eq}$ [lb]	ϕ_{steel}	$\phi\ V_{sa}$ [lb]	V_{ua} [lb]
17560	0.650	11414	8728

4.2 Pryout Strength (Bond Strength controls)

$V_{cp} = k_{cp}\left[\left(\frac{A_{Na}}{A_{Na0}}\right) \psi_{ed,Na}\ \psi_{p,Na}\ N_{a0}\right]$ ACI 318-11 Eq. (D-40)

$\phi\ V_{cp} \geq V_{ua}$ ACI 318-11 Table (D.4.1.1)

A_{Na} see ACI 318-11, Part D.5.5.1, Fig. RD.5.5.1(b)

$A_{Na0} = (2\ c_{Na})^2$ ACI 318-11 Eq. (D-20)

$c_{Na} = 10\ d_a \sqrt{\frac{\tau_{uncr}}{1100}}$ ACI 318-11 Eq. (D-21)

$\psi_{ec,Na} = \left(\frac{1}{1 + \frac{e_N}{c_{Na}}}\right) \leq 1.0$ ACI 318-11 Eq. (D-23)

$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{ac}}\right) \leq 1.0$ ACI 318-11 Eq. (D-25)

$\psi_{cp,Na} = \text{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}}\right) \leq 1.0$ ACI 318-11 Eq. (D-27)

$N_{ba} = \lambda_a \cdot \tau_{k,c} \cdot \alpha_{N,seis} \cdot \kappa_{bond} \cdot \pi \cdot d_a \cdot h_{ef}$ ACI 318-11 Eq. (D-22)

Variables

k_{cp}	$\tau_{k,c,uncr}$ [psi]	d_a [in.]	h_{ef} [in.]	$c_{a,min}$ [in.]	$\tau_{k,c}$ [psi]
2	2065	0.750	6.000	28.000	1000

$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	c_{ac} [in.]	κ_{bond}	λ_a	$\alpha_{N,seis}$
0.000	0.000	14.703	1.00	1.000	0.650

Calculations

c_{Na} [in.]	A_{Na} [in.^{2}]	A_{Na0} [in.^{2}]	$\psi_{ed,Na}$
10.230	418.58	418.58	1.000

$\psi_{ec1,Na}$	$\psi_{ec2,Na}$	$\psi_{cp,Na}$	N_{ba} [lb]
1.000	1.000	1.000	9189

Results

V_{cp} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	$\phi\ V_{cp}$ [lb]	V_{ua} [lb]
18378	0.700	1.000	1.000	12865	8728

4.3 Concrete edge failure in direction x-

$V_{cb} = \left(\frac{A_{Vc}}{A_{Vc0}}\right) \psi_{ed,V}\, \psi_{c,V}\, \psi_{h,V}\, \psi_{parallel,V}\, V_b$	ACI 318-11 Eq. (D-30)
$\phi\, V_{cb} \geq V_{ua}$	ACI 318-11 Table D.4.1.1
A_{Vc} see ACI 318-11, Part D.6.2.1, Fig. RD.6.2.1(b)	
$A_{Vc0} = 4.5\, c_{a1}^2$	ACI 318-11 Eq. (D-32)
$\psi_{ec,V} = \left(\frac{1}{1 + \frac{2e_V'}{3c_{a1}}}\right) \leq 1.0$	ACI 318-11 Eq. (D-36)
$\psi_{ed,V} = 0.7 + 0.3\left(\frac{c_{a2}}{1.5c_{a1}}\right) \leq 1.0$	ACI 318-11 Eq. (D-38)
$\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \geq 1.0$	ACI 318-11 Eq. (D-39)
$V_b = 9\, \lambda_a \sqrt{f_c'}\, c_{a1}^{1.5}$	ACI 318-11 Eq. (D-34)

Variables

c_{a1} [in.]	c_{a2} [in.]	e_{cV} [in.]	$\psi_{c,V}$	h_a [in.]
28.000	-	0.000	1.000	8.000

l_e [in.]	λ_a	d_a [in.]	f_c' [psi]	$\psi_{parallel,V}$
6.000	1.000	0.750	4000	2.000

Calculations

A_{Vc} [in.^{2}]	A_{Vc0} [in.^{2}]	$\psi_{ec,V}$	$\psi_{ed,V}$	$\psi_{h,V}$	V_b [lb]
672.00	3528.00	1.000	1.000	2.291	84335

Results

V_{cb} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	$\phi\, V_{cb}$ [lb]	V_{ua} [lb]
73614	0.700	1.000	1.000	51530	8728

5 Warnings

- Load re-distributions on the anchors due to elastic deformations of the anchor plate are not considered. The anchor plate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the loading! Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Condition A applies when supplementary reinforcement is used. The Φ factor is increased for non-steel Design Strengths except Pullout Strength and Pryout strength. Condition B applies when supplementary reinforcement is not used and for Pullout Strength and Pryout Strength. Refer to your local standard.
- Design Strengths of adhesive anchor systems are influenced by the cleaning method. Refer to the INSTRUCTIONS FOR USE given in the Evaluation Service Report for cleaning and installation instructions
- Checking the transfer of loads into the base material and the shear resistance are required in accordance with ACI 318 or the relevant standard!
- An anchor design approach for structures assigned to Seismic Design Category C, D, E or F is given in ACI 318-11 Appendix D, Part D.3.3.4.3 (a) that requires the governing design strength of an anchor or group of anchors be limited by ductile steel failure. If this is NOT the case, the connection design (tension) shall satisfy the provisions of Part D.3.3.4.3 (b), Part D.3.3.4.3 (c), or Part D.3.3.4.3 (d). The connection design (shear) shall satisfy the provisions of Part D.3.3.5.3 (a), Part D.3.3.5.3 (b), or Part D.3.3.5.3 (c).
- Part D.3.3.4.3 (b) / part D.3.3.5.3 (a) requires that the attachment the anchors are connecting to the structure be designed to undergo ductile yielding at a load level corresponding to anchor forces no greater than the controlling design strength. Part D.3.3.4.3 (c) / part D.3.3.5.3 (b) waives the ductility requirements and requires that the anchors shall be designed for the maximum tension / shear that can be transmitted to the anchors by a non-yielding attachment. Part D.3.3.4.3 (d) / part D.3.3.5.3 (c) waives the ductility requirements and requires the design strength of the anchors to equal or exceed the maximum tension / shear obtained from design load combinations that include E, with E increased by Ω_0.
- Installation of Hilti adhesive anchor systems shall be performed by personnel trained to install Hilti adhesive anchors. Reference ACI 318-11, Part D.9.1

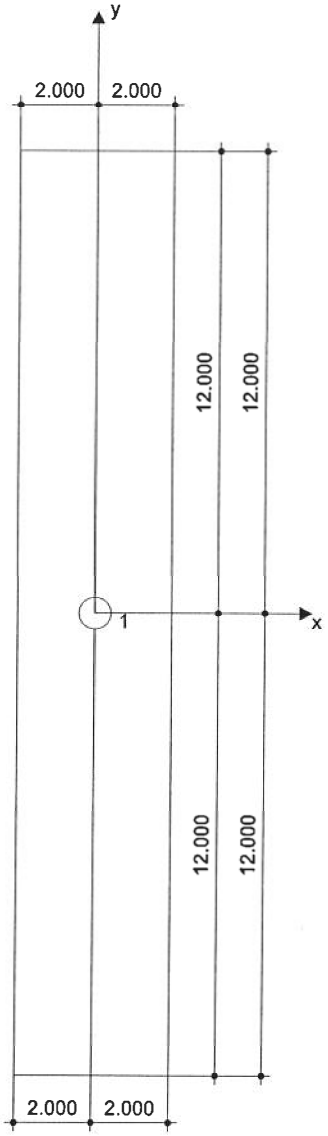
Fastening meets the design criteria!

Company:	Carollo Engineers	Page:	5
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Area 09
Phone I Fax:	|	Date:	5/21/2015
E-Mail:			

6 Installation data

Anchor plate, steel: -
Profile: no profile; 0.000 x 0.000 x 0.000 in.
Hole diameter in the fixture: d_f = 0.813 in.
Plate thickness (input): 0.500 in.
Recommended plate thickness: not calculated
Cleaning: Premium cleaning of the drilled hole is required

Anchor type and diameter: HIT-RE 500-SD + HAS B7 3/4
Installation torque: 600.000 in.lb
Hole diameter in the base material: 0.875 in.
Hole depth in the base material: 6.000 in.
Minimum thickness of the base material: 7.750 in.



Coordinates Anchor in.

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	0.000	0.000	28.000	-	-	-

Company:	Carollo Engineers	Page:	6
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Area 09
Phone I Fax:	|	Date:	5/21/2015
E-Mail:			

7 Remarks; Your Cooperation Duties

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Engineers...Working Wonders With Water™

BY:	JAD	DATE	May-15	CLIENT	Tualatin Valley Water District	SHEET	
CHKD BY:				DESCRIPTION	Finished Water Pump Station	JOB NO.	9865A.00
DESIGN TASK	Weight Estimate						

Building Weight Summary - Finished Water Pump Station (Reference Drawings13S, 18S, and 19S)

North-South Seismic

Material Properties		
Concrete Density	150.0	pcf
8" Masonry DL	84.00	psf
		psf

Element	Quantity	Length (ft)		Width/Trib. Height (ft)	Area (ft^2)	Seismic Weight (psf)	Weight, w_i (kip)	Weight, w_i (kip/ft)	
Roof		138.00		27.17	3749.05	15.00	56.24	2.07	
Exterior Conc Walls	2	27.17		13.67	371.29	100.00	74.26	2.73	
Interior Conc Walls	2	27.17		11.00	298.84	100.00	59.77	2.20	
							190.26		

East-West Seismic

Material Properties		
Concrete Density	150.0	pcf
8" Masonry DL	84.00	psf
		psf

Element	Quantity	Length (ft)		Width/Trib. Height (ft)	Area (ft^2)	Seismic Weight (psf)	Weight, w_i (kip)	Weight, w_i (kip/ft)	
Roof		27.17		138.00	3749.05	15.00	56.24	0.41	
West Wall	1	138.00		17.00	2346.00	150.00	351.90	2.55	
East Wall	1	138.00		13.67	1886.05	150.00	282.91	2.05	
							691.04		

BY JAD	DATE 5/21/15	SUBJECT WILLAMETTE RIVER WTP	SHEET NO. ____ OF ____
CHKD. BY	DATE	FINISHED WATER P.S.	JOB NO. 9865A.00

BUILDING ANALYSIS PER SEC. 5.2.4 (EAST-WEST DIRECTION ONLY)

- EVALUATION OF DIAPHRAGM
- " OF OVERTURNING/SHEAR TRANSFER @ DISCONTINUOUS WALLS
- " OF WALL ANCHORAGE

$V = C_1 C_2 C_m S_a W$

$m_{max} < 2 \quad T < 0.3\ s$

$C_1 C_2 = 1.1$ PER TABLE 7-3

$C_m = 1.0$ PER TABLE 7-4

$T_s = S_{X1}/S_{XS} = 0.372/0.611 = 0.61$

$T_0 = 0.20(0.61) = 0.12$

$T_L = 16\ s$

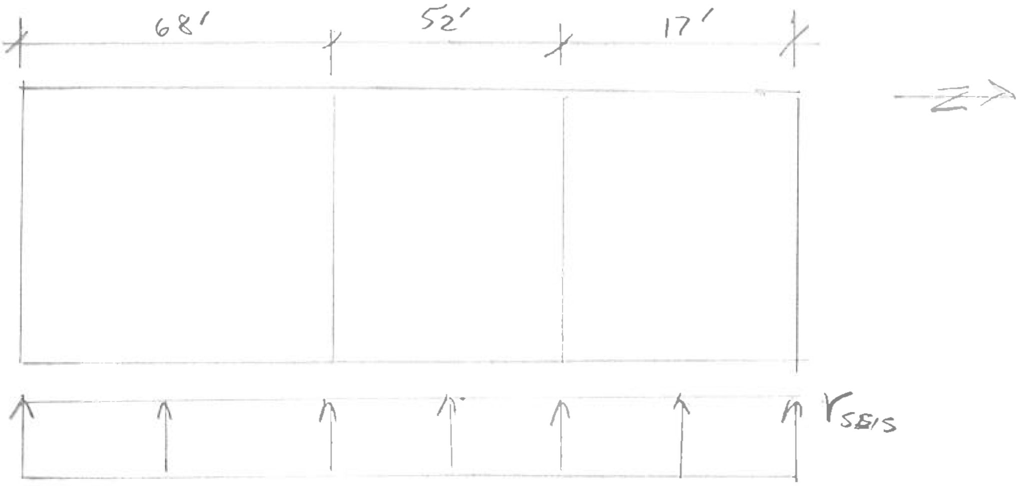
$\beta = 0.02$ (NO CLADDING @ THE EXTERIOR) $\beta = 0.05$ (ASSUMING CONC WALLS ARE CLADDING)

$S_a = S_{XS}/B_1$ (EQ 2-6)

$B_1 = \dfrac{4}{(5.6 - \ln(100 \times \beta_1))} = \dfrac{4}{(5.6 - \ln 2)} = 0.815 \quad (1.00)$

$\Rightarrow S_a = 0.611/0.815 = 0.75$ 2% DAMPED 5% DAMPED

$V = 1.1(1.0)(0.75)W = 0.825\ W \quad (0.672\ W)$



BY JAD	DATE 5/21/15	SUBJECT WILLAMETTE RIVER WTP	SHEET NO. ___ OF ___
CHKD. BY	DATE	FINISHED WATER P.S.	JOB NO. 9865A.00

$$V_{SEIS} = 0.825\,(\underset{\substack{\uparrow\\ \text{ROOF}}}{410\text{ PLF}} + \underset{\substack{\uparrow\\ \text{WEST WALL}\\ (8'' + 12'')\\ 17'\text{ TRIB}}}{2{,}550\text{ PLF}} + \underset{\substack{\uparrow\\ \text{EAST WALL}\\ (8'' + 12'')\\ 13.5'\text{ TRIB}}}{1{,}688\text{ PLF}})$$

$$= 4{,}648\text{ PLF}$$

$$F_{P1} = \frac{\Sigma F_i}{\Sigma W_i} W_x = \frac{V}{W} w_1 = \frac{0.825\cancel{W}}{\cancel{W}} W_1 = 0.825\,W_1$$

$$F_{P1} = 0.825\,(4{,}648\text{ PLF}) = 3{,}835\text{ PLF}$$

$$F_D = (3{,}835\text{ PLF})(68\text{ FT}) = 260{,}780\text{ LB}$$

$$f_d = 260{,}780\text{ LB} / 2 = 130{,}390\text{ LB}$$

$$V_{\substack{DIAP\\E-W}} = \frac{(130{,}390\text{ LB})}{27.17\text{ FT}} = 4{,}800\text{ PLF}$$

$Q_{UD} = 4{,}800\text{ PLF}$ (DEFORMATION CONTROLLED)

$$Q_{UF} = \frac{Q_E}{C_1 C_2 J} = \frac{4{,}800\text{ PLF}}{(1.1)(1.0)} = 4{,}364\text{ PLF}$$

$m\kappa Q_{CE} > Q_{UD}$

$m = 1.25$ $\kappa = 1.0$ (ASSUMING 1/2" ϕ WELDS @ 36/5 PATTERN AND @ TSW @ 12" o.c.)

1 1/2" × 20 GA VERCO DECK (HSB-36) / SPANS @ 6'-0"

$Q_{CE} = 1.60\,(1{,}069\text{ PLF}) = 1{,}710\text{ PLF}$

$(1.25)(1.0)(1{,}710\text{ PLF}) = 2{,}138\text{ PLF}$

$DCR = 4{,}800 / 2{,}138 = 2.25 > 1.0$ NG

PER UES ER-0217, USE MODIFICATION FACTOR "C" TO OBTAIN STRENGTH LEVEL CAPACITIES FOR LISTED ASD VALUES.

PANEL BUCKLING: $C_{BUCKLING} = 2.00 \times 0.80 = 1.60$

WELD CONNECTIONS: $C_{WELDS} = 3.00 \times 0.55 = 1.55$

BY JAD DATE 5/21/15 SUBJECT WILLAMETTE RIVER WTP SHEET NO. ____ OF ____
CHKD. BY ________ DATE ________ FINISHED WATER P.S. JOB NO. 98654.00

$KQ_{CL} > Q_{UF}$

$Q_{CL} = (1{,}091\ LB/WELD)(1.55) = 1{,}691\ LB/WELD$

$n_{WELDS} = 5/3\ FT = 1.67\ WELDS/FT$

↳ @ EACH SIDE OF WALL
NO DETAIL, BUT PHOTOS SHOW LEDGERS ON EACH SIDE.

~~ADJACENT SPAN SHEAR,~~

~~$V_{DIAP\ E\text{-}W\ ADJ} = \frac{(2857\ PLF)(52\ FT/2)}{27.17\ FT} = 2{,}734\ PLF$~~

~~$Q_{UF\ TOT} = (3{,}598\ PLF + 2{,}734\ PLF)$~~

$Q_{CL} = (1{,}691\ LB/WELD)(1.67\ WELD/FT)(27.17\ FT) = 76{,}718\ LB$

$Q_{UF} = (4{,}364\ PLF)(27.17\ FT) = 118{,}557\ LB$

$DCR = 119/76.7 = 1.55 > 1.0$ NG

⟹ ROOF DIAPHRAGM HAS INSUFFICIENT SHEAR CAPACITY @ BOUNDARIES OF 68' AND 52' SPAN DIAPHRAGMS. ROUGHLY 50% OF THE DIAPHRAGM IS OVERSTRESSED.

CHECK CHORD FORCE,

$Q_{UD} = \frac{(4{,}800\ PLF)(68\ FT)^2}{8(27.17\ FT)} = 102{,}124\ LB$

$Q_{CE} = \emptyset T_n = (1.0)(4)(0.31\ in^2)(60\ ksi)(1.25) = 93\ k$

$DCR = 102/93 = 1.10 > 1.0$ NG

CONNECTIONS @ TALL WINDOWS ARE FORCE-CONTROLLED,

HSS 5x5x3/8
$A_{ST} = 6.18\ in^2$
$F_y = 46\ ksi$

⟹ RETROFIT SHOULD ENHANCE OR REPLACE TUBE STL TIES FROM WALL TO WALL FOR CHORD CONTINUITY.

BY JAD DATE 5/21/15 SUBJECT WILLAMETTE RIVER WTP SHEET NO. ___ OF ___
CHKD. BY ______ DATE ______ FINISHED WATER PS JOB NO. 9865A.00

CHECK SHEAR TRANSFER TO WALLS FROM DIAPHRAGM,

3/4"Ø ADHESIVE ANCHORS W/ 6" EMBED @ 2'-0" O.C.

USING $\phi = 1.0$

$Q_{UF} = (4,364 \text{ PLF})(2 \text{ FT}) = 8,728 \text{ LB}$

$Q_{CL} = (2,249 \text{ LB})(1.0) = 2,249 \text{ LB}$ (CONC EDGE BREAK-OUT)

$DCR = 8728/2,249 = 3.9 > 1.0$ NG

EDGE DISTANCE IS ACTUALLY 1.5 IN., WHICH DOES NOT ALLOW FOR DEVELOPMENT OF SHEAR STRENGTH OF DECK OR THE ANCHOR.

→ REPLACE EAST-WEST LEDGERS @ INTERIOR WALLS AND REDUCE ANCHOR SPACING.

CHECK SHEAR TRANSFER @ END WALLS,

$Q_{UF} = 8,728 \text{ LB}$

$Q_{CL} = 12,865 \text{ LB}$

$DCR = 8728/12865 = 0.68 < 1.0$ OK

BY JAD DATE 5/21/15 SUBJECT WILLAMETTE RIVER WTP SHEET NO.____OF____
CHKD. BY ____ DATE ____ FINISHED WATER P.S. JOB NO. 9865A.00

CHECK DISCONTINUOUS SHEAR WALLS:

1) SOUTH INTERIOR WALL

$Q_{UD} = (4{,}648 \text{ PLF})\frac{(68 \text{ FT} + 52 \text{ FT})}{2} = 278{,}880 \text{ LB}$

ESTIMATE WALL SHEAR CAPACITY (PER ACI 318, CHPT 21)

$V_n = A_{cv}(\alpha_c \lambda \sqrt{f'_c} + \rho_t f_y)$

WALL IS 8" THICK x 250" LONG

$A_{cv} = (8 \text{ IN.})(250 \text{ IN.}) = 2{,}000 \text{ IN.}^2$

$h_w / l_w = (22 \times 12)/250 = 1.06 \quad \alpha_c = 3.0$

$\lambda = 1.0$ (NORMAL-WT CONC)

$f'_{ce} = 4{,}000 \text{ PSI} \times 1.5 = 6{,}000 \text{ PSI}$

TABLE 10-1
ASCE 41-13

$f_{ye} = 60{,}000 \text{ PSI} \times 1.25 = 75{,}000 \text{ PSI}$

$\phi = 1.0$

#5@12"

$\phi V_n = (2{,}000 \text{ IN.}^2)\left[(0.30)(1.0)\sqrt{6{,}000 \text{ PSI}} + (0.00323)(75{,}000 \text{ PSI})\right](1.0) = 530{,}976 \text{ LB}$

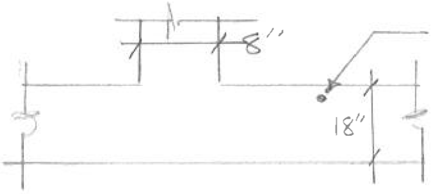
$\phi V_n = 1{,}421 \text{ k}$

ACCEPTANCE CRITERIA FOR SHEAR,

$mKQ_{CE} = (2.0)(1.0)(531 \text{ k}) = 1{,}062 \text{ k}$

$DCR = 279/1062 = 0.26 < 1.0 \text{ OK}$

2) CHECK SHEAR TRANSFER TO CONC DECK



$\rho = \frac{(0.88 \text{ IN}^2)(2)}{(12 \text{ IN.})(18 \text{ IN.})} = 0.00815$

BY JAD	DATE 5/21/15	SUBJECT WILLAMETTE RIVER WTP	SHEET NO. ___ OF ___
CHKD. BY ___	DATE ___	FINISHED WATER P.S.	JOB NO. 9865A.00

$$V_n = A_{cv}(2\lambda\sqrt{f'_{ce}} + \rho_t f_{ye})$$

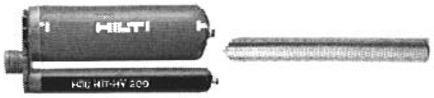
$$\phi V_n = (12\text{ in.})(18\text{ in.})\left[2(1.0)\sqrt{6{,}000\text{ psi}} + (0.00815)(75{,}000\text{ psi})\right](1.0)$$

$$= 165\text{ k/ft} \quad \text{OK}$$

Company:	Carollo Engineers	Page:	1
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Seismic Evaluation
Phone I Fax:	|	Date:	5/26/2015
E-Mail:			

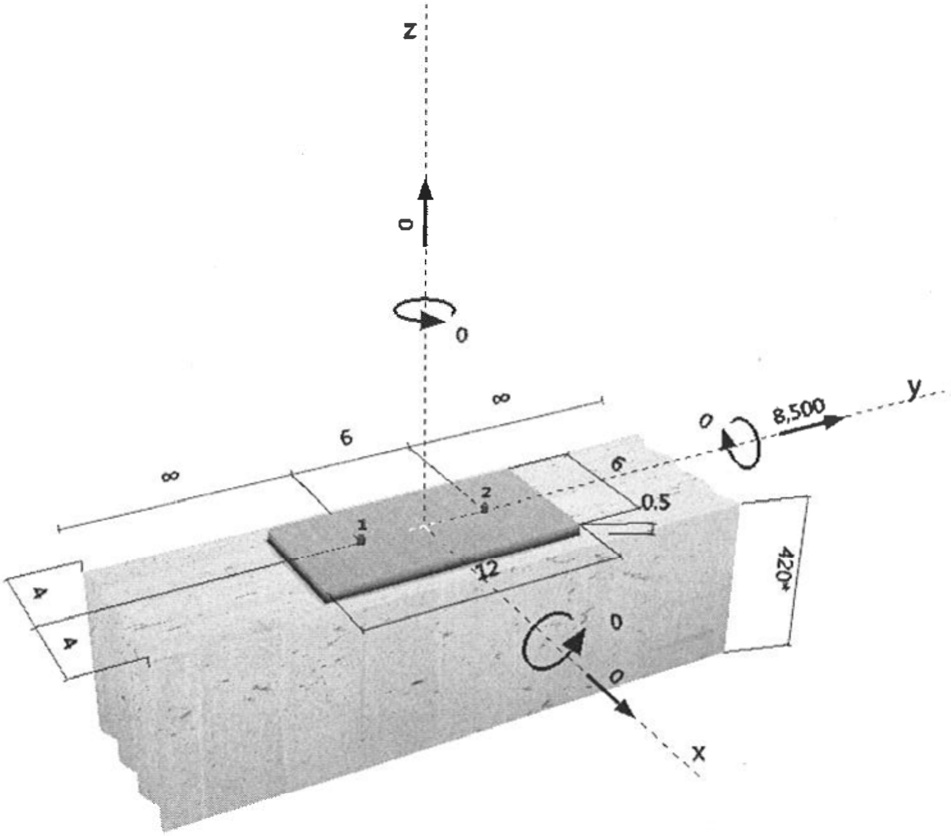
Specifier's comments: Area 09 - Diaphragm shear transfer to interior shear walls

1 Input data



Anchor type and diameter:	**HIT-HY 200 + HAS B7 3/4**
Effective embedment depth:	$h_{ef,act}$ = 8.000 in. ($h_{ef,limit}$ = - in.)
Material:	ASTM A 193 Grade B7
Evaluation Service Report:	ESR-3187
Issued I Valid:	5/1/2014 | 3/1/2016
Proof:	Design method ACI 318-11 / Chem
Stand-off installation:	e_b = 0.000 in. (no stand-off); t = 0.500 in.
Anchor plate:	l_x x l_y x t = 6.000 in. x 12.000 in. x 0.500 in.; (Recommended plate thickness: not calculated)
Profile:	no profile
Base material:	cracked concrete, 4000, f_c' = 4000 psi; h = 420.000 in., Temp. short/long: 32/32 °F
Installation:	hammer drilled hole, Installation condition: Dry
Reinforcement:	tension: condition B, shear: condition A; no supplemental splitting reinforcement present edge reinforcement: none or < No. 4 bar
Seismic loads (cat. C, D, E, or F)	Tension load: yes (D.3.3.4.3 (a)) Shear load: yes (D.3.3.5.3 (c))

Geometry [in.] & Loading [lb, in.lb]



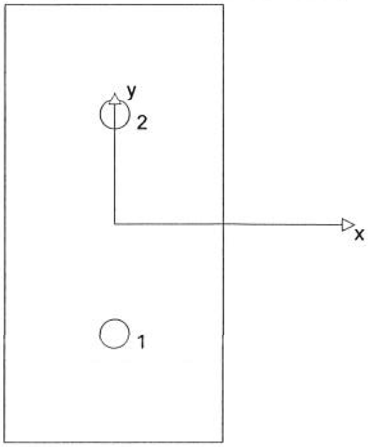
2 Load case/Resulting anchor forces

Load case: Design loads

Anchor reactions [lb]
Tension force: (+Tension, -Compression)

Anchor	Tension force	Shear force	Shear force x	Shear force y
1	0	4250	0	4250
2	0	4250	0	4250

max. concrete compressive strain: - [‰]
max. concrete compressive stress: - [psi]
resulting tension force in (x/y)=(0.000/0.000): 0 [lb]
resulting compression force in (x/y)=(0.000/0.000): 0 [lb]



3 Tension load

	Load N_{ua} [lb]	Capacity ϕN_n [lb]	Utilization $\beta_N = N_{ua}/\phi N_n$	Status
Steel Strength*	N/A	N/A	N/A	N/A
Bond Strength**	N/A	N/A	N/A	N/A
Sustained Tension Load Bond Strength*	N/A	N/A	N/A	N/A
Concrete Breakout Strength**	N/A	N/A	N/A	N/A

* anchor having the highest loading **anchor group (anchors in tension)

4 Shear load

	Load V_{ua} [lb]	Capacity ϕV_n [lb]	Utilization $\beta_V = V_{ua}/\phi V_n$	Status
Steel Strength*	4250	11414	38	OK
Steel failure (with lever arm)*	N/A	N/A	N/A	N/A
Pryout Strength (Bond Strength controls)**	8500	9890	86	OK
Concrete edge failure in direction x+**	8500	10246	83	OK

* anchor having the highest loading **anchor group (relevant anchors)

4.1 Steel Strength

$V_{sa} = \alpha_{V,seis} (n\ 0.6\ A_{se,V}\ f_{uta})$ refer to ICC-ES ESR-3187

$\phi\ V_{steel} \geq V_{ua}$ ACI 318-11 Table D.4.1.1

Variables

n	$A_{se,V}$ [in.^{2}]	f_{uta} [psi]	$\alpha_{V,seis}$	$(n\ 0.6\ A_{se,V}\ f_{uta})$ [lb]
1	0.33	125000	0.700	25085

Calculations

$V_{sa,eq}$ [lb]
17560

Results

$V_{sa,eq}$ [lb]	ϕ_{steel}	$\phi\ V_{sa}$ [lb]	V_{ua} [lb]
17560	0.650	11414	4250

4.2 Pryout Strength (Bond Strength controls)

$V_{cpg} = k_{cp}\left[\left(\frac{A_{Na}}{A_{Na0}}\right) \psi_{ec1,Na}\ \psi_{ec2,Na}\ \psi_{ed,Na}\ \psi_{cp,Na}\ N_{ba}\right]$ ACI 318-11 Eq. (D-41)

$\phi\ V_{cpg} \geq V_{ua}$ ACI 318-11 Table (D.4.1.1)

A_{Na} see ACI 318-11, Part D.5.5.1, Fig. RD.5.5.1(b)

$A_{Na0} = (2\ c_{Na})^2$ ACI 318-11 Eq. (D-20)

$c_{Na} = 10\ d_a \sqrt{\frac{\tau_{uncr}}{1100}}$ ACI 318-11 Eq. (D-21)

$\psi_{ec,Na} = \left(\frac{1}{1 + \frac{e_N}{c_{Na}}}\right) \leq 1.0$ ACI 318-11 Eq. (D-23)

$\psi_{ed,Na} = 0.7 + 0.3 \left(\frac{c_{a,min}}{c_{ac}}\right) \leq 1.0$ ACI 318-11 Eq. (D-25)

$\psi_{cp,Na} = \mathrm{MAX}\left(\frac{c_{a,min}}{c_{ac}}, \frac{c_{Na}}{c_{ac}}\right) \leq 1.0$ ACI 318-11 Eq. (D-27)

$N_{ba} = \lambda_a \cdot \tau_{k,c} \cdot \alpha_{N,seis} \cdot \kappa_{bond} \cdot \pi \cdot d_a \cdot h_{ef}$ ACI 318-11 Eq. (D-22)

Variables

k_{cp}	$\tau_{k,c,uncr}$ [psi]	d_a [in.]	h_{ef} [in.]	$c_{a,min}$ [in.]	$\tau_{k,c}$ [psi]
2	1880	0.750	8.000	4.000	1062

$e_{c1,N}$ [in.]	$e_{c2,N}$ [in.]	c_{ac} [in.]	κ_{bond}	λ_a	$\alpha_{N,seis}$
0.000	0.000	13.417	1.00	1.000	0.800

Calculations

c_{Na} [in.]	A_{Na} [in.^{2}]	A_{Na0} [in.^{2}]	$\psi_{ed,Na}$
9.760	204.15	381.00	0.823

$\psi_{ec1,Na}$	$\psi_{ec2,Na}$	$\psi_{cp,Na}$	N_{ba} [lb]
1.000	1.000	1.000	16020

Results

V_{cpg} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	$\phi\ V_{cpg}$ [lb]	V_{ua} [lb]
14128	0.700	1.000	1.000	9890	8500

4.3 Concrete edge failure in direction x+

$V_{cbg} = \left(\frac{A_{Vc}}{A_{Vc0}}\right) \psi_{ec,V}\ \psi_{ed,V}\ \psi_{c,V}\ \psi_{h,V}\ \psi_{parallel,V}\ V_b$ ACI 318-11 Eq. (D-31)

$\phi\ V_{cbg} \geq V_{ua}$ ACI 318-11 Table D.4.1.1

A_{Vc} see ACI 318-11, Part D.6.2.1, Fig. RD.6.2.1(b)

$A_{Vc0} = 4.5\ c_{a1}^2$ ACI 318-11 Eq. (D-32)

$\psi_{ec,V} = \left(\frac{1}{1 + \frac{2e_V}{3c_{a1}}}\right) \leq 1.0$ ACI 318-11 Eq. (D-36)

$\psi_{ed,V} = 0.7 + 0.3\left(\frac{c_{a2}}{1.5c_{a1}}\right) \leq 1.0$ ACI 318-11 Eq. (D-38)

$\psi_{h,V} = \sqrt{\frac{1.5c_{a1}}{h_a}} \geq 1.0$ ACI 318-11 Eq. (D-39)

$V_b = 9\ \lambda_a \sqrt{f'_c}\ c_{a1}^{1.5}$ ACI 318-11 Eq. (D-34)

Variables

c_{a1} [in.]	c_{a2} [in.]	e_{cV} [in.]	$\psi_{c,V}$	h_a [in.]
4.000	-	0.000	1.000	420.000

l_e [in.]	λ_a	d_a [in.]	f'_c [psi]	$\psi_{parallel,V}$
6.000	1.000	0.750	4000	2.000

Calculations

A_{Vc} [in.^{2}]	A_{Vc0} [in.^{2}]	$\psi_{ec,V}$	$\psi_{ed,V}$	$\psi_{h,V}$	V_b [lb]
108.00	72.00	1.000	1.000	1.000	4554

Results

V_{cbg} [lb]	$\phi_{concrete}$	$\phi_{seismic}$	$\phi_{nonductile}$	$\phi\ V_{cbg}$ [lb]	V_{ua} [lb]
13661	0.750	1.000	1.000	10246	8500

5 Warnings

- Load re-distributions on the anchors due to elastic deformations of the anchor plate are not considered. The anchor plate is assumed to be sufficiently stiff, in order not to be deformed when subjected to the loading! Input data and results must be checked for agreement with the existing conditions and for plausibility!
- Condition A applies when supplementary reinforcement is used. The Φ factor is increased for non-steel Design Strengths except Pullout Strength and Pryout strength. Condition B applies when supplementary reinforcement is not used and for Pullout Strength and Pryout Strength. Refer to your local standard.
- Design Strengths of adhesive anchor systems are influenced by the cleaning method. Refer to the INSTRUCTIONS FOR USE given in the Evaluation Service Report for cleaning and installation instructions
- Checking the transfer of loads into the base material and the shear resistance are required in accordance with ACI 318 or the relevant standard!
- An anchor design approach for structures assigned to Seismic Design Category C, D, E or F is given in ACI 318-11 Appendix D, Part D.3.3.4.3 (a) that requires the governing design strength of an anchor or group of anchors be limited by ductile steel failure. If this is NOT the case, the connection design (tension) shall satisfy the provisions of Part D.3.3.4.3 (b), Part D.3.3.4.3 (c), or Part D.3.3.4.3 (d). The connection design (shear) shall satisfy the provisions of Part D.3.3.5.3 (a), Part D.3.3.5.3 (b), or Part D.3.3.5.3 (c).
- Part D.3.3.4.3 (b) / part D.3.3.5.3 (a) requires that the attachment the anchors are connecting to the structure be designed to undergo ductile yielding at a load level corresponding to anchor forces no greater than the controlling design strength. Part D.3.3.4.3 (c) / part D.3.3.5.3 (b) waives the ductility requirements and requires that the anchors shall be designed for the maximum tension / shear that can be transmitted to the anchors by a non-yielding attachment. Part D.3.3.4.3 (d) / part D.3.3.5.3 (c) waives the ductility requirements and requires the design strength of the anchors to equal or exceed the maximum tension / shear obtained from design load combinations that include E, with E increased by Ω_0.
- Installation of Hilti adhesive anchor systems shall be performed by personnel trained to install Hilti adhesive anchors. Reference ACI 318-11, Part D.9.1

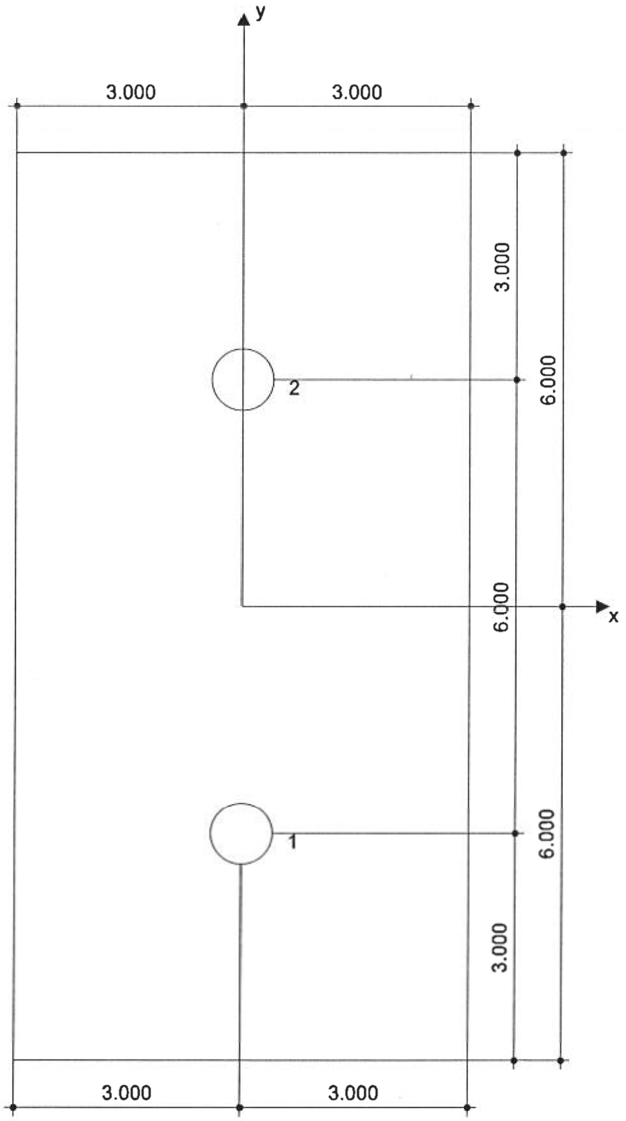
Fastening meets the design criteria!

Company:	Carollo Engineers	Page:	5
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Seismic Evaluation
Phone I Fax:	|	Date:	5/26/2015
E-Mail:			

6 Installation data

Anchor plate, steel: -
Profile: no profile; 0.000 x 0.000 x 0.000 in.
Hole diameter in the fixture: d_f = 0.813 in.
Plate thickness (input): 0.500 in.
Recommended plate thickness: not calculated
Cleaning: Premium cleaning of the drilled hole is required

Anchor type and diameter: HIT-HY 200 + HAS B7 3/4
Installation torque: 1200.002 in.lb
Hole diameter in the base material: 0.875 in.
Hole depth in the base material: 8.000 in.
Minimum thickness of the base material: 9.750 in.



Coordinates Anchor in.

Anchor	x	y	c_{-x}	c_{+x}	c_{-y}	c_{+y}
1	0.000	-3.000	4.000	4.000	-	-
2	0.000	3.000	4.000	4.000	-	-

Company:	Carollo Engineers	Page:	6
Specifier:	James Doering	Project:	Willamette River WTP
Address:		Sub-Project I Pos. No.:	Seismic Evaluation
Phone I Fax:	|	Date:	5/26/2015
E-Mail:			

7 Remarks; Your Cooperation Duties

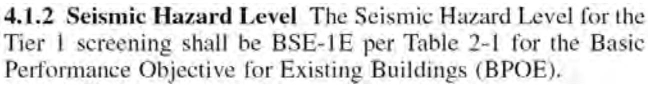
- Any and all information and data contained in the Software concern solely the use of Hilti products and are based on the principles, formulas and security regulations in accordance with Hilti's technical directions and operating, mounting and assembly instructions, etc., that must be strictly complied with by the user. All figures contained therein are average figures, and therefore use-specific tests are to be conducted prior to using the relevant Hilti product. The results of the calculations carried out by means of the Software are based essentially on the data you put in. Therefore, you bear the sole responsibility for the absence of errors, the completeness and the relevance of the data to be put in by you. Moreover, you bear sole responsibility for having the results of the calculation checked and cleared by an expert, particularly with regard to compliance with applicable norms and permits, prior to using them for your specific facility. The Software serves only as an aid to interpret norms and permits without any guarantee as to the absence of errors, the correctness and the relevance of the results or suitability for a specific application.
- You must take all necessary and reasonable steps to prevent or limit damage caused by the Software. In particular, you must arrange for the regular backup of programs and data and, if applicable, carry out the updates of the Software offered by Hilti on a regular basis. If you do not use the AutoUpdate function of the Software, you must ensure that you are using the current and thus up-to-date version of the Software in each case by carrying out manual updates via the Hilti Website. Hilti will not be liable for consequences, such as the recovery of lost or damaged data or programs, arising from a culpable breach of duty by you.

Area 11 - Sludge Thickener Stair Housing
ASCE 41 Evaluation

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 11 - Sludge Thickeneter	**JOB NO.**	10721A.00
DESIGN TASK					ASCE 41 (Tier 1 Screening) - Seismic		

SEISMIC HAZARD LEVEL & BASIC PERFORMANCE OBJECTIVE

Note:



4.1.2 Seismic Hazard Level The Seismic Hazard Level for the Tier 1 screening shall be BSE-1E per Table 2-1 for the Basic Performance Objective for Existing Buildings (BPOE).

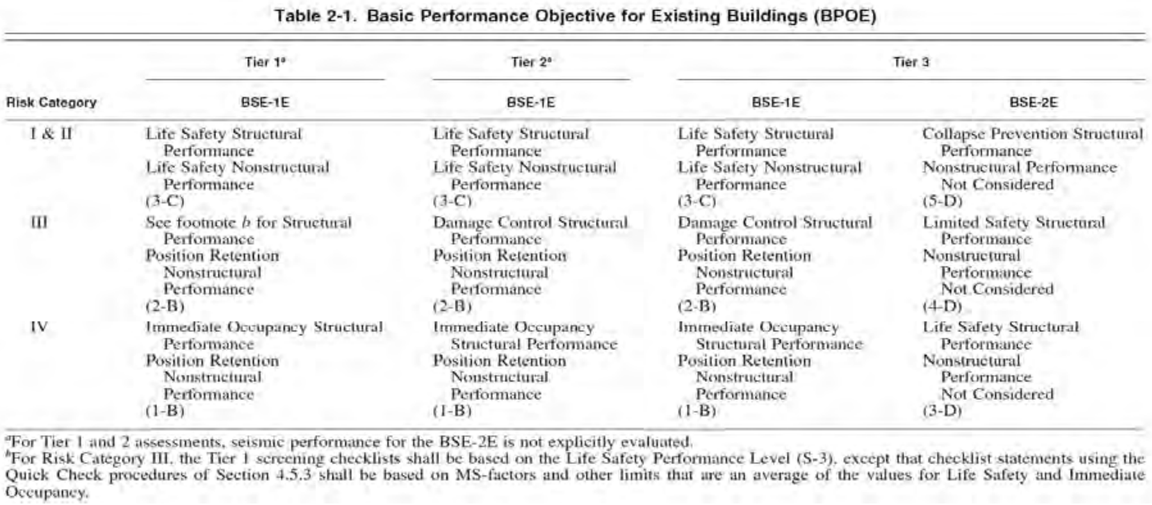


Table 2-1. Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1[a]	Tier 2[a]	Tier 3	
Risk Category	BSE-1E	BSE-1E	BSE-1E	BSE-2E
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III	See footnote *b* for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

[a] For Tier 1 and 2 assessments, seismic performance for the BSE-2E is not explicitly evaluated.

[b] For Risk Category III, the Tier 1 screening checklists shall be based on the Life Safety Performance Level (S-3), except that checklist statements using the Quick Check procedures of Section 4.5.3 shall be based on MS-factors and other limits that are an average of the values for Life Safety and Immediate Occupancy.

BUILDING PERIOD (SECTION 4.5.2.4)

building height, h_n = 10.50 ft

building period adjustment factor, C_t = 0.020

effective viscous damping ratio, β = 0.75

fundamental building period, T = 0.117 sec

SEISMIC PARAMETERS

Building Type = C2a Table 3-1

modification factor, C = 1.00 Table 4-8

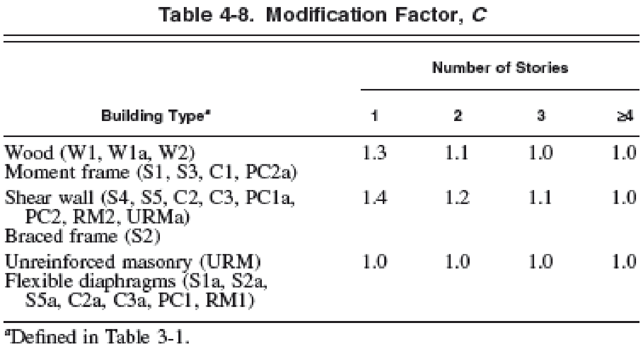


Table 4-8. Modification Factor, *C*

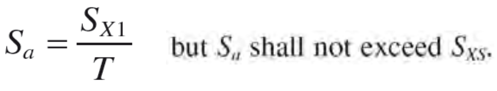
	Number of Stories			
Building Type[a]	1	2	3	≥4
Wood (W1, W1a, W2) Moment frame (S1, S3, C1, PC2a)	1.3	1.1	1.0	1.0
Shear wall (S4, S5, C2, C3, PC1a, PC2, RM2, URMa) Braced frame (S2)	1.4	1.2	1.1	1.0
Unreinforced masonry (URM) Flexible diaphragms (S1a, S2a, S5a, C2a, C3a, PC1, RM1)	1.0	1.0	1.0	1.0

[a] Defined in Table 3-1.

spectral acceleration at 1-sec for BSE-1E, S_{x1} = 0.372 g USGS Seismic Map

spectral acceleration at short period for BSE-1E, S_{xs} = 0.611 g USGS Seismic Map

spectral acceleration, S_a = 0.611 g



$$S_a = \frac{S_{X1}}{T} \quad \text{but } S_a \text{ shall not exceed } S_{XS}.$$

base shear coefficient, V = 0.611 W Eq 4-1

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SHEET					
CHKD BY		**DESCRIPTION**	Area 11 - Sludge Thickener	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening) - Building Weight & Base Shear				

DEAD LOAD (Seismic Weight)

Roof Weight

Roofing	=	10.00	psf
Metal Roof Deck	=	3.00	psf
Miscellaneous (MEP)	=	7.00	psf
Total	=	20.00	psf

Roof Length	=	34.00	ft
Roof Width	=	20.67	ft
Total Roof Weight	=	14.05	kips

	Thick (in)	Trib Ht (ft)	Length (ft)			
Parapet Wall	8.00	2.00	54.67	=	10.93	kips
Wall Below	8.00	5.25	54.67	=	28.70	kips
			Seismic Weight	**=**	***53.69***	***kips***

Seismic Weight & Base Shear

Base Shear Coefficient	=	0.611	g
Total Seismic Weight	=	54	kips
Design Base Shear	=	33	kips

LIVE LOAD

Roof Live Load	=	30.0	psf

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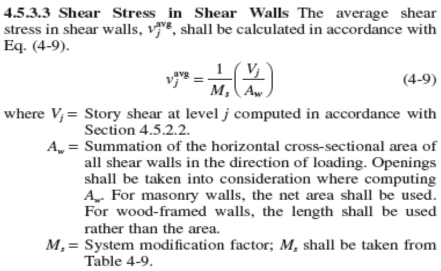
				JOB NO.	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Shear Stress				

SEISMIC LOAD VERTICAL DISTRIBUTION

Wall Shear Stress Check



4.5.3.3 Shear Stress in Shear Walls The average shear stress in shear walls, v_j^{avg}, shall be calculated in accordance with Eq. (4-9).

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{A_w}\right) \tag{4-9}$$

where V_j = Story shear at level j computed in accordance with Section 4.5.2.2.

A_w = Summation of the horizontal cross-sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration where computing A_w. For masonry walls, the net area shall be used. For wood-framed walls, the length shall be used rather than the area.

M_s = System modification factor; M_s shall be taken from Table 4-9.

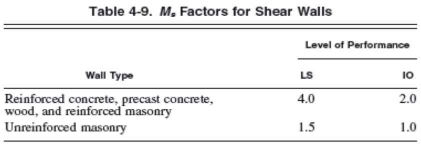


Table 4-9. M_s Factors for Shear Walls

Wall Type	Level of Performance	
	LS	IO
Reinforced concrete, precast concrete, wood, and reinforced masonry	4.0	2.0
Unreinforced masonry	1.5	1.0

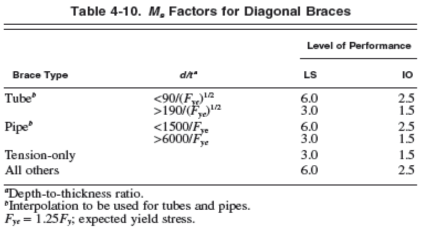


Table 4-10. M_s Factors for Diagonal Braces

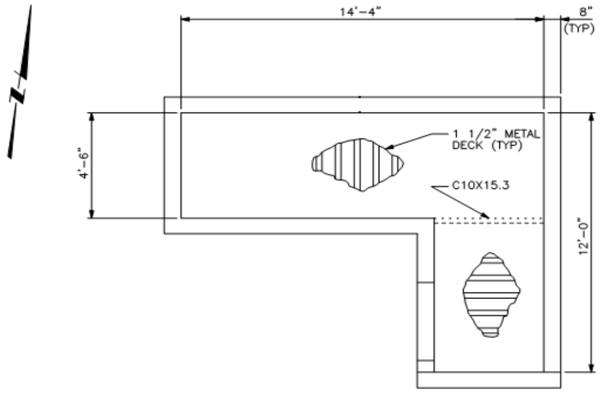
Brace Type	d/t[a]	Level of Performance	
		LS	IO
Tube[b]	$<90/(F_{ye})^{1/2}$	6.0	2.5
	$>190/(F_{ye})^{1/2}$	3.0	1.5
Pipe[b]	$<1500/F_{ye}$	6.0	2.5
	$>6000/F_{ye}$	3.0	1.5
Tension-only		3.0	1.5
All others		6.0	2.5

[a] Depth-to-thickness ratio.
[b] Interpolation to be used for tubes and pipes.
$F_{ye} = 1.25F_y$; expected yield stress.

$v_{s,allow}$ = 126 psi

M_s = 3.0 <-- Damage Control (between "LS" & "IO")

	t_{wall} (in)	$L_{net,\ wall}$ (ft)	A_{wall} (in^2)	*V* *(kips)*	*v_{shear}* *(psi)*	
Walls in NS-Dir	8.00	26.67	2560	*33.00*	*4.30*	***<= OK***
Walls in EW-Dir	8.00	32.34	3105	*33.00*	*3.54*	***<= OK***



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DESIGN TASK	ASCE 41 - Damage Control - Roof Diaph Shear in North-South Direction				

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, K = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

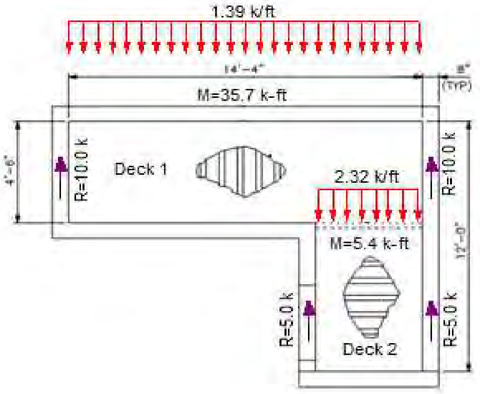
diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

spectral acceleration, S_a = 0.611 g
building seismic weight, W = 35 kips roof seismic wt for diaph in transverse dir

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 30 kips



diaph shear, Q_{UD1} = 2222 plf Deck 1 shear
diaph shear, Q_{UD2} = 667 plf Deck 2 shear
diaph shear, Q_{UD3} = 1250 plf Deck 1+Deck 2 shear
diaph shear, $Q_{UD,max}$ = 2222 plf

allowable diaphragm shear = 1110 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1776 plf
m_1*K*Q_{CE} = 2886 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 4'-6" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

chord force, Q_{UD1} = 7933 lbs
chord force, Q_{UD2} = 720 lbs
chord force, $Q_{UD,max}$ = 7933 lbs

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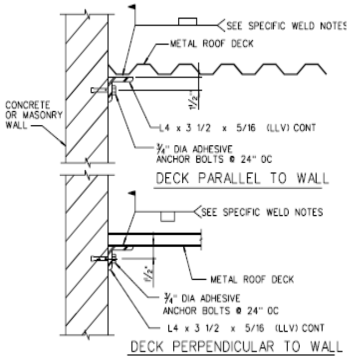
DESIGN TASK	ASCE 41 - Damage Control - Roof Diaph Shear in North-South Direction						

strength reduction factor, ϕ = 1.00
Number of Bars = 2 bars
Bar Size = #5
Yield Stress f_y = 60,000 psi
$A_{s,total}$ = 0.62 in^2
Tensile Capacity at Opng, ϕT_n = 37200 lbs
$m_2 K Q_{CE}$ = 134850 lbs



Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in

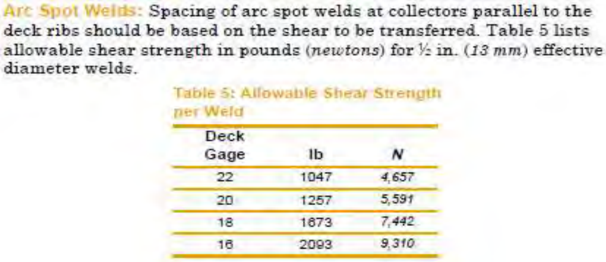
anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

anchor bolt shear, Q_{E1} = 4444 lbs /bolt
anchor bolt shear, Q_{E2} = 1333 lbs /bolt
anchor bolt shear, Q_{E3} = 2500 lbs /bolt
$Q_{UF} = Q_{E,max} / (J*C_1*C_2)$ = 1587 lbs /bolt

projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt
cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

strength reduction factor, ϕ = 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y$ = 15904 lbs /bolt steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

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DESIGN TASK	ASCE 41 - Damage Control - Roof Diaph Shear in North-South Direction				

puddle weld shear, Q_{E1} = 2222 lbs /weld

puddle weld shear, Q_{E2} = 667 lbs /weld

puddle weld shear, Q_{E3} = 1250 lbs /weld

$Q_{UF} = Q_{E,max} / (J^*C_1^*C_2)$ = 794 lbs /weld

allowable strength of weld = 1257 lbs /weld

conversion factor for strength design, C_{WELD} = 1.65 per IAPMO- allowable multiplied by 1.4 for

KQ_{CL} = 2074 lbs /weld

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.77	<--	***OK***	diaphragm shear
demand capcity ratio, DCR =	*0.06*	<--	***OK***	diaphragm chord
demand capcity ratio, DCR =	*0.27*	<--	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.30*	<--	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.07*	<--	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.10*	<--	***OK***	steel yielding
demand capcity ratio, DCR =	0.38	<--	***OK***	puddle weld strength

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CHKD BY **DESCRIPTION** Area 11 - Sludge Thickener **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Roof Diaph Shear in East-West Direction

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, κ = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

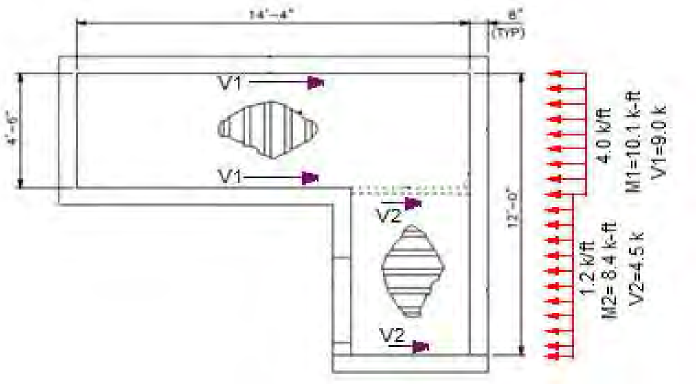
diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

spectral acceleration, S_a = 0.611 g
building seismic weight, W = 32 kips roof seismic wt for diaph in longitudinal dir

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 27 kips



diaph shear, Q_{UD1} = 628 plf Deck 1 shear
diaph shear, Q_{UD2} = 1039 plf Deck 2 shear
diaph shear, $Q_{UD,max}$ = 1039 plf

allowable diaphragm shear = 1110 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1776 plf
$m_1 {}^* \kappa {}^* Q_{CE}$ = 2886 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 4'-6" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

chord force, Q_{UD1} = 705 lbs
chord force, Q_{UD2} = 1940 lbs
chord force, $Q_{UD,max}$ = 1940 lbs

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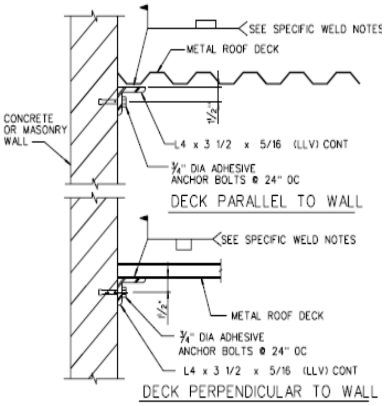
CHKD BY **DESCRIPTION** Area 11 - Sludge Thickener **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Roof Diaph Shear in East-West Direction

strength reduction factor, ϕ = 1.00
Number of Bars = 2 bars
Bar Size = #5
Yield Stress f_y = 60,000 psi
$A_{s,total}$ = 0.62 in^2
Tensile Capacity at Opng, ϕT_n = 37200 lbs
m_2*K*Q_{CE} = 134850 lbs



Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in

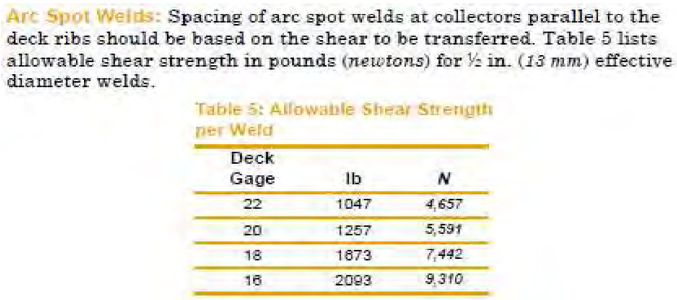
anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

anchor bolt shear, Q_{E1} = 1256 lbs /bolt
anchor bolt shear, Q_{E2} = 2079 lbs /bolt
$Q_{UF} = Q_{E,max} / (J*C_1*C_2)$ = 742 lbs /bolt

projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt
cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

strength reduction factor, ϕ = 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y$ = 15904 lbs /bolt steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddle weld shear, Q_{E1} = 628 lbs /weld
puddle weld shear, Q_{E2} = 1039 lbs /weld
$Q_{UF} = Q_{E,max} / (J*C_1*C_2)$ = 371 lbs /weld

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**		Area 11 - Sludge Thickener		**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 - Damage Control - Roof Diaph Shear in East-West Direction					

allowable strength of weld = 1257 lbs /weld

conversion factor for strength design, C_{WELD} = 1.65 per IAPMO- allowable multiplied by 1.4 for

KQ_{CL} = 2074 lbs /weld

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.36	<--	***OK***	diaphragm shear
demand capcity ratio, DCR =	*0.01*	<--	***OK***	diaphragm chord
demand capcity ratio, DCR =	*0.12*	<--	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.14*	<--	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.03*	<--	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.05*	<--	***OK***	steel yielding
demand capcity ratio, DCR =	0.18	<--	***OK***	puddle weld strength

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DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger					

WALL ANCHORAGE

4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \qquad (4\text{-}13)$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

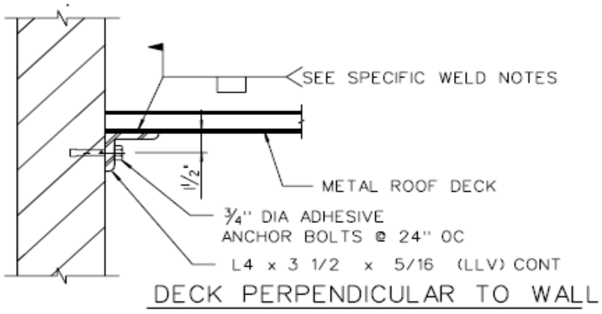
wall thickness, t_w = 8.00 in
wall height to diaphragm, h_w = 10.50 ft
parapet height, h_p = 2.00 ft

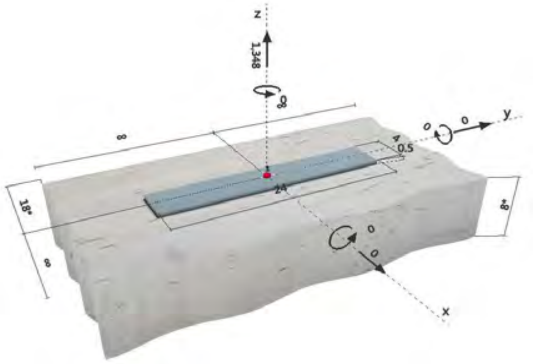
unit weight of wall, w_p = 150.00 pcf
Ψ ("IO") = 1.50 <-- Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

anchor bolt spacing = 24.00 in
wall out-of-plane load = 664 lbs/ ft

wall anchorage force, T_c = 1329 lbs /bolt

Anchor Bolts (Assumed 3.5" Min Embed)





Anchor Bolt Strength Parameters

anchor bolt diameter, d_a = 0.75 in
tensile stress area, A_{se} = 0.33 in^2
anchor bolt embed, h_{ef} = 3.50 in minimum embed assumed

specified anchor bolt strength, f_{uta} = 58,000 psi
concrete strength, f'_c = 4,000 psi

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DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger

k_c = 17.00
λ = 1.00
N_b = 7,040 lbs /bolt

A_{Nc} = 110.25 in^2
A_{Nco} = 110.25 in^2

$\Psi_{ed,N}$ = 1.00
$\Psi_{c,N}$ = 1.00
$\Psi_{CP,N}$ = 1.00

steel strength, N_{sa} = 19,372 lbs /bolt
concrete pullout strength, N_{cb} = 7,040 lbs /bolt
concrete overstrength factor, Ω_{cb} = 2.5 concrete governed

Ledger Angle

yield strength, f_y = 36,000 psi
ledger angle thick, t = 0.31 in
moment arm, l_{arm} = 1.19 in distance from top of ledger to center of AB
effective width, b = 3.00 in
section modulus, S = 0.0488 in^3

shear stress = 1,418 psi

moment = 1,581 lb-in
flexural stress = 32,387 psi

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = *0.07* <-- ***OK*** steel strength
demand capcity ratio, DCR = *0.47* <-- ***OK*** concrete strength

demand capcity ratio, DCR = *0.04* <-- ***OK*** ledger shear
demand capcity ratio, DCR = *0.90* <-- ***OK*** ledger flexural

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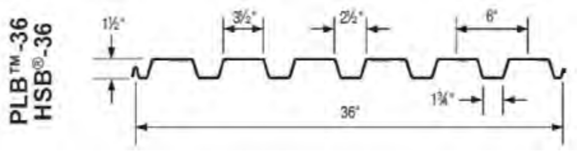
DESIGN TASK			ASCE 41 (Tier 1 Screening "IO") - Wall Anchorage at Metal Deck				

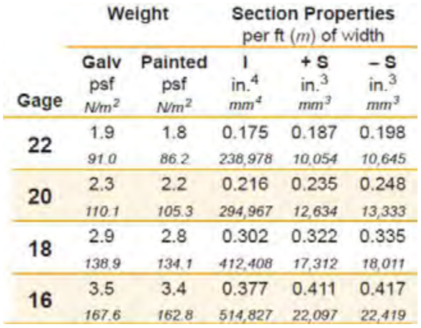
STEEL DECK PROPERTIES (ASTM A653, Grade 33)

Modulus of Elasticity, E = 29500 ksi

Yield Strength, F_y = 38 ksi

Ultimate Strength, F_u = 52 ksi





Gage	Weight Galv psf *N/m²*	 Painted psf *N/m²*	Section Properties per ft (*m*) of width I in.⁴ *mm⁴*	 + S in.³ *mm³*	 – S in.³ *mm³*
22	1.9 *91.0*	1.8 *86.2*	0.175 *238,978*	0.187 *10,054*	0.198 *10,645*
20	2.3 *110.1*	2.2 *105.3*	0.216 *294,967*	0.235 *12,634*	0.248 *13,333*
18	2.9 *138.9*	2.8 *134.1*	0.302 *412,408*	0.322 *17,312*	0.335 *18,011*
16	3.5 *167.6*	3.4 *162.8*	0.377 *514,827*	0.411 *22,097*	0.417 *22,419*

Steel Deck = HSB-36

Gage = 20

Deck Span, L = 5.67 ft

DESIGN LOAD (Service Level)

Roof Load, w = 30 psf *--- steel deck gravity*

Wall Out-of-Plane Load, F = 664 lb/ft *--- deck axial load*

Design Flexural Moment :

Neutral Axis, y_b = 0.919 in

M_{roof} = 1.447 kip-in /ft *--- moment due to gravity load = w * L2 / 8*

M_{ecc} = 0.436 kip-in /ft *--- moment due to wall out-of-plane = (F/1.4) * yb*

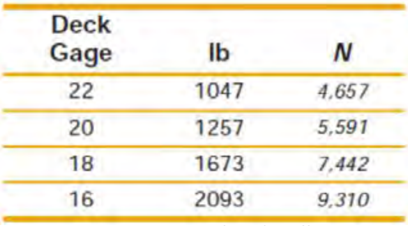
M_{total} = 1.883 kip-in /ft

ARC-SPOT WELD (WALL OUT-OF-PLANE)

Effective Weld Size Dia, d_e = 1/2 in

Weld Pattern = 5 per 36/sheet

Allowable Weld Capacity = 2.10 kip/ft **<= OK**



Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

Allowable shear strength for 1/2" effective diameter puddle welds.

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CHKD BY **DESCRIPTION** Area 11 - Sludge Thickener **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "IO") - Wall Anchorage at Metal Deck

STEEL DECK ALLOWABLE COMPRESSION

Effective Length Factor, K = 1.00

Deck Thickness, t = 0.0359 in

Width of Top Flange, w = 3.50 in

Gross Section Area, A_g = 0.599 in^2/ft

radius of gyration, r = 0.601 in

KL/r = 113

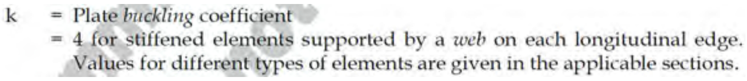
λ_c = 1.29

F_n = 18.85 ksi

Effective Width of Top & Bottom Flange Under Compression
(Assume Bottom Flange Fully Effective)

Ω_c = 1.8 --- *factor of safety*

k = 4



k = Plate *buckling* coefficient
= 4 for stiffened elements supported by a *web* on each longitudinal edge. Values for different types of elements are given in the applicable sections.

Poisson's Ratio = 0.300

F_{cr} = 11.22

λ = 1.296

ρ = 0.641

Effective Flange Width, b = 2.242 in --- *effective flange width = ρw*

Effective Section Area, A_e = 0.554 in^2/ft --- *effective section area*

P_n / Ω_c = 5.80 kip /ft **<= OK** --- $A_e * F_n / \Omega_c$

STEEL DECK ALLOWABLE TENSION

Gross Section Area, A_g = 0.599 in^2/ft

Ω_{T1} = 1.67

T_{n1} / Ω_{T1} = 13.63 kip /ft **<= OK** --- $A_g * F_y / \Omega_{T1}$

Ω_{T2} = 2.00

T_{n2} / Ω_{T2} = 15.57 kip /ft **<= OK** --- $A_g * F_u / \Omega_{T2}$

STEEL DECK ALLOWABLE BENDING

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CHKD BY		**DESCRIPTION**			Area 11 - Sludge Thickener	**JOB NO.**	10721A.00
DESIGN TASK					ASCE 41 (Tier 1 Screening "IO") - Wall Anchorage at Metal Deck		

Ω_b = 1.67

S_+ = 0.235 in^3/ft --- *positive section modulus*

M_n / Ω_b = 5.35 kip-in /ft **<= OK** --- $S_+ * F_y / \Omega_b$

COMBINED LOAD INTERACTION

Bending-Tension Interaction:

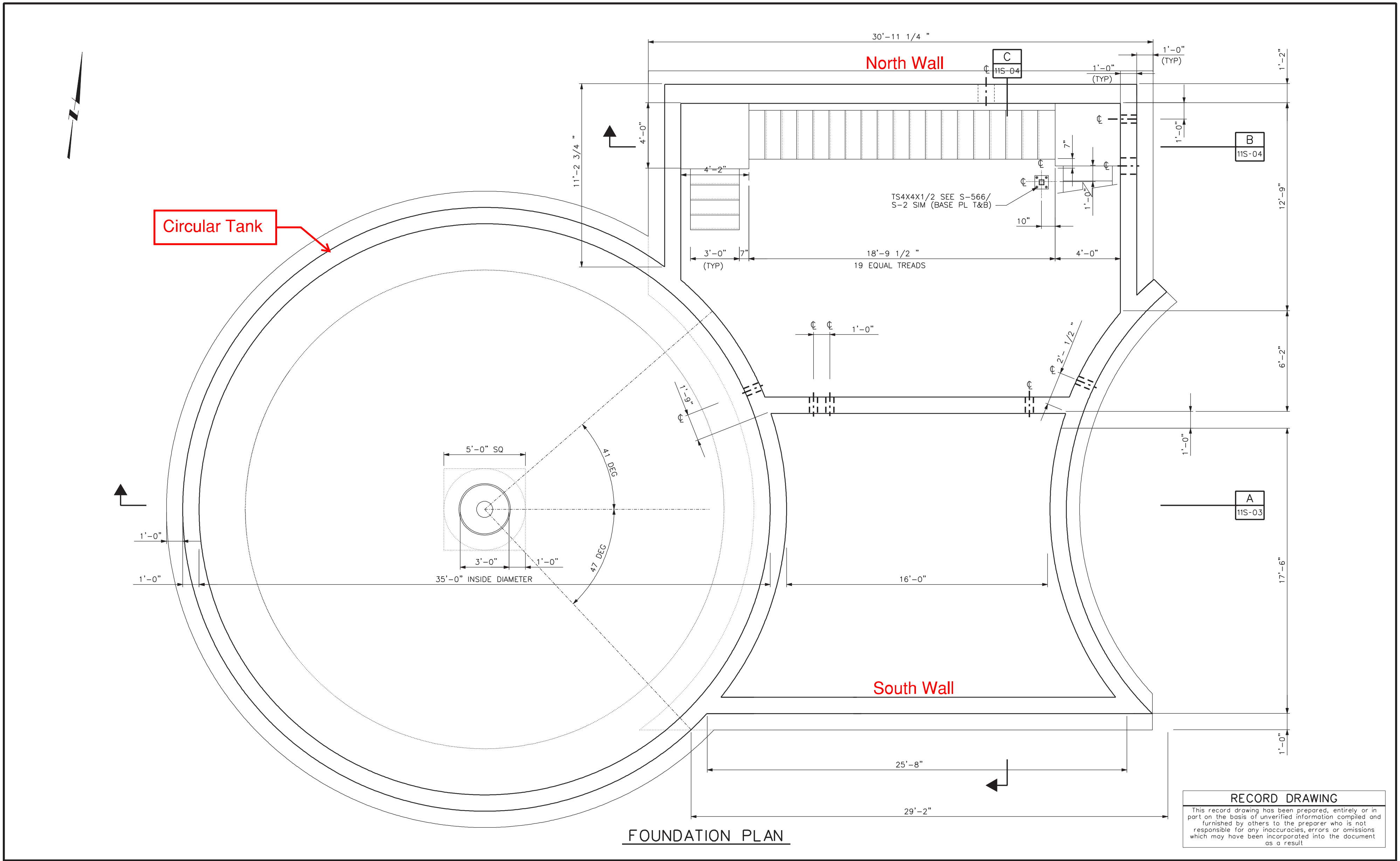
DCR = 0.401 **<= OK**

Bending-Compression Interaction:

DCR = 0.467 **<= OK**

Area 11 - Sludge Thickener Concrete Structures
ACI 350 Evaluation

WALL IDENTIFICATION



FOUNDATION PLAN

RECORD DRAWING

This record drawing has been prepared, entirely or in part on the basis of unverified information compiled and furnished by others to the preparer who is not responsible for any inaccuracies, errors or omissions which may have been incorporated into the document as a result

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REV	DATE	BY	DESCRIPTION
R	12-02	AP	RECORD DRAWING

SCALE
3/8"=1'-0"

WARNING
0 ½ 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

DESIGNED B. CROOK
DRAWN B. CROOK
CHECKED

SUBMITTED BY
LICENSE NO. DATE
LICENSE NO. DATE

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Oregon

City of
WILSONVILLE
in OREGON

CITY OF WILSONVILLE
WILLAMETTE RIVER WATER TREATMENT PLANT
SLUDGE THICKENER
STRUCTURAL
FOUNDATION PLAN

SHEET
11S-01

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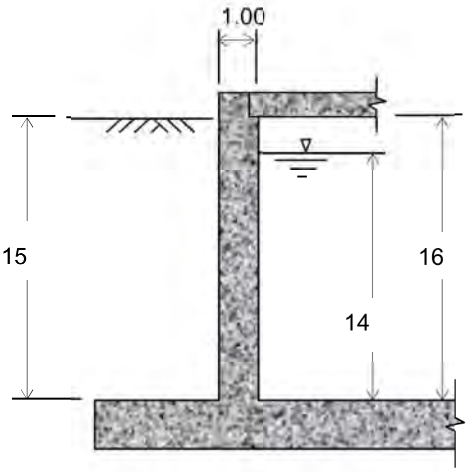
BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: Wall Pressures

Static, Seismic, and Hydrodynamic Seismic Wall Pressures using ACI 350.3-06 and an IBC 2012:

wall connection fixity = **pinned at roof & fixed at floor**

tank unit width perpendicular to EQ., B = 1 ft
tank inside length in direction of seismic, L = **18.5** ft
tank wall thickness, t_w = **12** inch
wall height to underside of roof, H_w = **16** ft

liquid height, H_L = **14** ft
liquid specific gravity = **1**
liquid density, $\gamma_L = (\text{sp.gr.})*\gamma_w$ = 0.0624 k/ft^3
acceleration due to gravity, g = 32.17 ft/sec^2
liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$



WALL SECTION
(wall fixity = pinned at roof & fixed at floor)

Soil Data

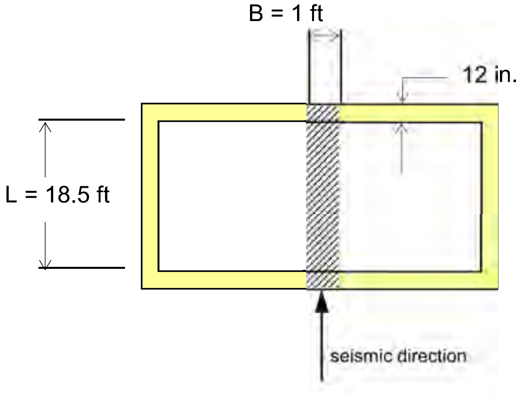
The site has no groundwater.

soil height above top of foundation base = **15** ft
groundwater ht. above foundation base = **0** ft
dry soil lateral pressure = **0.055** k/ft^3
saturated soil lateral pressure = **0** k/ft^3
dry soil unit weight = **0.11** k/ft^3
live load lateral surcharge = **0.100** ksf
0
concrete strength, f'_c = **4** ksi
concrete density, γ_c = 0.150 k/ft^3
concrete modulus of elasticity, E_c = 3605.0 ksi
concrete mass density, $\rho_c = \gamma_c / g$ = 0.004663 $k\text{-}sec^2/ft^4$

Seismic:

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g
Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

Structure Risk Category = **3**
Importance factor, I = **1.25**
Response modification factor, R_{wi} = **2.72**
Response modification factor, R_{wc} = **1.27**



WALL PLAN

Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

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CHKD:		**DESCRIPTION:**			Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:					Wall Pressures		

Weights:

unit 1-ft width wall mass, W_w = (12/12) * (16) * 0.15 = 2.40 kip
wall c.g. relative to base, h_w = 16 / 2 = 8.000 ft

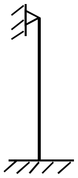
unit width liquid mass, W_L = (18.5) * (1) * (14) * 32.17 = 16.16 kip

Seismic:

1). structure stiffness and dynamic property:

Note: per ASCE 7-10 and IBC 2012, the terms S_{ai} and S_{ac} have been appropriatetly substituted into the seismic equation of ACI 350.

Note: Wi and hi are impulsive component variables calculated on page 3.
wall mass, $m_w = H_w*(t_w / 12)*\rho_c$ = 0.07460 $\text{k-sec}^2/\text{ft}^2$
liquid mass, $m_i = (W_i / W_L)*(L/2)*H_L*\rho_L$ = 0.17907 $\text{k-sec}^2/\text{ft}^2$
centroidal distance of masses, $h = (h_w*m_w + h_i*m_i) / (m_w + m_i)$ = 6.07 ft



wall fixity condition is pinned at roof & fixed at floor:
wall stiffness is determined using a unit mass load located at the centroidal distance h.
wall flexure stiffness, k = Ec*(tw*Hw/h)³ / (12*(4*Hw-h)*(Hw-h)²) = 1664.41 k/ft/ft

$$\omega_i = \sqrt{\frac{k}{m_w + m_i}} = \quad (1664.41 / (0.0746 + 0.1791))\hat{}½ = 81.0018 \text{ rad/sec}$$

period of tank plus impulsive mass, $T_i = 2\pi / \omega_i$ = 2 π / 81.0018 = 0.0776 sec

(note: acceleration values to be from a maximum considered earthquake response spectra which will produce a factored load)
design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

2). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$\lambda = \sqrt{3.16\ g\ \tanh\left(3.16\left(\frac{H_L}{L}\right)\right)} = \quad (3.16*32.2*\tanh(3.16*(0.7568)))\hat{}½ = 9.9984$$

$$\omega_c = \frac{\lambda}{\sqrt{L}} = \quad 9.9984 / (18.5)\hat{}½ = 2.3246 \text{ rad/sec,}$$

period of the convective mass, $T_c = 2\pi / \omega_c$ = 2 π / 2.3246 = 2.7029 sec
Long transition period (from map figure 22-15 ASCE 7), T_L = **16** sec
design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.364 g

$$\text{effective mass coeff., } \varepsilon = 0.0151\left(\frac{L}{H_L}\right)^2 - 0.1908\left(\frac{L}{H_L}\right) + 1.021\ ,\quad \text{but} \le 1.0 = \quad 0.7952$$

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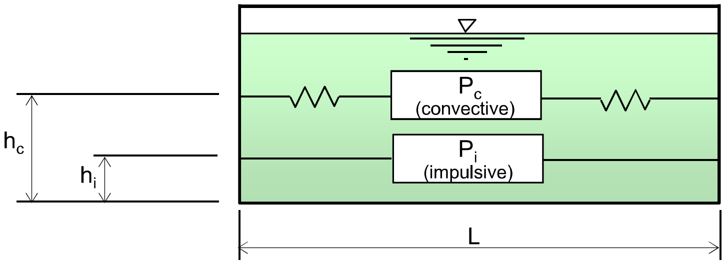
DESIGN TASK:	Wall Pressures				



Dynamic Model

L =	18.5	ft
B =	1	ft
H_L =	14	ft
W_L =	16.16	kip
L / H_L =	1.32143	
H_L / L =	0.75676	

3). lateral fluid impulsive force:

Wi = equivalent mass of the impulsive component of liquid.

$$W_i = W_L\left(\frac{\tanh\left(0.866\frac{L}{H_L}\right)}{0.866\frac{L}{H_L}}\right) =$$ 16.16*(tanh(0.866*(1.3214)) / 0.866*(1.3214)) = 11.52 kip

hi (EBP) = HL * (0.5-0.09375*(L/HL)) = 14*(0.5-0.09375*(1.3214)) = 5.266 ft

hi (IBP) = HL * {{(0.866*L/HL)/(2*tanh(0.866*L/HL))} -1/8 } = 8.068 ft

$$\text{impulsive force, } P_i = \left(\frac{S_{ai}\ I}{R_{wi}}\right)W_i =$$ (0.611 * 1.25 / 2.72)*11.52 = 3.2 kip

4). lateral fluid convective force:

Wc = equivalent mass of the convective component of liquid.

$$W_c = W_L\left(0.264\left(\frac{L}{H_L}\right)\tanh\left(3.16\left(\frac{H_L}{L}\right)\right)\right) =$$ 16.16*(0.264*(1.3214)*tanh(3.16*(0.7568))) = 5.54 kip

$$h_{c\ (EBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 1}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 9.127 ft

$$h_{c\ (IBP)} = H_L\left(1 - \frac{\cosh\left(3.16\left(\frac{H_L}{L}\right)\right) - 2.01}{3.16\left(\frac{H_L}{L}\right)\sinh\left(3.16\left(\frac{H_L}{L}\right)\right)}\right) =$$ 10.218 ft

$$\text{convective force,} P_c = \left(\frac{S_{ac}\ I}{R_{wc}}\right)W_c =$$ (0.3641 * 1.25 / 1.27)*5.54 = 2.0 kip

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CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: Wall Pressures

5). lateral inertia force of the accelerating wall:

unit width wall mass, W_w = 2.40 kip
wall c.g. relative to base, h_w = 8.000 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_{wi}}\right) W_w = \quad (0.611*1.25*0.7952/2.72)*2.4 = \quad 0.54 \text{ kip}$$

6). maximum wave slosh height displacement:

$$d_{(max)} = \left(\frac{L}{2}\right)\left(\frac{S_{ac}}{1.4}\ I\right) = \quad (18.5/2)*(0.3641/1.4*1.25) = \quad 3.01 \text{ ft}$$

Wave height is greater than the freeboard of 2-ft. Check possible effects on the roof.

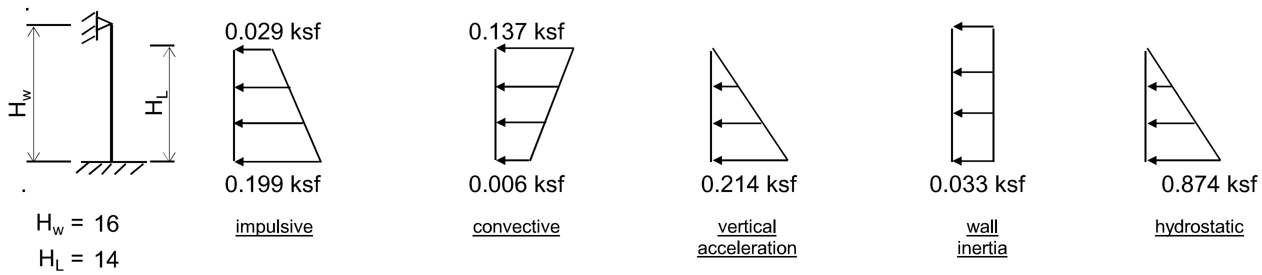
7). vertical acceleration:

design horizontal accereration, S_{DS} = 0.611 *g
vertical spectral response acceleration (per ACI 350 para 9.4.3), $S_{av} = C_t = 0.4*S_{DS}$ = 0.2444 g

per ASCE 7-10 para. 15.7.7.2(b), use $I = R_i = b = 1.0$

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.2444*1*1/1 = \quad 0.2444 \text{ g}$$

8). vertical force distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



impulsive:

$$p_{iy} = \frac{P_i\left[4H_L - 6h_i - (6H_L - 12h_i)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_i = 3.20 kip
h_i = 5.266 ft
at $y = H_L$, p_{iy} = 0.029 ksf
at base $y = 0$, p_{iy} = 0.199 ksf

convective:

$$p_{cy} = \frac{P_c\left[4H_L - 6h_c - (6H_L - 12h_c)\left(\frac{y}{H_L}\right)\right]}{2\ B\ H_L^2} =$$

P_c = 2.00 kip
h_c = 9.127 ft
at $y = H_L$, p_{cy} = 0.137 ksf
at base $y = 0$, p_{cy} = 0.006 ksf

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BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: Wall Pressures

vertical acceleration:

$p_{vy} = \ddot{u}\,\gamma_L\,(H_L - y) =$

ü = 0.2444
at y = H_L, p_{vy} = 0.000 ksf
at base y = 0, p_{vy} = 0.214 ksf

wall inertia:

$$p_{wy} = \frac{S_{ai}\ \mathrm{I}\ \varepsilon\,\gamma_c\,(t_w/12)}{R_{wi}} =$$

p_{wy} = 0.2233 * γ_c * (t_w/12)
at y = H_w, p_{wy} = 0.033 ksf
at base y = 0, p_{wy} = 0.033 ksf

hydrostatic:

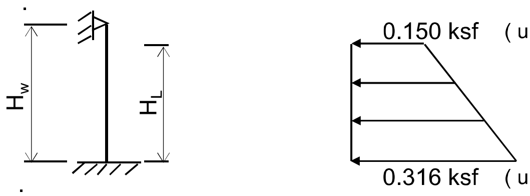
$q_{hy} = \gamma_L\,(H_L - y) =$

at y = H_L, q_{hy} = 0.000 ksf
at base y = 0, q_{hy} = 0.874 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{(p_{iy} + p_{wy})^2 + p_{cy}^2 + p_{vy}^2} =$$

at y = H_w, p_y = 0.150 ksf
at base y = 0, p_y = 0.316 ksf



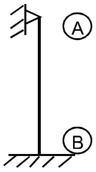
(unfactored = 0.15 / 1.4 = 0.107 ksf)

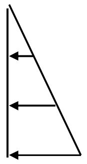
(unfactored = 0.316 / 1.4 = 0.226 ksf)

resultant dynamic pressures

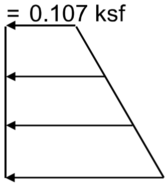
9). wall design pressures for hydrostatic + dynamic:

wall height, H_w = 16 ft
liquid height, H_L = 14 ft





0.874 ksf
hydrostatic



unfactored load = 0.107 ksf

unfactored load = 0.226 ksf

resultant dynamic pressures

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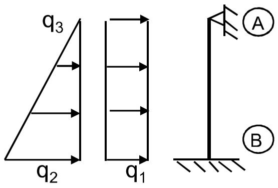
BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:	Wall Pressures				

10). wall design pressures for external soil loading:

static soil:



The site has no groundwater.

wall height = 16 ft

soil height above top of base = 15 ft

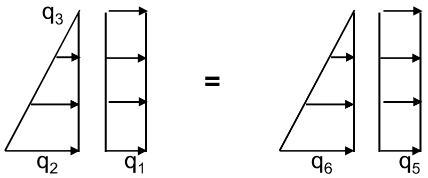
groundwater ht. above base = 0 ft

dry soil lateral pressure = 0.055 k/ft^3

sat. soil lateral pressure = 0.000 k/ft^3

live load lateral surcharge = 0.100 ksf

equivalent static soil loadings:



LL lateral surcharge, q1 = 0.1000 ksf

unfactored soil, q2 = 0.8250 ksf

unfactored soil, q3 = 0.0000 ksf

equivalent soil loadings:

unfactored q5 = 0.1000 ksf

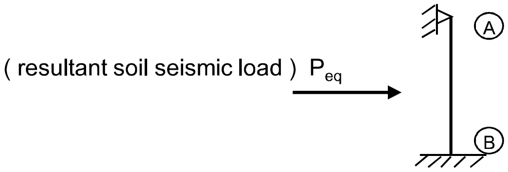
unfactored q6 = 0.8250 ksf

soil seismic:

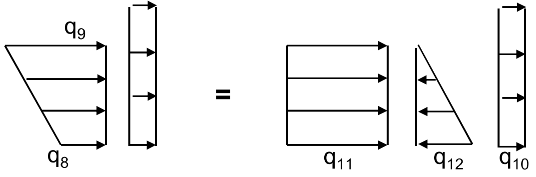
resultant factored soil seismic load per foot of wall width, $P_{u\,(eq)}$ = **3.825** k/ft

centroid location of the resultant soil seismic from the bottom of wall, h_{eq} = **10** ft

The resultant soil seismic load will be resolved into an equivalent pressure loading…



Equivalent factored seismic soil pressure loading & seismic wall loadings…



equivalent soil seismic, q8 = 0.0000 ksf

equivalent soil seismic, q9 = 0.5100 ksf

wall seismic (see wall page 5), q10 = 0.0335 ksf

equivalent soil seismic, q11 = q9 = 0.5100 ksf

equivalent soil seismic, q12 = q8 - q9 = -0.5100 ksf

unfactored equivalent soil seismic, q8 =0 / 1.4 = 0.0000 ksf

unfactored equivalent soil seismic, q9 =0.51 / 1.4 = 0.3643 ksf

unfactored wall seismic , q10 = 0.0335 / 1.4 = 0.0239 ksf

unfactored equivalent soil seismic, q11 =0.51 / 1.4 = 0.3643 ksf

unfactored equivalent soil seismic, q12 =-0.51 / 1.4 = -0.3643 ksf

BY:	C. Che	**DATE:** Sep-17	**CLIENT:** Willamette River WTP	**SHEET:**	
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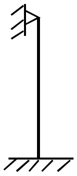
DESIGN TASK:			Wall Pressures		

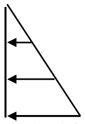
11). Summary of equivalent unfactored pressure loadings for wall load cases 1 thru 4:



Load Cases:
case 1 = water
case 2 = water + water seismic + wall seismic
case 3 = soil + lateral surcharge
case 4 = soil + soil seismic + wall seismic

a). load case 1: hydrostatic water

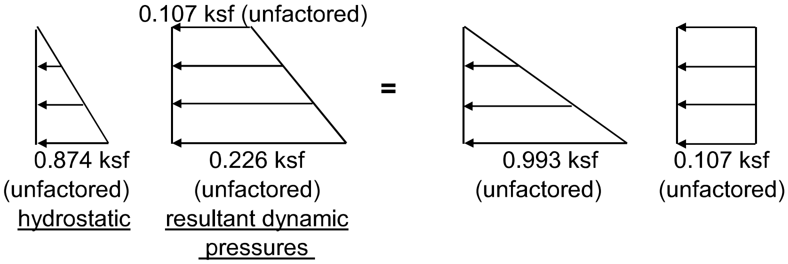
wall height = 16 ft
water depth = 14 ft



(unfactored) 0.874 ksf

b). load case 2: hydrostatic + dynamic:

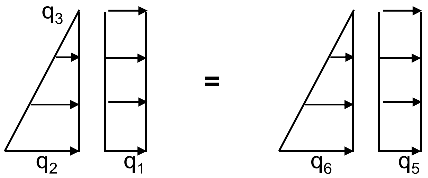
wall height = 16 ft
water depth = 14 ft



c). load case 3: static soil + LL surcharge:

wall height = 16 ft
soil height on wall = 15 ft

equivalent static soil & surcharge loadings...



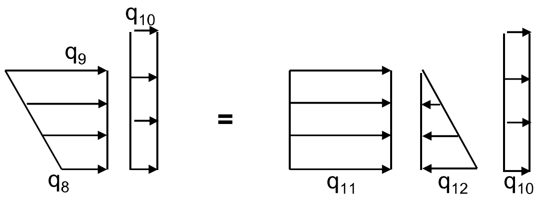
LL lateral surcharge, q1 =	0.100	ksf
unfactored soil, q2 =	0.825	ksf
unfactored soil, q3 =	0.000	ksf

equivalent soil loadings:

unfactored q5 =	0.100	ksf
unfactored q6 =	0.825	ksf

d). load case 4: soil seismic: (*note: add static soil pressure q6 & q7 to the seismic soil shown below)
equivalent seismic soil pressure loading & seismic wall loadings…

wall height = 16 ft
soil height on wall = 15 ft



unfactored equivalent soil seismic, q8 =	0.000	ksf
unfactored equivalent soil seismic, q9 =	0.364	ksf
unfactored equivalent soil seismic, q10 =	0.024	ksf
unfactored equivalent soil seismic, q11 =	0.364	ksf
unfactored equivalent soil seismic, q12 =	-0.364	ksf

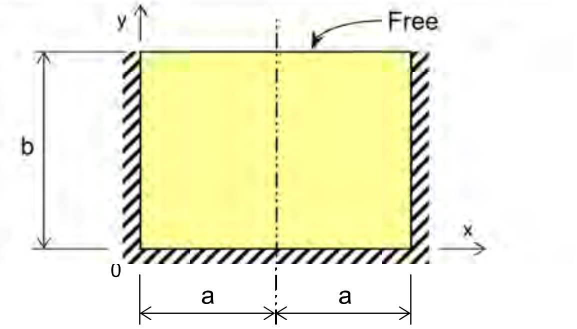
BY:	C. Che	**DATE:** Aug-17	**CLIENT** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:			North Exterior Wall - Soil EQ		

Rectangular Plate:

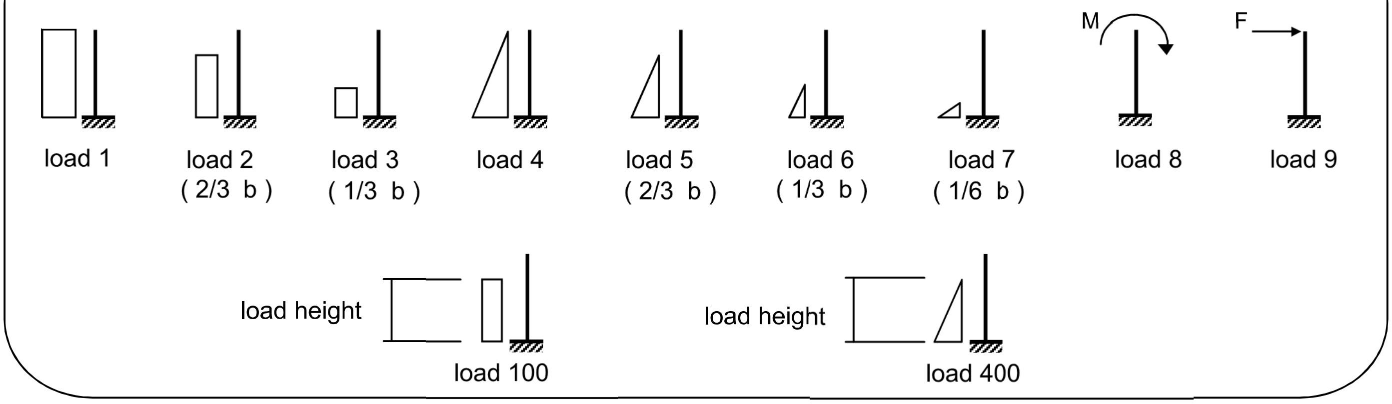
plate boundary condition case number (1, 2, 3, 4, or 5) = **1**

total plate width = 2*a = 2 * 14.5 = 29 ft
plate dimension, a = **14.5** ft
plate dimension, b = **17** ft

plate sides ratio, a/b = 0.8529



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , M , or F (ksf, ft-k/ft, k/ft)	concrete load factors for moment	for shear
A	**400**	**15.000**	**0.825**	**1.6**	**1.6**
B	**100**	**15.000**	**0.364**	**1.4**	**1.4**
C	**400**	**15.000**	**-0.364**	**1.4**	**1.4**
D	**1**		**0.025**	**1.4**	**1.4**

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **14** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00300**
minimum ratio of vertical shrinkage-temperature steel = **0.00300**

bar locations	d (in)	d' (in)
Mx bending	11"	3"
My bending	11.5"	2.5"

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: North Exterior Wall - Soil EQ

M_x - Moment Summary

a = 14.5
b = 17
a / b = 0.8529

	Loads: q , M , or F			
Loads	0.825	0.364	-0.364	0.025
Moment Coefficient Multipliers	238.425	105.196	-105.196	7.225

Boundary Case 1

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 11")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0350	0.1466	0.0350	0.2141	8.35	15.42	-3.68	1.55	21.63	31.95	0.68	0.44
0	0.8	0.0367	0.1327	0.0367	0.1815	8.74	13.96	-3.86	1.31	20.16	29.97	0.63	0.44
0	0.6	0.0360	0.1105	0.0360	0.1366	8.58	11.62	-3.78	0.99	17.40	26.08	0.55	0.44
0	0.4	0.0302	0.0755	0.0302	0.0853	7.19	7.95	-3.17	0.62	12.58	19.05	0.40	0.44
0	0.2	0.0143	0.0281	0.0143	0.0298	3.41	2.96	-1.50	0.22	5.08	7.79	0.16	0.25
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
0.2	0	0.0032	0.0053	0.0032	0.0054	0.76	0.56	-0.33	0.04	1.02	1.58	0.03	0.25
0.4	0	0.0068	0.0136	0.0068	0.0147	1.63	1.43	-0.72	0.11	2.45	3.75	0.08	0.25
0.6	0	0.0096	0.0208	0.0096	0.0232	2.29	2.19	-1.01	0.17	3.63	5.55	0.11	0.25
0.8	0	0.0112	0.0254	0.0112	0.0288	2.68	2.67	-1.18	0.21	4.37	6.66	0.14	0.25
1	0	0.0118	0.0269	0.0118	0.0307	2.81	2.83	-1.24	0.22	4.62	7.03	0.14	0.25
1	0.2	-0.0019	-0.0023	-0.0019	-0.0018	-0.46	-0.24	0.20	-0.01	-0.52	-0.82	-0.02	-0.25
1	0.4	-0.0110	-0.0290	-0.0110	-0.0335	-2.62	-3.05	1.16	-0.24	-4.75	-7.18	-0.15	-0.25
1	0.6	-0.0152	-0.0474	-0.0152	-0.0591	-3.62	-4.99	1.60	-0.43	-7.43	-11.13	-0.23	-0.30
1	0.8	-0.0167	-0.0579	-0.0167	-0.0776	-3.98	-6.09	1.75	-0.56	-8.87	-13.21	-0.27	-0.36
1	1	-0.0177	-0.0657	-0.0177	-0.0911	-4.22	-6.91	1.86	-0.66	-9.93	-14.75	-0.30	-0.41
0.8	1	-0.0158	-0.0594	-0.0158	-0.0827	-3.77	-6.25	1.66	-0.60	-8.95	-13.28	-0.27	-0.36
0.8	0.8	-0.0151	-0.0526	-0.0151	-0.0705	-3.60	-5.53	1.59	-0.51	-8.05	-11.99	-0.25	-0.33
0.8	0.6	-0.0141	-0.0436	-0.0141	-0.0540	-3.36	-4.59	1.48	-0.39	-6.86	-10.27	-0.21	-0.28
0.8	0.4	-0.0105	-0.0272	-0.0105	-0.0310	-2.51	-2.86	1.11	-0.22	-4.48	-6.78	-0.14	-0.25
0.8	0.2	-0.0021	-0.0024	-0.0021	-0.0018	-0.50	-0.25	0.22	-0.01	-0.55	-0.87	-0.02	-0.25

max negative moment, $M_{ux}(-)$ = -14.75 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.30 in^2/ft
minimum steel req'd = -0.41 in^2/ft
Use #8@12" (Existing)

max positive moment, $M_{ux}(+)$ = 31.95 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.68 in^2/ft
minimum steel req'd = 0.44 in^2/ft
Use #8@6" (Existing)

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BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: North Exterior Wall - Soil EQ

M_y - Moment Summary

a = 14.5
b = 17
a / b = 0.8529

Loads: q , M , or F	0.825	0.364	-0.364	0.025
Moment Coefficient Multipliers	238.425	105.196	-105.196	7.225

Boundary Case 1

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 11.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
0	0.8	0.0074	0.0265	0.0074	0.0363	1.75	2.79	-0.77	0.26	4.03	5.99	0.12	0.25
0	0.6	0.0072	0.0221	0.0072	0.0273	1.72	2.32	-0.76	0.20	3.48	5.21	0.10	0.25
0	0.4	0.0060	0.0151	0.0060	0.0170	1.44	1.59	-0.64	0.12	2.52	3.82	0.07	0.25
0	0.2	0.0029	0.0056	0.0029	0.0060	0.69	0.59	-0.30	0.04	1.02	1.57	0.03	0.25
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
0.2	0	0.0159	0.0267	0.0159	0.0272	3.78	2.81	-1.67	0.20	5.12	7.92	0.15	0.25
0.4	0	0.0342	0.0681	0.0342	0.0737	8.15	7.16	-3.60	0.53	12.25	18.78	0.37	0.46
0.6	0	0.0479	0.1039	0.0479	0.1160	11.43	10.94	-5.04	0.84	18.16	27.71	0.56	0.46
0.8	0	0.0561	0.1269	0.0561	0.1440	13.37	13.35	-5.90	1.04	21.86	33.28	0.67	0.46
1	0	0.0588	0.1347	0.0588	0.1536	14.01	14.17	-6.18	1.11	23.11	35.16	0.71	0.46
1	0.2	0.0044	0.0308	0.0044	0.0434	1.06	3.24	-0.47	0.31	4.14	6.01	0.12	0.25
1	0.4	-0.0136	-0.0180	-0.0136	-0.0080	-3.23	-1.90	1.43	-0.06	-3.76	-5.91	-0.12	-0.25
1	0.6	-0.0124	-0.0296	-0.0124	-0.0257	-2.95	-3.11	1.30	-0.19	-4.95	-7.52	-0.15	-0.25
1	0.8	-0.0056	-0.0174	-0.0056	-0.0218	-1.34	-1.83	0.59	-0.16	-2.74	-4.10	-0.08	-0.25
1	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
1	0.4	-0.0136	-0.0180	-0.0136	-0.0080	-3.23	-1.90	1.43	-0.06	-3.76	-5.91	-0.12	-0.25
0.8	0.4	-0.0131	-0.0174	-0.0131	-0.0077	-3.12	-1.83	1.38	-0.06	-3.63	-5.70	-0.11	-0.25
0.6	0.4	-0.0114	-0.0149	-0.0114	-0.0063	-2.72	-1.57	1.20	-0.05	-3.14	-4.94	-0.10	-0.25
0.4	0.4	-0.0081	-0.0096	-0.0081	-0.0027	-1.92	-1.01	0.85	-0.02	-2.10	-3.32	-0.06	-0.25
0.2	0.4	-0.0021	0.0003	-0.0021	0.0047	-0.51	0.03	0.23	0.03	-0.22	-0.41	-0.01	-0.25

max negative moment, $M_{uy}(-)$ = -7.52 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.15 in^2/ft
minimum steel req'd = -0.25 in^2/ft
Use #5@12" (Existing)

max positive moment, $M_{uy}(+)$ = 35.16 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.71 in^2/ft
minimum steel req'd = 0.46 in^2/ft
Use #6@6" (Existing)

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: North Exterior Wall - Soil EQ

Shear Summary

a = 14.5
b = 17
a / b = 0.8529

Loads: q , M , or F			
0.825	0.364	-0.364	0.025
Shear Coefficient Multipliers			
14.025	6.188	-6.188	0.425

Boundary Case 1

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	0.0815	0.5876	0.0815	1.0039	1.14	3.64	-0.50	0.43	4.70	6.81	13.09
0	0.8	0.1587	0.6077	0.1587	0.8663	2.23	3.76	-0.98	0.37	5.37	7.97	13.09
0	0.6	0.1887	0.5637	0.1887	0.6208	2.65	3.49	-1.17	0.26	5.23	7.85	13.09
0	0.4	0.2253	0.4546	0.2253	0.4291	3.16	2.81	-1.39	0.18	4.76	7.30	13.09
0	0.2	0.1295	0.1184	0.1295	0.0877	1.82	0.73	-0.80	0.04	1.78	2.86	13.09
0	0.00	-0.0151	-0.0726	-0.0151	-0.0814	-0.21	-0.45	0.09	-0.03	-0.60	-0.89	13.09
0.2	0	0.1510	0.1259	0.1510	0.0950	2.12	0.78	-0.93	0.04	2.00	3.23	13.09
0.4	0	0.2793	0.3924	0.2793	0.3830	3.92	2.43	-1.73	0.16	4.78	7.48	13.09
0.6	0	0.3480	0.5705	0.3480	0.5911	4.88	3.53	-2.15	0.25	6.51	10.09	13.09
0.8	0	0.3815	0.6680	0.3815	0.7103	5.35	4.13	-2.36	0.30	7.43	11.47	13.09
1	0	0.3915	0.6988	0.3915	0.7487	5.49	4.32	-2.42	0.32	7.71	11.89	13.09

Concrete strength reduction factor for shear, ϕ = 0.75

d = 11.5 in
maximum shear, V_u = 11.89 k/ft **OK**
$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d =$ (0.75*2*(4000)ˆ½ *12*11.5)/1000 = 13.09 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

carollo
Engineers...Working Wonders With Water™

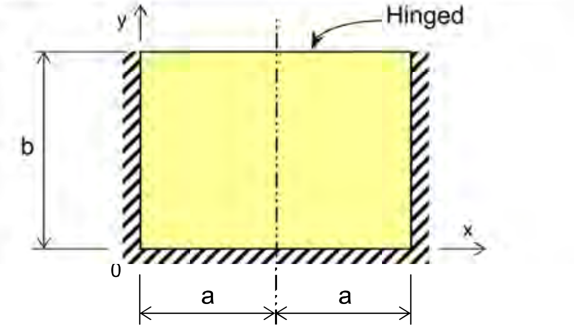
BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:					South Exterior Wall - Hydrostatic		

Rectangular Plate:

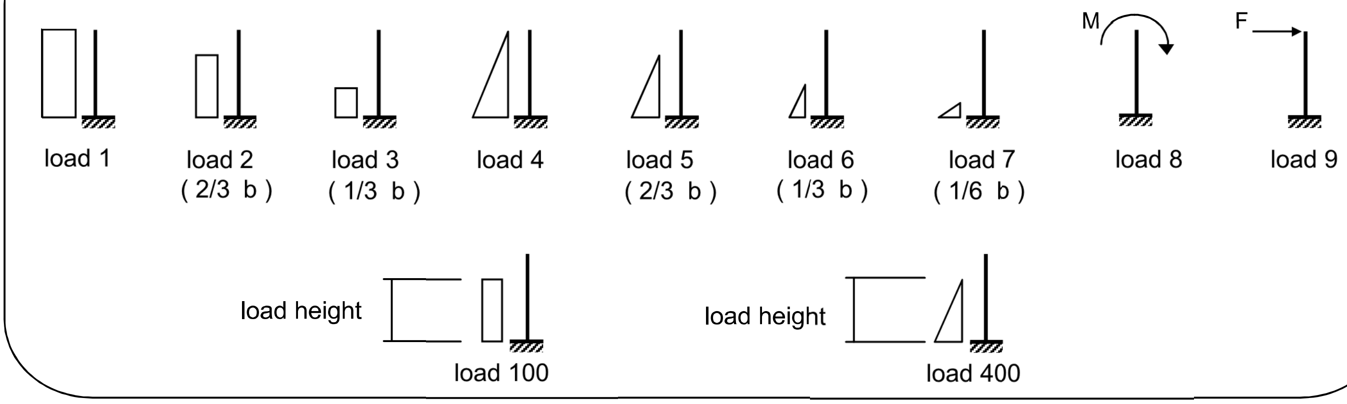
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 12.84 = 25.68 ft
plate dimension, a = **12.84** ft
plate dimension, b = **16** ft

plate sides ratio, a/b = 0.8025



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**14.000**	**0.874**	**2.25**	**1.4**
B					
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00300**
minimum ratio of vertical shrinkage-temperature steel = **0.00300**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

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Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Hydrostatic

M_x - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

Loads: q , or M: 0.874
Moment Coefficient Multipliers: 223.744

Boundary Case 2

		Moment Coefficients				M_x Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.22
0	0.8	0.0137				3.07				3.07	6.91	0.17	0.23
0	0.6	0.0239				5.35				5.35	12.05	0.31	0.36
0	0.4	0.0256				5.72				5.72	12.87	0.33	0.36
0	0.2	0.0137				3.08				3.08	6.92	0.17	0.23
0	0	0.0000				0.00				0.00	0.00	0.00	0.22
0.2	0	0.0029				0.64				0.64	1.44	0.04	0.22
0.4	0	0.0059				1.31				1.31	2.96	0.07	0.22
0.6	0	0.0079				1.76				1.76	3.97	0.10	0.22
0.8	0	0.0090				2.02				2.02	4.55	0.11	0.22
1	0	0.0094				2.09				2.09	4.71	0.12	0.22
1	0.2	-0.0026				-0.58				-0.58	-1.30	-0.03	-0.22
1	0.4	-0.0088				-1.98				-1.98	-4.44	-0.11	-0.22
1	0.6	-0.0091				-2.05				-2.05	-4.60	-0.11	-0.22
1	0.8	-0.0055				-1.22				-1.22	-2.75	-0.07	-0.22
1	1	0.0000				0.00				0.00	0.00	0.00	0.22
0.8	1	0.0000				0.00				0.00	0.00	0.00	0.22
0.8	0.8	-0.0053				-1.19				-1.19	-2.67	-0.07	-0.22
0.8	0.6	-0.0089				-2.00				-2.00	-4.49	-0.11	-0.22
0.8	0.4	-0.0087				-1.96				-1.96	-4.40	-0.11	-0.22
0.8	0.2	-0.0027				-0.61				-0.61	-1.37	-0.03	-0.22

max negative moment, $M_{ux}(-)$ = -4.60 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.11 in^2/ft
minimum steel req'd = -0.22 in^2/ft
Use #6@12" (Existing)

max positive moment, $M_{ux}(+)$ = 12.87 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.33 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use #6@12" (Existing)

Engineers...Working Wonders With Water™

BY:	C. Che	**DATE:** Aug-17	**CLIENT** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:			South Exterior Wall - Hydrostatic		

M_y - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

Loads: q , or M: 0.874

Moment Coefficient Multipliers: 223.744

Boundary Case 2

		Moment Coefficients				M_y Moments, ft-k/ft				SUMMARY: Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000				0.00				0.00	0.00	0.00	0.22
0	0.8	0.0027				0.61				0.61	1.37	0.03	0.22
0	0.6	0.0048				1.06				1.06	2.39	0.06	0.22
0	0.4	0.0051				1.14				1.14	2.55	0.06	0.22
0	0.2	0.0028				0.62				0.62	1.39	0.03	0.22
0	0	0.0000				0.00				0.00	0.00	0.00	0.22
0.2	0	0.0142				3.18				3.18	7.15	0.17	0.23
0.4	0	0.0292				6.54				6.54	14.72	0.35	0.38
0.6	0	0.0395				8.84				8.84	19.88	0.48	0.38
0.8	0	0.0450				10.08				10.08	22.68	0.55	0.38
1	0	0.0468				10.47				10.47	23.55	0.58	0.38
1	0.2	-0.0028				-0.63				-0.63	-1.43	-0.03	-0.22
1	0.4	-0.0184				-4.11				-4.11	-9.24	-0.22	-0.29
1	0.6	-0.0162				-3.62				-3.62	-8.14	-0.19	-0.26
1	0.8	-0.0085				-1.89				-1.89	-4.26	-0.10	-0.22
1	1	0.0000				0.00				0.00	0.00	0.00	0.22
1	0.4	-0.0184				-4.11				-4.11	-9.24	-0.22	-0.29
0.8	0.4	-0.0175				-3.92				-3.92	-8.82	-0.21	-0.28
0.6	0.4	-0.0150				-3.36				-3.36	-7.56	-0.18	-0.24
0.4	0.4	-0.0104				-2.33				-2.33	-5.25	-0.12	-0.22
0.2	0.4	-0.0035				-0.77				-0.77	-1.74	-0.04	-0.22

max negative moment, $M_{uy}(-)$ = -9.24 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.22 in^2/ft
minimum steel req'd = -0.29 in^2/ft
Use #7@12" (Existing)

max positive moment, $M_{uy}(+)$ = 23.55 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.58 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use #7@12" (Existing)

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Hydrostatic

Shear Summary

a = 12.84
b = 16
a / b = 0.8025

Loads: q , or M
0.874

Shear Coefficient Multipliers
13.984

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0532				-0.74				-0.74	-1.04	10.81
0	0.8	0.0858				1.20				1.20	1.68	10.81
0	0.6	0.1725				2.41				2.41	3.38	10.81
0	0.4	0.2308				3.23				3.23	4.52	10.81
0	0.2	0.1451				2.03				2.03	2.84	10.81
0	0.00	-0.0104				-0.14				-0.14	-0.20	10.81
0.2	0	0.1546				2.16				2.16	3.03	10.81
0.4	0	0.2733				3.82				3.82	5.35	10.81
0.6	0	0.3295				4.61				4.61	6.45	10.81
0.8	0	0.3535				4.94				4.94	6.92	10.81
1	0	0.3600				5.03				5.03	7.05	10.81
0.2	1	-0.0232				-0.32				-0.32	-0.45	10.81
0.4	1	0.0321				0.45				0.45	0.63	10.81
0.6	1	0.0607				0.85				0.85	1.19	10.81
0.8	1	0.0737				1.03				1.03	1.44	10.81
1	1	0.0773				1.08				1.08	1.51	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 7.05 k/ft **OK**
$\phi V_c = \phi*2*(f\,'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

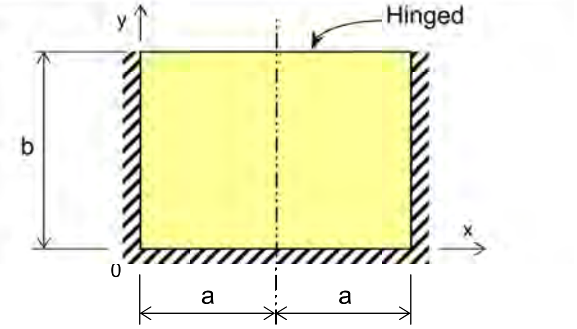
BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Hydrodynamic

Rectangular Plate:

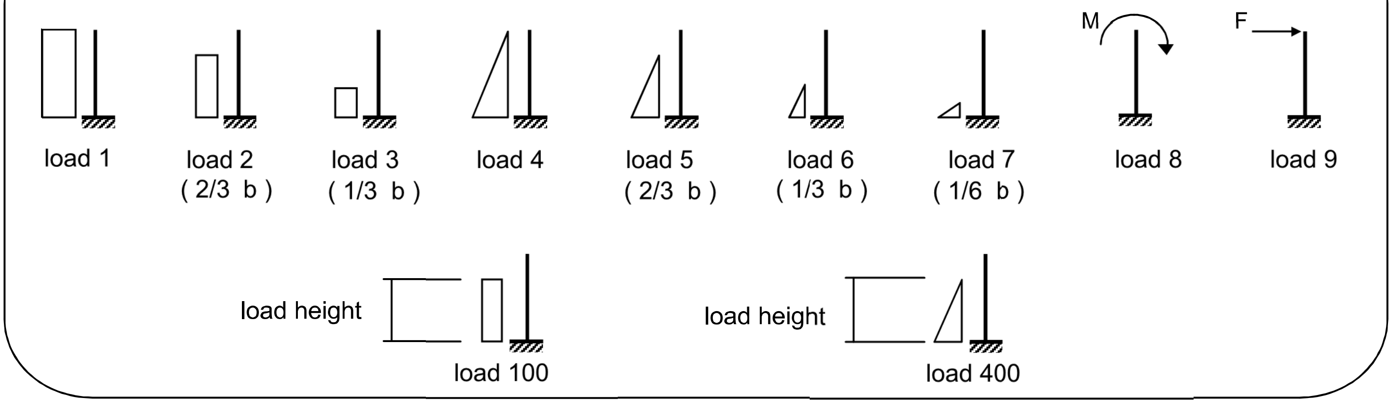
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 12.84 = 25.68 ft
plate dimension, a = **12.84** ft
plate dimension, b = **16** ft

plate sides ratio, a/b = 0.8025



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings

load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads 100 or 400	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**14.000**	**0.874**	**1.2**	**1.2**
B	**100**	**14.000**	**0.107**	**1.4**	**1.4**
C	**400**	**14.000**	**0.119**	**1.4**	**1.4**
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00300**
minimum ratio of vertical shrinkage-temperature steel = **0.00300**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Hydrodynamic

M_x - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

Loads: q , or M			
0.874	0.107	0.119	
Moment Coefficient Multipliers			
223.744	27.392	30.464	

Boundary Case 2

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.22
0	0.8	0.0137	0.0404	0.0137		3.07	1.11	0.42		4.60	5.82	0.15	0.22
0	0.6	0.0239	0.0636	0.0239		5.35	1.74	0.73		7.82	9.88	0.25	0.33
0	0.4	0.0256	0.0575	0.0256		5.72	1.58	0.78		8.07	10.16	0.26	0.34
0	0.2	0.0137	0.0252	0.0137		3.08	0.69	0.42		4.18	5.24	0.13	0.22
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.22
0.2	0	0.0029	0.0046	0.0029		0.64	0.13	0.09		0.85	1.06	0.03	0.22
0.4	0	0.0059	0.0105	0.0059		1.31	0.29	0.18		1.78	2.23	0.06	0.22
0.6	0	0.0079	0.0150	0.0079		1.76	0.41	0.24		2.42	3.03	0.08	0.22
0.8	0	0.0090	0.0176	0.0090		2.02	0.48	0.28		2.78	3.49	0.09	0.22
1	0	0.0094	0.0185	0.0094		2.09	0.51	0.28		2.88	3.62	0.09	0.22
1	0.2	-0.0026	-0.0041	-0.0026		-0.58	-0.11	-0.08		-0.77	-0.96	-0.02	-0.22
1	0.4	-0.0088	-0.0204	-0.0088		-1.98	-0.56	-0.27		-2.80	-3.53	-0.09	-0.22
1	0.6	-0.0091	-0.0244	-0.0091		-2.05	-0.67	-0.28		-2.99	-3.78	-0.09	-0.22
1	0.8	-0.0055	-0.0159	-0.0055		-1.22	-0.44	-0.17		-1.82	-2.31	-0.06	-0.22
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.22
0.8	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.22
0.8	0.8	-0.0053	-0.0154	-0.0053		-1.19	-0.42	-0.16		-1.77	-2.24	-0.06	-0.22
0.8	0.6	-0.0089	-0.0238	-0.0089		-2.00	-0.65	-0.27		-2.92	-3.69	-0.09	-0.22
0.8	0.4	-0.0087	-0.0201	-0.0087		-1.96	-0.55	-0.27		-2.77	-3.49	-0.09	-0.22
0.8	0.2	-0.0027	-0.0044	-0.0027		-0.61	-0.12	-0.08		-0.82	-1.02	-0.03	-0.22

max negative moment, $M_{ux}(-)$ = -3.78 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.09 in^2/ft
minimum steel req'd = -0.22 in^2/ft
Use #6@12" (Existing)

max positive moment, $M_{ux}(+)$ = 10.16 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.26 in^2/ft
minimum steel req'd = 0.34 in^2/ft
Use #6@12" (Existing)

Engineers...Working Wonders With Water™

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Hydrodynamic

M_y - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

	A	B	C	D
Loads: q , or M	0.874	0.107	0.119	
Moment Coefficient Multipliers	223.744	27.392	30.464	

Boundary Case 2

SUMMARY

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.22
0	0.8	0.0027	0.0081	0.0027		0.61	0.22	0.08		0.91	1.15	0.03	0.22
0	0.6	0.0048	0.0127	0.0048		1.06	0.35	0.14		1.56	1.97	0.05	0.22
0	0.4	0.0051	0.0115	0.0051		1.14	0.31	0.15		1.60	2.02	0.05	0.22
0	0.2	0.0028	0.0050	0.0028		0.62	0.14	0.08		0.84	1.05	0.02	0.22
0	0	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.22
0.2	0	0.0142	0.0244	0.0142		3.18	0.67	0.43		4.28	5.36	0.13	0.22
0.4	0	0.0292	0.0528	0.0292		6.54	1.45	0.89		8.88	11.12	0.27	0.35
0.6	0	0.0395	0.0752	0.0395		8.84	2.06	1.20		12.10	15.17	0.37	0.38
0.8	0	0.0450	0.0881	0.0450		10.08	2.41	1.37		13.86	17.39	0.42	0.38
1	0	0.0468	0.0922	0.0468		10.47	2.53	1.42		14.42	18.09	0.44	0.38
1	0.2	-0.0028	0.0035	-0.0028		-0.63	0.10	-0.09		-0.62	-0.75	-0.02	-0.22
1	0.4	-0.0184	-0.0385	-0.0184		-4.11	-1.05	-0.56		-5.72	-7.19	-0.17	-0.23
1	0.6	-0.0162	-0.0467	-0.0162		-3.62	-1.28	-0.49		-5.39	-6.82	-0.16	-0.22
1	0.8	-0.0085	-0.0294	-0.0085		-1.89	-0.81	-0.26		-2.96	-3.76	-0.09	-0.22
1	1	0.0000	0.0000	0.0000		0.00	0.00	0.00		0.00	0.00	0.00	0.22
1	0.4	-0.0184	-0.0385	-0.0184		-4.11	-1.05	-0.56		-5.72	-7.19	-0.17	-0.23
0.8	0.4	-0.0175	-0.0367	-0.0175		-3.92	-1.00	-0.53		-5.46	-6.86	-0.16	-0.22
0.6	0.4	-0.0150	-0.0310	-0.0150		-3.36	-0.85	-0.46		-4.67	-5.87	-0.14	-0.22
0.4	0.4	-0.0104	-0.0209	-0.0104		-2.33	-0.57	-0.32		-3.23	-4.05	-0.10	-0.22
0.2	0.4	-0.0035	-0.0062	-0.0035		-0.77	-0.17	-0.11		-1.05	-1.31	-0.03	-0.22

max negative moment, $M_{uy}(-)$ = -7.19 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.17 in^2/ft
minimum steel req'd = -0.23 in^2/ft
Use #7@12" (Existing)

max positive moment, $M_{uy}(+)$ = 18.09 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.44 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use #7@12" (Existing)

BY: C. Che **DATE:** Sep-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Hydrodynamic

Shear Summary

a = 12.84
b = 16
a / b = 0.8025

	Loads: q , or M				Boundary Case 2	SUMMARY
Loads	0.874	0.107	0.119			Final Shears
Shear Coefficient Multipliers	13.984	1.712	1.904			

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0532	-0.1388	-0.0532		-0.74	-0.24	-0.10		-1.08	-1.37	10.81
0	0.8	0.0858	0.3107	0.0858		1.20	0.53	0.16		1.89	2.41	10.81
0	0.6	0.1725	0.5117	0.1725		2.41	0.88	0.33		3.62	4.58	10.81
0	0.4	0.2308	0.4845	0.2308		3.23	0.83	0.44		4.50	5.65	10.81
0	0.2	0.1451	0.1788	0.1451		2.03	0.31	0.28		2.61	3.25	10.81
0	0.00	-0.0104	-0.0541	-0.0104		-0.14	-0.09	-0.02		-0.26	-0.33	10.81
0.2	0	0.1546	0.1660	0.1546		2.16	0.28	0.29		2.74	3.41	10.81
0.4	0	0.2733	0.3910	0.2733		3.82	0.67	0.52		5.01	6.25	10.81
0.6	0	0.3295	0.5150	0.3295		4.61	0.88	0.63		6.12	7.64	10.81
0.8	0	0.3535	0.5727	0.3535		4.94	0.98	0.67		6.60	8.25	10.81
1	0	0.3600	0.5892	0.3600		5.03	1.01	0.69		6.73	8.41	10.81
0.2	1	-0.0232	-0.0006	-0.0232		-0.32	0.00	-0.04		-0.37	-0.45	10.81
0.4	1	0.0321	0.1600	0.0321		0.45	0.27	0.06		0.78	1.01	10.81
0.6	1	0.0607	0.2379	0.0607		0.85	0.41	0.12		1.37	1.75	10.81
0.8	1	0.0737	0.2718	0.0737		1.03	0.47	0.14		1.64	2.08	10.81
1	1	0.0773	0.2812	0.0773		1.08	0.48	0.15		1.71	2.18	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 8.41 k/ft **OK**
$\phi V_c = \phi*2*(f\,'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:
"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:
Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water™

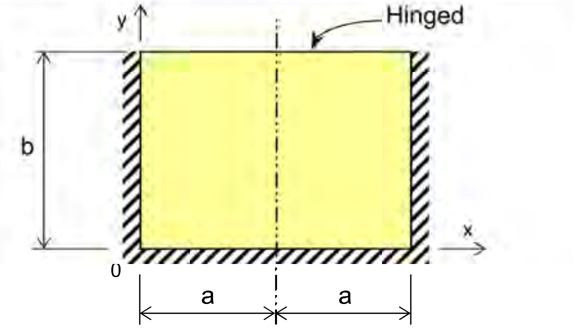
BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Soil Static

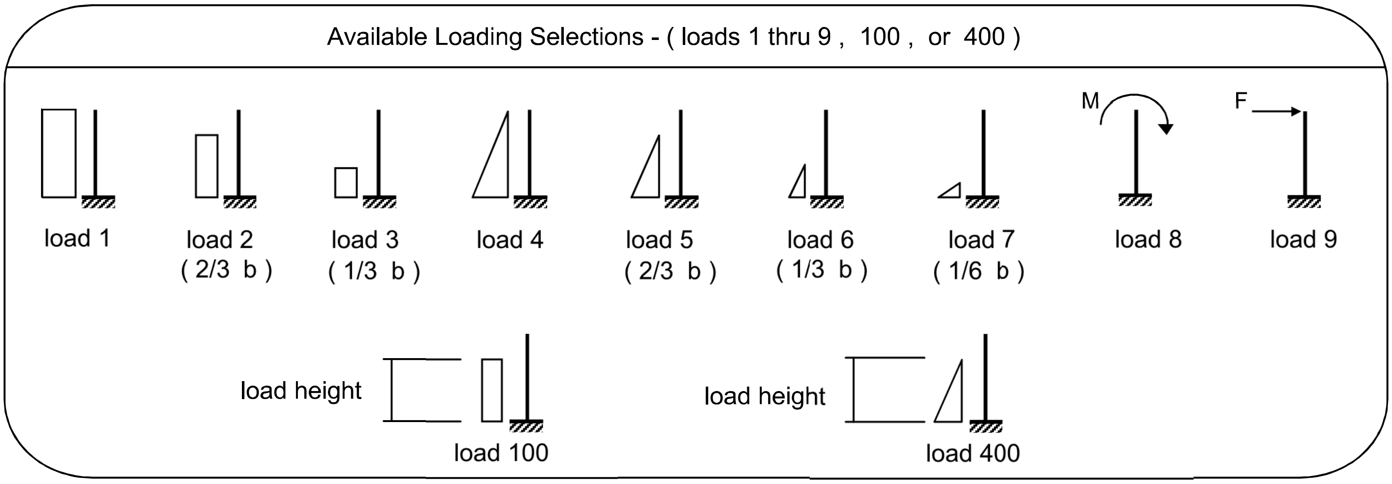
Rectangular Plate:

plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 12.84 = 25.68 ft
plate dimension, a = **12.84** ft
plate dimension, b = **16** ft

plate sides ratio, a/b = 0.8025





Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors	
				for moment	for shear
A	**400**	**15.000**	**0.825**	**2.25**	**1.6**
B	**100**	**15.000**	**0.100**	**2.25**	**1.6**
C					
D					

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00300**
minimum ratio of vertical shrinkage-temperature steel = **0.00300**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Soil Static

M_x - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

Loads: q , or M			
0.825	0.100		
Moment Coefficient Multipliers			
211.200	25.600		

Boundary Case 2

SUMMARY

		Moment Coefficients				M_x Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.22
0	0.8	0.0160	0.0449			3.37	1.15			4.52	10.18	0.26	0.34
0	0.6	0.0271	0.0671			5.72	1.72			7.44	16.74	0.43	0.36
0	0.4	0.0279	0.0590			5.89	1.51			7.40	16.65	0.43	0.36
0	0.2	0.0145	0.0255			3.07	0.65			3.72	8.37	0.21	0.28
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.22
0.2	0	0.0030	0.0046			0.63	0.12			0.75	1.68	0.04	0.22
0.4	0	0.0062	0.0107			1.31	0.27			1.58	3.56	0.09	0.22
0.6	0	0.0084	0.0153			1.77	0.39			2.16	4.86	0.12	0.22
0.8	0	0.0097	0.0180			2.04	0.46			2.50	5.63	0.14	0.22
1	0	0.0100	0.0189			2.11	0.48			2.60	5.84	0.15	0.22
1	0.2	-0.0027	-0.0041			-0.56	-0.11			-0.67	-1.51	-0.04	-0.22
1	0.4	-0.0097	-0.0210			-2.04	-0.54			-2.58	-5.81	-0.15	-0.22
1	0.6	-0.0104	-0.0257			-2.19	-0.66			-2.85	-6.41	-0.16	-0.22
1	0.8	-0.0063	-0.0176			-1.34	-0.45			-1.79	-4.03	-0.10	-0.22
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.22
0.8	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.22
0.8	0.8	-0.0062	-0.0171			-1.30	-0.44			-1.74	-3.91	-0.10	-0.22
0.8	0.6	-0.0101	-0.0251			-2.14	-0.64			-2.78	-6.26	-0.16	-0.22
0.8	0.4	-0.0096	-0.0206			-2.02	-0.53			-2.55	-5.74	-0.14	-0.22
0.8	0.2	-0.0028	-0.0044			-0.60	-0.11			-0.71	-1.60	-0.04	-0.22

max negative moment, $M_{ux}(-)$ = -6.41 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.16 in^2/ft
minimum steel req'd = -0.22 in^2/ft
Use #6@12" (Existing)

max positive moment, $M_{ux}(+)$ = 16.74 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.43 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use #6@12" (Existing)

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Soil Static

M_y - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

Loads: q , or M			
0.825	0.100		
Moment Coefficient Multipliers			
211.200	25.600		

Boundary Case 2

SUMMARY

Final Moments		Reinforcing: (d = 9.5")	

		Moment Coefficients				M_y Moments, ft-k/ft				M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
x / a	y / b	A	B	C	D	A	B	C	D				
0	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.22
0	0.8	0.0032	0.0090			0.67	0.23			0.90	2.02	0.05	0.22
0	0.6	0.0054	0.0134			1.14	0.34			1.48	3.34	0.08	0.22
0	0.4	0.0055	0.0118			1.17	0.30			1.47	3.31	0.08	0.22
0	0.2	0.0029	0.0051			0.61	0.13			0.74	1.67	0.04	0.22
0	0	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.22
0.2	0	0.0148	0.0241			3.13	0.62			3.74	8.42	0.20	0.27
0.4	0	0.0308	0.0536			6.51	1.37			7.89	17.74	0.43	0.38
0.6	0	0.0420	0.0767			8.87	1.96			10.83	24.38	0.60	0.38
0.8	0	0.0481	0.0900			10.17	2.31			12.47	28.06	0.69	0.38
1	0	0.0500	0.0943			10.57	2.41			12.98	29.21	0.72	0.38
1	0.2	-0.0022	0.0045			-0.47	0.12			-0.35	-0.79	-0.02	-0.22
1	0.4	-0.0197	-0.0384			-4.16	-0.98			-5.15	-11.58	-0.28	-0.37
1	0.6	-0.0187	-0.0492			-3.94	-1.26			-5.20	-11.70	-0.28	-0.37
1	0.8	-0.0104	-0.0346			-2.19	-0.89			-3.07	-6.91	-0.16	-0.22
1	1	0.0000	0.0000			0.00	0.00			0.00	0.00	0.00	0.22
1	0.4	-0.0197	-0.0384			-4.16	-0.98			-5.15	-11.58	-0.28	-0.37
0.8	0.4	-0.0188	-0.0366			-3.97	-0.94			-4.91	-11.04	-0.26	-0.35
0.6	0.4	-0.0161	-0.0308			-3.39	-0.79			-4.18	-9.40	-0.22	-0.30
0.4	0.4	-0.0111	-0.0205			-2.34	-0.53			-2.87	-6.45	-0.15	-0.22
0.2	0.4	-0.0036	-0.0057			-0.76	-0.15			-0.91	-2.04	-0.05	-0.22

max negative moment, $M_{uy}(-)$ = -11.70 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.28 in^2/ft
minimum steel req'd = -0.37 in^2/ft
Use #7@12" (Existing)

max positive moment, $M_{uy}(+)$ = 29.21 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.72 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use #7@12" (Existing)
DCR = 0.72 / (0.6 /0.9) = 1.08

BY:	C. Che	**DATE:**	Aug-17	**CLIENT**	Willamette River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:	South Exterior Wall - Soil Static				

Shear Summary

a = 12.84
b = 16
a / b = 0.8025

Loads: q , or M			
0.825	0.100		
Shear Coefficient Multipliers			
13.200	1.600		

Boundary Case 2

SUMMARY

Final Shears

		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0616	-0.1465			-0.81	-0.23			-1.05	-1.68	10.81
0	0.8	0.1066	0.3754			1.41	0.60			2.01	3.21	10.81
0	0.6	0.2004	0.5354			2.65	0.86			3.50	5.60	10.81
0	0.4	0.2474	0.4831			3.27	0.77			4.04	6.46	10.81
0	0.2	0.1462	0.1756			1.93	0.28			2.21	3.54	10.81
0	0.00	-0.0134	-0.0555			-0.18	-0.09			-0.27	-0.43	10.81
0.2	0	0.1546	0.1630			2.04	0.26			2.30	3.68	10.81
0.4	0	0.2806	0.3916			3.70	0.63			4.33	6.93	10.81
0.6	0	0.3419	0.5194			4.51	0.83			5.34	8.55	10.81
0.8	0	0.3684	0.5796			4.86	0.93			5.79	9.26	10.81
1	0	0.3757	0.5968			4.96	0.95			5.91	9.46	10.81
0.2	1	-0.0231	0.0284			-0.30	0.05			-0.26	-0.42	10.81
0.4	1	0.0411	0.2053			0.54	0.33			0.87	1.39	10.81
0.6	1	0.0737	0.2891			0.97	0.46			1.44	2.30	10.81
0.8	1	0.0883	0.3253			1.17	0.52			1.69	2.70	10.81
1	1	0.0925	0.3352			1.22	0.54			1.76	2.81	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in

maximum shear, V_u = 9.46 k/ft **OK**

$\phi V_c = \phi * 2 * (f'c)^{1/2} * b * d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.

The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.

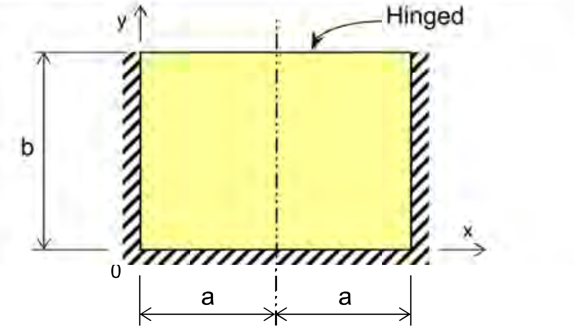
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Soil EQ

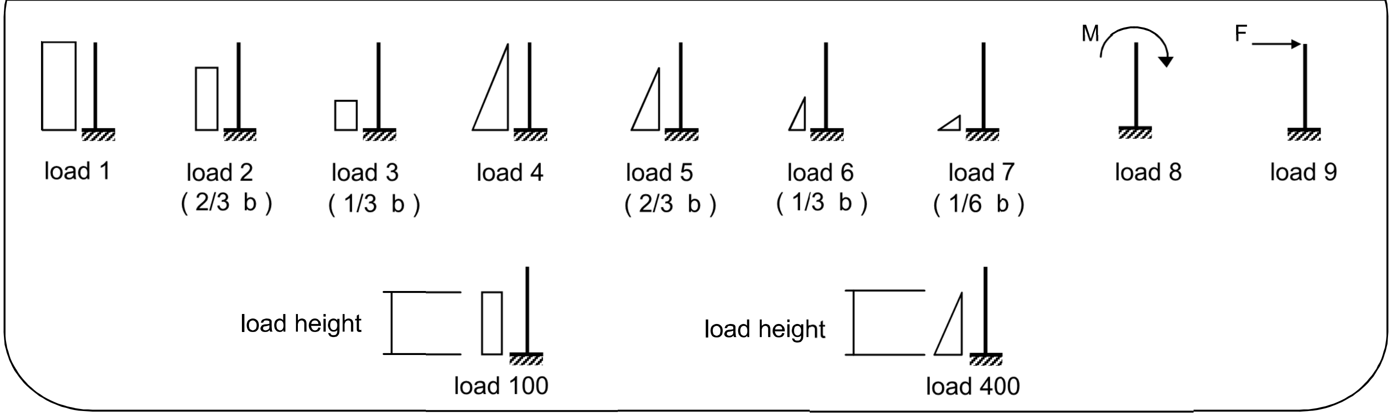
Rectangular Plate:
plate boundary condition case number (1, 2, 3, 4, or 5) = **2**

total plate width = 2*a = 2 * 12.84 = 25.68 ft
plate dimension, a = **12.84** ft
plate dimension, b = **16** ft

plate sides ratio, a/b = 0.8025



Available Loading Selections - (loads 1 thru 9 , 100 , or 400)



Choice of Available Loadings					
load conditions (4 max)	load type Loading Selection Number	load height, (ft) ...only for custom loads **100** or **400**	unfactored loads: q , or M (ksf, ft-k/ft)	concrete load factors for moment	concrete load factors for shear
A	**400**	**15.000**	**0.825**	**1.6**	**1.6**
B	**100**	**15.000**	**0.364**	**1.4**	**1.4**
C	**400**	**15.000**	**-0.364**	**1.4**	**1.4**
D	**1**		**0.025**	**1.4**	**1.4**

Notes: 1). Load 100 = uniform load of any load height ≥ b/3; Load 400 = triangular load of any load height ≥ b/6.
2). load height must be less than or equal to "b", and uniform load height ≥ "b / 3", and triangular load height ≥ "b / 6" .
3). loads may be positive or negative.

plate thickness, h = **12** in

concrete strength, f 'c = **4** ksi
reinforcing steel strength, fy = **60** ksi
reinforcing clear cover to face of concrete = **2** in
number of curtains of reinforcing, (1 or 2) = **2**
Are bars in "x" or "y" direction closest to face of concrete ? **y**
minimum ratio of horizontal shrinkage-temperature steel = **0.00300**
minimum ratio of vertical shrinkage-temperature steel = **0.00300**

bar locations	d (in)	d' (in)
Mx bending	9"	3"
My bending	9.5"	2.5"

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Soil EQ

M_x - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

Boundary Case 2

	A	B	C	D
Loads: q , or M	0.825	0.364	-0.364	0.025
Moment Coefficient Multipliers	211.200	93.184	-93.184	6.400

		Moment Coefficients				M_x Moments, ft-k/ft				SUMMARY			
										Final Moments		Reinforcing: (d = 9")	
x / a	y / b	A	B	C	D	A	B	C	D	M_x ft-k/ft	M_{ux} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
0	0.8	0.0160	0.0449	0.0160	0.0493	3.37	4.18	-1.49	0.32	6.38	9.61	0.24	0.32
0	0.6	0.0271	0.0671	0.0271	0.0701	5.72	6.26	-2.53	0.45	9.90	15.01	0.38	0.36
0	0.4	0.0279	0.0590	0.0279	0.0597	5.89	5.50	-2.60	0.38	9.17	14.02	0.36	0.36
0	0.2	0.0145	0.0255	0.0145	0.0255	3.07	2.37	-1.35	0.16	4.25	6.57	0.16	0.22
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
0.2	0	0.0030	0.0046	0.0030	0.0046	0.63	0.43	-0.28	0.03	0.81	1.26	0.03	0.22
0.4	0	0.0062	0.0107	0.0062	0.0107	1.31	0.99	-0.58	0.07	1.79	2.77	0.07	0.22
0.6	0	0.0084	0.0153	0.0084	0.0155	1.77	1.43	-0.78	0.10	2.52	3.88	0.10	0.22
0.8	0	0.0097	0.0180	0.0097	0.0182	2.04	1.68	-0.90	0.12	2.94	4.52	0.11	0.22
1	0	0.0100	0.0189	0.0100	0.0191	2.11	1.76	-0.93	0.12	3.06	4.71	0.12	0.22
1	0.2	-0.0027	-0.0041	-0.0027	-0.0041	-0.56	-0.39	0.25	-0.03	-0.73	-1.13	-0.03	-0.22
1	0.4	-0.0097	-0.0210	-0.0097	-0.0214	-2.04	-1.96	0.90	-0.14	-3.24	-4.94	-0.12	-0.22
1	0.6	-0.0104	-0.0257	-0.0104	-0.0269	-2.19	-2.40	0.97	-0.17	-3.79	-5.75	-0.14	-0.22
1	0.8	-0.0063	-0.0176	-0.0063	-0.0193	-1.34	-1.64	0.59	-0.12	-2.51	-3.78	-0.09	-0.22
1	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
0.8	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
0.8	0.8	-0.0062	-0.0171	-0.0062	-0.0187	-1.30	-1.59	0.57	-0.12	-2.44	-3.67	-0.09	-0.22
0.8	0.6	-0.0101	-0.0251	-0.0101	-0.0262	-2.14	-2.34	0.94	-0.17	-3.70	-5.61	-0.14	-0.22
0.8	0.4	-0.0096	-0.0206	-0.0096	-0.0209	-2.02	-1.92	0.89	-0.13	-3.19	-4.86	-0.12	-0.22
0.8	0.2	-0.0028	-0.0044	-0.0028	-0.0044	-0.60	-0.41	0.26	-0.03	-0.78	-1.21	-0.03	-0.22

max negative moment, $M_{ux}(-)$ = -5.75 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.14 in^2/ft
minimum steel req'd = -0.22 in^2/ft
Use #6@12" (Existing)

max positive moment, $M_{ux}(+)$ = 15.01 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.38 in^2/ft
minimum steel req'd = 0.36 in^2/ft
Use #6@12" (Existing)

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Engineers...Working Wonders With Water™

BY: C. Che	**DATE:** Aug-17	**CLIENT**	Willamette River WTP	**SHEET:**	
CHKD:	**DESCRIPTION:**		Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:			South Exterior Wall - Soil EQ		

M_y - Moment Summary

a = 12.84
b = 16
a / b = 0.8025

Boundary Case 2

Loads: q , or M	A	B	C	D
Loads	0.825	0.364	-0.364	0.025
Moment Coefficient Multipliers	211.200	93.184	-93.184	6.400

SUMMARY: Final Moments; Reinforcing: (d = 9.5")

		Moment Coefficients				M_y Moments, ft-k/ft				Final Moments		Reinforcing: (d = 9.5")	
x / a	y / b	A	B	C	D	A	B	C	D	M_y ft-k/ft	M_{uy} ft-k/ft	$A_{s(req'd)}$ in^2/ft	$A_{s(min)}$ in^2/ft
0	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
0	0.8	0.0032	0.0090	0.0032	0.0099	0.67	0.84	-0.30	0.06	1.27	1.92	0.04	0.22
0	0.6	0.0054	0.0134	0.0054	0.0140	1.14	1.25	-0.50	0.09	1.98	3.00	0.07	0.22
0	0.4	0.0055	0.0118	0.0055	0.0120	1.17	1.10	-0.52	0.08	1.83	2.80	0.07	0.22
0	0.2	0.0029	0.0051	0.0029	0.0051	0.61	0.47	-0.27	0.03	0.85	1.31	0.03	0.22
0	0	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
0.2	0	0.0148	0.0241	0.0148	0.0233	3.13	2.25	-1.38	0.15	4.14	6.42	0.15	0.22
0.4	0	0.0308	0.0536	0.0308	0.0538	6.51	4.99	-2.87	0.34	8.98	13.87	0.33	0.38
0.6	0	0.0420	0.0767	0.0420	0.0774	8.87	7.14	-3.91	0.50	12.60	19.41	0.47	0.38
0.8	0	0.0481	0.0900	0.0481	0.0911	10.17	8.39	-4.49	0.58	14.65	22.55	0.55	0.38
1	0	0.0500	0.0943	0.0500	0.0955	10.57	8.79	-4.66	0.61	15.31	23.54	0.58	0.38
1	0.2	-0.0022	0.0045	-0.0022	0.0055	-0.47	0.42	0.21	0.03	0.19	0.18	0.00	0.22
1	0.4	-0.0197	-0.0384	-0.0197	-0.0377	-4.16	-3.58	1.84	-0.24	-6.15	-9.44	-0.22	-0.30
1	0.6	-0.0187	-0.0492	-0.0187	-0.0512	-3.94	-4.58	1.74	-0.33	-7.11	-10.74	-0.26	-0.34
1	0.8	-0.0104	-0.0346	-0.0104	-0.0401	-2.19	-3.22	0.96	-0.26	-4.70	-7.02	-0.17	-0.22
1	1	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
1	0.4	-0.0197	-0.0384	-0.0197	-0.0377	-4.16	-3.58	1.84	-0.24	-6.15	-9.44	-0.22	-0.30
0.8	0.4	-0.0188	-0.0366	-0.0188	-0.0358	-3.97	-3.41	1.75	-0.23	-5.85	-8.99	-0.21	-0.29
0.6	0.4	-0.0161	-0.0308	-0.0161	-0.0300	-3.39	-2.87	1.50	-0.19	-4.96	-7.62	-0.18	-0.24
0.4	0.4	-0.0111	-0.0205	-0.0111	-0.0197	-2.34	-1.91	1.03	-0.13	-3.35	-5.16	-0.12	-0.22
0.2	0.4	-0.0036	-0.0057	-0.0036	-0.0051	-0.76	-0.53	0.33	-0.03	-0.99	-1.54	-0.04	-0.22

max negative moment, $M_{uy}(-)$ = -10.74 ft-k/ft
max negative steel req'd, $A_s(-)$ = -0.26 in^2/ft
minimum steel req'd = -0.34 in^2/ft
Use #7@12" (Existing)

max positive moment, $M_{uy}(+)$ = 23.54 ft-k/ft
max positive steel req'd, $A_s(+)$ = 0.58 in^2/ft
minimum steel req'd = 0.38 in^2/ft
Use #7@12" (Existing)

BY: C. Che **DATE:** Aug-17 **CLIENT** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: South Exterior Wall - Soil EQ

Shear Summary

		Loads: q , or M				Boundary Case 2				SUMMARY		
a =	12.84	0.825	0.364	-0.364	0.025							
b =	16	Shear Coefficient Multipliers								Final Shears		
a / b =	0.8025	13.200	5.824	-5.824	0.400							
		Shear Coefficients				Shears, k/ft				V	V_u	ϕV_c
x / a	y / b	A	B	C	D	A	B	C	D	k/ft	k/ft	k/ft
0	1	-0.0616	-0.1465	-0.0616	-0.1528	-0.81	-0.85	0.36	-0.06	-1.37	-2.08	10.81
0	0.8	0.1066	0.3754	0.1066	0.4464	1.41	2.19	-0.62	0.18	3.15	4.69	10.81
0	0.6	0.2004	0.5354	0.2004	0.5528	2.65	3.12	-1.17	0.22	4.82	7.27	10.81
0	0.4	0.2474	0.4831	0.2474	0.4726	3.27	2.81	-1.44	0.19	4.83	7.41	10.81
0	0.2	0.1462	0.1756	0.1462	0.1718	1.93	1.02	-0.85	0.07	2.17	3.42	10.81
0	0.00	-0.0134	-0.0555	-0.0134	-0.0558	-0.18	-0.32	0.08	-0.02	-0.44	-0.66	10.81
0.2	0	0.1546	0.1630	0.1546	0.1596	2.04	0.95	-0.90	0.06	2.15	3.42	10.81
0.4	0	0.2806	0.3916	0.2806	0.3894	3.70	2.28	-1.63	0.16	4.51	7.05	10.81
0.6	0	0.3419	0.5194	0.3419	0.5196	4.51	3.03	-1.99	0.21	5.75	8.96	10.81
0.8	0	0.3684	0.5796	0.3684	0.5816	4.86	3.38	-2.15	0.23	6.33	9.83	10.81
1	0	0.3757	0.5968	0.3757	0.5994	4.96	3.48	-2.19	0.24	6.49	10.07	10.81
0.2	1	-0.0231	0.0284	-0.0231	0.0631	-0.30	0.17	0.13	0.03	0.02	-0.03	10.81
0.4	1	0.0411	0.2053	0.0411	0.2562	0.54	1.20	-0.24	0.10	1.60	2.35	10.81
0.6	1	0.0737	0.2891	0.0737	0.3457	0.97	1.68	-0.43	0.14	2.37	3.51	10.81
0.8	1	0.0883	0.3253	0.0883	0.3839	1.17	1.89	-0.51	0.15	2.70	4.01	10.81
1	1	0.0925	0.3352	0.0925	0.3943	1.22	1.95	-0.54	0.16	2.79	4.15	10.81

Concrete strength reduction factor for shear, ϕ = 0.75

d = 9.5 in
maximum shear, V_u = 10.07 k/ft **OK**
$\phi V_c = \phi*2*(f\ 'c)^{1/2}*b*d$ = (0.75*2*(4000)ˆ½ *12*9.5)/1000 = 10.81 k/ft

Reference:

"Moments and Reactions for Rectangular Plates"
Engineering Monograph No. 27
By: W. T. Moody, United States Bureau of Reclamation

Notes:

Quadratic interpolation is used for intermediate values within the Moody tables and between Moody figures.
The positive sign convention for moments M_x and M_y is tension on the loaded face of the plate.
The M_x moment is in the direction of the x-axis and the M_y moment is in the direction of the y-axis by plate sign convention.

Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:					Interior Liquid Load Case		

Hydrostatic and Hydrodynamic Seismic Analysis of a Circular Tank per ASCE 7-10 and the 2012 IBC code:

Does groundwater exist in which to consider buoyancy? **No Groundwater**

tank inside diameter, D = 35 ft

tank inside radius, R = **17.5** ft

tank wall thickness, t_w = **12** inch

tank wall height to underside of roof = **13.67** ft

roof thickness = **0** inch

misc roof weights included with seismic = **0** ksf

liquid height, H_L = **12** ft

liquid specific gravity = **1**

liquid density, $\gamma_L = (\text{sp.gr.})^*\gamma_w$ = 0.0624 k/ft^3

acceleration due to gravity, g = 32.17 ft/sec^2

liquid mass density, $\rho_L = \gamma_L / g$ = 0.00194 $k\text{-}sec^2/ft^4$

concrete strength, f'_c = **4** ksi

concrete density, γ_c = 0.150 k/ft^3

concrete modulus of elasticity, E_c = 3605.0 ksi

concrete mass density, $\rho_c = \gamma_c / g$ = 0.00466 $k\text{-}sec^2/ft^4$

(Note: Response spectra values shall be strength level.)

tank wall mass, W_w = 231.9 kip

wall c.g. relative to base, h_w = 6.835 ft

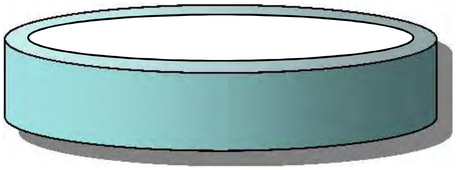
tank roof weight = 0.0 kip

total misc roof weight = 0.0 kip

total roof mass, W_r = 0.0 kip

roof c.g. relative to base, h_r = 0.000 ft

liquid mass, $W_L = \pi R^2 * H_L * \gamma_L$ = 720.4 kip



tank inside diameter, D = 35 ft

Seismic:

Structure Risk Category = **3**

Importance factor, I = **1.25**

Response modification factor, R_i = **2**

Response modification factor, R_c = **1.5**

(acceleration values from a maximum considered earthquake)

Deisgn, 5% damped, spectral response acceleration at the short period of 0.2-second, S_{DS} = **0.611** *g

Deisgn, 5% damped, spectral response acceleration at a period of 1-second, S_{D1} = **0.656** *g

1). Dynamic properties, Spectral amplification factors, and Effective mass coefficient:

$$C_w = 0.09375 + 0.2039\left(\frac{H_L}{D}\right) - 0.1034\left(\frac{H_L}{D}\right)^2 - 0.1253\left(\frac{H_L}{D}\right)^3 + 0.1267\left(\frac{H_L}{D}\right)^4 - 0.03186\left(\frac{H_L}{D}\right)^5 = 0.14805$$

$C_l = C_w * 10*((t_w/12)/R)^{1/2}$ = 0.1481*10*(12/12/17.5)^½ = 0.3539

$\omega_i = C_l * 12/H_L*(E_c / \rho_c)^{1/2}$ = 0.3539*12 / 12*(3605 / 0.00466)^½ = 311.1948 rad/sec

impulsive period of oscillation, $T_i = 2\pi / \omega_i$ = 2π / 311.1948 = 0.0202 sec

design factored spectral response acceleration for impulsive mass (5% damping), $S_{ai} = S_{DS}$ = 0.611 g

$$\lambda = \sqrt{3.68\ g\ \tanh\left(3.68\left(\frac{H_L}{D}\right)\right)} =$$ (3.68*32.17*tanh(3.68*(12/35))^½ = 10.0404

convective circular frequency, $\omega_c = \frac{\lambda}{\sqrt{D}} =$ 10.0404 / (35)^½ = 1.6971 rad/sec

convective period of sloshing, $T_c = 2\pi / \omega_c$ = 2π / 1.6971 = 3.7022 sec

Long transition period (from map figure 22-12 ASCE 7), T_L = **16** sec.

design spectral response acceleration for convective mass (0.5% damping), S_{ac} = 1.5 * Sd1 / Tc = 0.2658 g

effective mass coeff., $\varepsilon = 0.0151\left(\frac{D}{H_L}\right)^2 - 0.1908\left(\frac{D}{H_L}\right) + 1.021$, but $\leq$ 1.0 = 0.5930

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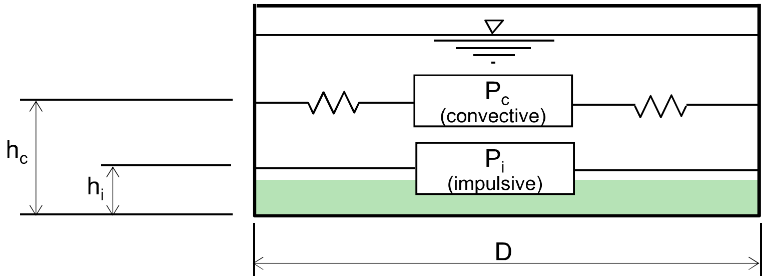
Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**		Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:		Interior Liquid Load Case				



Dynamic Model

D = 35 ft

H_L = 12 ft

W_L = 720.4 kip

D / H_L = 2.91667

H_L / D = 0.34286

2). lateral fluid impulsive force:

equivalent impulsive mass component, $W_i = W_L\left(\dfrac{\tanh\left(0.866\dfrac{D}{H_L}\right)}{0.866\dfrac{D}{H_L}}\right) =$ 281.6 kip

height above base to the impulsive lateral force, hi (EBP) = HL * 0.375 = 4.5 ft

hi (IBP) = HL * {{(0.866*D/HL)/(2*tanh(0.866*D/HL))} -1/8 } = 13.850 ft

impulsive force, $P_i = \left(\dfrac{S_{ai}\ I}{R_i}\right)W_i =$ (0.611 * 1.25 / 2) * 281.6 = 107.5 kip

impulsive force moment excluding bottom pressure , $M_{i(EBP)} = P_i{*}h_{i(EBP)} =$ 107.5 * 4.5 = 483.8 ft-k

impulsive force moment including bottom pressure , $M_{i(IBP)} = P_i{*}h_{i(IBP)} =$ 107.5 * 13.85 = 1488.9 ft-k

3). lateral fluid convective force:

equivalent convective mass component, $W_c = W_L\left(0.23\left(\dfrac{D}{H_L}\right)\tanh\left(3.68\left(\dfrac{H_L}{D}\right)\right)\right) =$ 411.5 kip

height above base to convective lateral force, $h_{c\ (EBP)} = H_L\left(1 - \dfrac{\cosh\left(3.68\left(\dfrac{H_L}{D}\right)\right) - 1}{3.68\left(\dfrac{H_L}{D}\right)\sinh\left(3.68\left(\dfrac{H_L}{D}\right)\right)}\right) =$ 6.687 ft

$h_{c(IBP)} = H_L\left(1 - \dfrac{\cosh\left(3.68\left(\dfrac{H_L}{D}\right)\right) - 2.01}{3.68\left(\dfrac{H_L}{D}\right)\sinh\left(3.68\left(\dfrac{H_L}{D}\right)\right)}\right) =$ 12.601 ft

convective force, $P_c = \left(\dfrac{S_{ac}\ I}{R_c}\right)W_c =$ (0.2658 * 1.25 / 1.5) * 411.5 = 91.1 kip

convective force moment excluding bottom pressure , $M_{c(EBP)} = P_c{*}h_{c(EBP)} =$ 91.1 * 6.687 = 609.2 ft-k

convective force moment including bottom pressure , $M_{c(IBP)} = P_c{*}h_{c(IBP)} =$ 91.1 * 12.601 = 1148.0 ft-k

BY:	C. Che	**DATE:** Sep-17	**CLIENT:** Willamette River WTP	**SHEET:**	
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DESIGN TASK:			Interior Liquid Load Case		

4). lateral inertia force of the accelerating wall:

tank wall mass, W_w = 231.9 kip

wall c.g. relative to base, h_w = 6.835 ft

$$\text{wall inertia force, } P_w = \left(\frac{S_{ai}\ I\ \varepsilon}{R_i}\right) W_w = \quad (\,0.611 * 1.25 * 0.593 / 2\,) * 231.9 = \quad 52.5 \text{ kip}$$

wall inertia force moment, $M_w = P_w * h_w$ = 52.5 * 6.835 = 358.8 ft-k

5). lateral inertia force of the accelerating roof:

total roof mass, W_r = 0.0 kip

roof c.g. relative to base, h_r = 0.0 ft

$$\text{roof inertia force, } P_r = \left(\frac{S_{ai}\ I}{R_i}\right) W_r = \quad (\,0.611 * 1.25 / 2\,) * 0 = \quad 0.0 \text{ kip}$$

roof inertia force moment, $M_r = P_r * h_r$ = 0 * 0 = 0.0 ft-k

6). total base shear:

$$V = \sqrt{(P_i + P_w + P_r)^2 + P_c^2}$$

V = ((107.5 + 52.5 + 0)² + (91.1)²)ˆ½ = 184.1 kip

7). total moment at the base excluding bottom pressure (EBP):

$$M_b = \sqrt{(M_i + M_w + M_r)^2 + M_c^2}$$

Mb = ((483.8 + 358.8 + 0)² + (609.2)²)ˆ½ = 1039.8 ft-k

8). total moment at the base including bottom pressure (IBP):

$$M_o = \sqrt{(M_i + M_w + M_r)^2 + M_c^{\,2}}$$

Mo = ((1488.9 + 358.8 + 0)² + (1148)²)ˆ½ = 2175.3 ft-k

9). maximum wave slosh height displacement: (see ASCE-10, 15.7.6.1 notes c and d)

(Risk Category = 3) I = 1.25 ,use TL = 4 ,Sd1 = 0.656 ,Tc = 3.7022

S_{ac} = 1.5 * Sd1 / Tc = 0.2658 *g

$$d_{(max)} = 0.42\,(\,D\,)(\,S_{ac}\ \ I\,) = \quad 0.42 * (\,35\,) * (\,0.2658 * 1.25\,) = \quad 4.88 \text{ ft}$$

(minimum freeboard see table 15.7-3 of ASCE 7) , d(min) = 0.7 * d(max) = 3.42 ft

Wave height is greater than the freeboard of 1.67-ft. Check effects of wave spillage.

10). Vertical acceleration:

design horizontal accereration, S_{DS} = 0.611 *g

period of vibration, $T_v = 2\pi * (\,\gamma_L * D * H_L^{\,2} / (24g * t_w * E_c)\,)^{1/2}$ = 0.0193 sec

$Ts = S_{D1} / S_{DS}$ = 0.656 / 0.611 = 1.0736 sec

vertical acceleration (per ACI 350 para 9.4.3), for $T_V \le T_S$ then $C_t = S_{DS}$, for $T_V \succ T_S$ then $C_t = \dfrac{S_{D1}}{T_V}$

therefore, vertical spectral response acceleration, $S_{av} = C_t$ = 0.6110 *g

per ASCE 7-10 para. 15.7.7.2(b), use I = R_i = b = 1.0

$$\text{Design vertical acceleration, } \ddot{u} = \frac{S_{av}\ I\ b}{R_i} = \quad 0.611*1*1/1 = \quad 0.6110 \text{ g}$$

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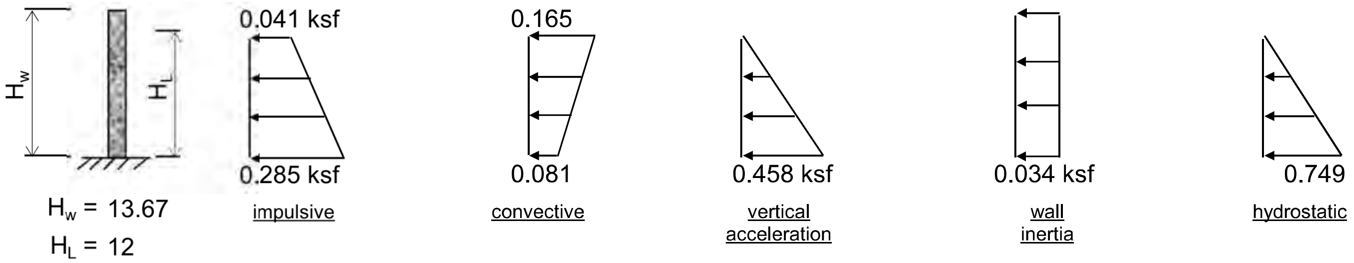
DESIGN TASK:			Interior Liquid Load Case		

12). vertical pressure distribution on a unit width using the linear distribution of ACI 350 sec 5.3:



$H_w = 13.67$
$H_L = 12$

impulsive pressure:

$$p_{iy} = \frac{2\left(\frac{P_i}{2}\right)\left[4H_L - 6h_i - \left(6H_L - 12h_i\right)\left(\frac{y}{H_L}\right)\right]}{\pi R H_L^2}\cos\theta =$$

use θ = 0°

impulsive force, P_i = 107.5 kip
h_i = 4.5 ft
at $y = H_L$, p_{iy} = 0.041 ksf
at base $y = 0$, p_{iy} = 0.285 ksf

convective pressure:

$$p_{cy} = \frac{16\left(\frac{P_c}{2}\right)\left[4H_L - 6h_c - \left(6H_L - 12h_c\right)\left(\frac{y}{H_L}\right)\right]}{9\,\pi\,R\,H_L^2}\cos\theta =$$

use θ = 0°

convective force, P_c = 91.1 kip
h_c = 6.687 ft
at $y = H_L$, p_{cy} = 0.165 ksf
at base $y = 0$, p_{cy} = 0.081 ksf

vertical acceleration pressure:

$$p_{vy} = \ddot{u}\,\gamma_L\,\left(H_L - y\right) =$$

vertical acceleration, ü = 0.611 g
at $y = H_L$, p_{vy} = 0 ksf
at base $y = 0$, p_{vy} = 0.458 ksf

wall inertia pressure:

$$p_{wy} = \frac{S_{ai}\;I\;\varepsilon\,\gamma_c\;(t_w/12)}{R_i} =$$

p_{wy} = 0.2264 * (γ_c * t_w)
at $y = H_w$, p_{wy} = 0.034 ksf
at base $y = 0$, p_{wy} = 0.034 ksf

hydrostatic pressure:

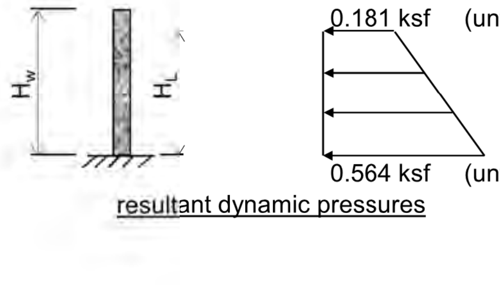
$$q_{hy} = \gamma_L\,\left(H_L - y\right) =$$

at $y = H_L$, q_{hy} = 0 ksf
at base $y = 0$, q_{hy} = 0.749 ksf

combine the effects of the dynamic pressures on the wall:

$$p_y = \sqrt{\left(p_{iy} + p_{wy}\right)^2 + p_{cy}^2 + p_{vy}^2} =$$

at $y = H_w$, p_y = 0.181 ksf
at base $y = 0$, p_y = 0.564 ksf



(unfactored load = 0.181 / 1.4 = 0.129 ksf)

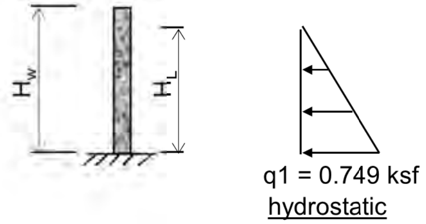
(unfactored load = 0.564 / 1.4 = 0.403 ksf)

resultant dynamic pressures

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:					Interior Liquid Load Case		

13). load cases:

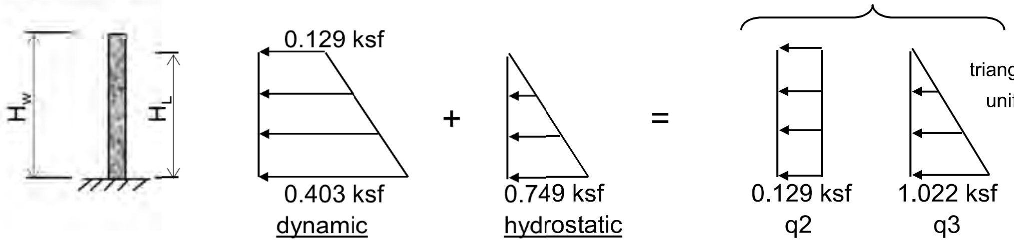
a). hydrostatic water load case:



triangular pressure = 0.749 ksf

Concrete load factor for hoop forces for the hydrostatic load case = **3.86**
Concrete load factor for moments for the hydrostatic load case = **2.25**
Concrete load factor for shears for the hydrostatic load case = **1.4**

b). seismic load case:
equivalent unfactored dynamic + static pressure loadings… equivalent loading (unfactored)



triangular pressure = 1.022 ksf
uniform pressure = 0.129 ksf

Concrete load factor for hoop forces for the seismic load case = **1.4**
Concrete load factor for moments for the seismic load case = **1.4**
Concrete load factor for shears for the seismic load case = **1.4**

14). concrete design data:

Reinforcement yield strength, f_y = **60** ksi
No. of reinforcing curtains, (1 or 2) = **2**
Depth to vert reinforcing, d = tw-3 = 9 in.
minimum gross hoop steel ratio, ρ = **0.00300**
min gross vert shrinkage/ temperature steel ratio, ρ = **0.00300**
ϕ, Bending = 0.9
ϕ for shear is dependent upon the load factors used. See code. (typically 0.85 or 0.75), ϕ, Shear = **1**

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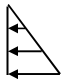
DESIGN TASK: Interior Liquid Load Case



pressure loading
triangular pressure = 0.749 ksf
tank radius, R = 17.5
fluid depth, H = 12
wall thickness, t_w = 12

$H^2 / (D*t_w) = 4.114$

STEEL TYPE	DISTANCE FROM TOP OF FLUID		*** HYDROSTATIC LOAD CASE *** FIXED BASE CIRCULAR WALL				
	Distance (% H)	Distance (feet)	Coefficient triangular loading	Concrete Tensile stress (ksi)	unfactored Hoop Tension, T (kip / ft)	factored Hoop T_u (kip / ft)	Hoop Steel Req'd. (in^2 / ft)
HOOP STEEL	0.0 H	0.00	0.0604	0.009	0.792	3.057	0.06
	0.1 H	1.20	0.1605	0.023	2.103	8.116	0.15
	0.2 H	2.40	0.2547	0.037	3.338	12.885	0.24
	0.3 H	3.60	0.3403	0.049	4.459	17.211	0.32
	0.4 H	4.80	0.4065	0.059	5.326	20.560	0.38
	0.5 H	6.00	0.4355	0.063	5.707	22.031	0.41
	0.6 H	7.20	0.4166	0.060	5.459	21.073	0.39
	0.7 H	8.40	0.3421	0.050	4.483	17.303	0.32
	0.8 H	9.60	0.2160	0.032	2.830	10.923	0.20
	0.9 H	10.80	0.0751	0.011	0.984	3.800	0.07
	1.0 H	12.00	0.0000	0.000	0.000	0.000	0.00

$$A_{(req'd)} = \frac{T_u}{\phi f_y}$$

	Distance (% H)	Distance (feet)	Coefficient triangular loading	unfactored Moment M (ft-kip / ft)	factored Moment M_u (ft-kip / ft)	Vertical Steel Req'd. for Bending (in^2/ft)
VERT STEEL	0.0 H	0.00	0.00000	0.000	0.000	0.00
	0.1 H	1.20	0.00029	0.031	0.070	0.00
	0.2 H	2.40	0.00141	0.152	0.342	0.01
	0.3 H	3.60	0.00264	0.285	0.641	0.02
	0.4 H	4.80	0.00445	0.480	1.081	0.03
	0.5 H	6.00	0.00634	0.684	1.538	0.04
	0.6 H	7.20	0.00747	0.805	1.812	0.04
	0.7 H	8.40	0.00678	0.731	1.644	0.04
	0.8 H	9.60	0.00238	0.256	0.577	0.01
	0.9 H	10.80	-0.00772	-0.833	-1.874	0.05
	1.0 H	12.00	-0.02622	-2.827	-6.361	0.16

$$R_u = \frac{M_u}{\phi\, b\, d^2}$$

$$A_s = \frac{0.85\, f'_c\, bd}{f_y}\left(1 - \sqrt{1 - \frac{2\,R_u}{0.85\, f'_c}}\right)$$

Critical Wall Shear	V = 1.550 kip / ft , (shear at a distance "d" from the bottom of the wall)
Factored Critical Wall Shear	V_u = 2.170 kip / ft
Base Horz Wall Reaction	Reaction = 2.094 kip /ft ,tri press coef = 0.2330
Foundation Ring Tension	F = 36.64 kip F_u = 141.44 kip , A_s (in^2) = 2.62

nominal design shear strength, $\phi V_c = \phi * 2 * f'_c \sqrt{bd} =$ 13.661 k / ft

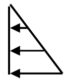
notes:
1). Reference: "Circular Concrete Tanks without Prestressing", Portland Cement Association, 1993.
2). Intermediate coefficient values from the PCA reference are found by quadratic interpolation to enhance accuracy.
3). Maximum allowable concrete tensile stress, 0.1 * f 'c = 0.400 ksi
4). Concrete tension, $f_c = (C*E_s*A_s + T) / (A_c + n*A_s)$,use C=0.0003
5). T = coef*(tri. pressure)*R , M = coef*(tri. pressure)*H^2

Engineers...Working Wonders With Water ™

BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: Interior Liquid Load Case

$H^2 / (D*t_w) = 4.114$

STEEL TYPE	DISTANCE FROM TOP OF FLUID		*** HYDROSTATIC LOAD CASE *** PINNED BASE CIRCULAR WALL				
HOOP STEEL	Distance (% H)	Distance (feet)	Coefficient triangular loading	Concrete Tensile stress (ksi)	unfactored Hoop Tension, T (kip / ft)	factored Hoop T_u (kip / ft)	Hoop Steel Req'd. (in^2 / ft)
	0.0 H	0.00	0.0130	0.002	0.171	0.659	0.01
	0.1 H	1.20	0.1338	0.020	1.753	6.766	0.13
	0.2 H	2.40	0.2506	0.037	3.284	12.678	0.23
	0.3 H	3.60	0.3658	0.053	4.794	18.505	0.34
	0.4 H	4.80	0.4693	0.068	6.150	23.738	0.44
	0.5 H	6.00	0.5476	0.079	7.176	27.698	0.51
	0.6 H	7.20	0.5842	0.084	7.655	29.547	0.55
	0.7 H	8.40	0.5599	0.080	7.336	28.319	0.52
	0.8 H	9.60	0.4540	0.065	5.949	22.964	0.43
	0.9 H	10.80	0.2606	0.038	3.415	13.181	0.24
	1.0 H	12.00	0.0000	0.000	0.000	0.000	0.00
VERT STEEL	Distance (% H)	Distance (feet)	Coefficient triangular loading	unfactored Moment M (ft-kip / ft)	factored Moment M_u (ft-kip / ft)	Vertical Steel Req'd. for Bending (in^2/ft)	
	0.0 H	0.00	0.00000	0.000	0.000	0.00	
	0.1 H	1.20	0.00008	0.009	0.020	0.00	
	0.2 H	2.40	0.00061	0.065	0.147	0.00	
	0.3 H	3.60	0.00146	0.157	0.353	0.01	
	0.4 H	4.80	0.00306	0.330	0.742	0.02	
	0.5 H	6.00	0.00540	0.582	1.309	0.03	
	0.6 H	7.20	0.00796	0.859	1.932	0.05	
	0.7 H	8.40	0.01051	1.134	2.551	0.06	
	0.8 H	9.60	0.01149	1.238	2.786	0.07	
	0.9 H	10.80	0.00902	0.973	2.188	0.05	
	1.0 H	12.00	0.00000	0.000	0.000	0.00	0.2052432



pressure loading

triangular pressure = 0.749 ksf
tank radius, R = 17.5
fluid depth, H = 12
wall thickness, t_w= 12

$$A_{(req'd)} = \frac{T_u}{\phi f_y}$$

$$R_u = \frac{M_u}{\phi b d^2}$$

$$A_s = \frac{0.85 f'_c bd}{f_y}\left(1-\sqrt{1-\frac{2R_u}{0.85 f'_c}}\right)$$

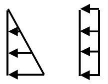
Critical Wall Shear	V = 0.668 kip / ft , (shear at a distance "d" from the bottom of the wall)
Factored Critical Wall Shear	V_u = 0.936 kip / ft
Base Horz Wall Reaction	Reaction = 1.212 kip /ft ,tri press coef = 0.1349
Foundation Ring Tension	F = 21.22 kip F_u = 81.89 kip , A_s (in^2) = 1.52

nominal design shear strength, $\phi V_c = \phi *2* f'_c \sqrt{bd} =$ 13.661 k / ft

notes:
1). Reference: "Circular Concrete Tanks without Prestressing", Portland Cement Association, 1993.
2). Intermediate coefficient values from the PCA reference are found by quadratic interpolation to enhance accuracy.
3). Maximum allowable concrete tensile stress, 0.1 * f 'c = 0.400 ksi
4). Concrete tension, $f_c = (C*E_s*A_s + T) / (A_c + n*A_s)$,use C=0.0003
5). T = coef*(tri. pressure)*R , M = coef*(tri. pressure)*H^2

Engineers...Working Wonders With Water ™

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**		Area 11 - Sludge Thickener		**JOB NO:**	10721A.10
DESIGN TASK:		Interior Liquid Load Case					



pressure loadings

triangular = 1.022 ksf

uniform = 0.129 ksf

radius, R = 17.5

fluid, H = 12

wall thk., t_w= 12

$H^2 / (D*t_w) = 4.114$

STEEL TYPE	**DISTANCE FROM TOP OF FLUID**		***** SEISMIC LOAD CASE *** FIXED BASE CIRCULAR WALL**					
	Distance (% H)	Distance (feet)	Coefficients triangular loading	Coefficients uniform loading	Concrete Tensile stress (ksi)	unfactored Hoop Tension, T (kip / ft)	factored Hoop T_u (kip / ft)	Hoop Steel Req'd. (in^2 / ft)
HOOP STEEL	0.0 H	0.00	0.0604	1.0785	0.030	3.521	4.930	0.09
	0.1 H	1.20	0.1605	1.0692	0.045	5.290	7.405	0.14
	0.2 H	2.40	0.2547	1.0558	0.059	6.946	9.724	0.18
	0.3 H	3.60	0.3403	1.0310	0.071	8.419	11.787	0.22
	0.4 H	4.80	0.4065	0.9823	0.080	9.493	13.290	0.25
	0.5 H	6.00	0.4355	0.8954	0.082	9.816	13.743	0.25
	0.6 H	7.20	0.4166	0.7563	0.077	9.163	12.828	0.24
	0.7 H	8.40	0.3421	0.5622	0.062	7.391	10.347	0.19
	0.8 H	9.60	0.2160	0.3288	0.039	4.607	6.449	0.12
	0.9 H	10.80	0.0751	0.1077	0.013	1.587	2.222	0.04
	1.0 H	12.00	0.0000	0.0000	0.000	0.000	0.000	0.00

$$A_{(req'd)} = \frac{T_u}{\phi f_y}$$

STEEL TYPE	Distance (% H)	Distance (feet)	Coefficients triangular loading	Coefficients uniform loading	unfactored Moment M (ft-kip / ft)	factored Moment M_u (ft-kip / ft)	Vertical Steel Req'd. for Bending (in^2/ft)
VERT STEEL	0.0 H	0.00	0.00000	0.00000	0.000	0.000	0.00
	0.1 H	1.20	0.00029	0.00037	0.049	0.069	0.00
	0.2 H	2.40	0.00141	0.00140	0.234	0.327	0.01
	0.3 H	3.60	0.00264	0.00311	0.447	0.626	0.02
	0.4 H	4.80	0.00445	0.00499	0.748	1.048	0.03
	0.5 H	6.00	0.00634	0.00660	1.056	1.479	0.04
	0.6 H	7.20	0.00747	0.00733	1.236	1.730	0.04
	0.7 H	8.40	0.00678	0.00530	1.096	1.534	0.04
	0.8 H	9.60	0.00238	-0.00102	0.331	0.463	0.01
	0.9 H	10.80	-0.00772	-0.01392	-1.396	-1.954	0.05
	1.0 H	12.00	-0.02622	-0.03557	-4.521	-6.330	0.32

$$R_u = \frac{M_u}{\phi b d^2}$$

$$A_s = \frac{0.85 f'_c bd}{f_y}\left(1-\sqrt{1-\frac{2R_u}{0.85 f'_c}}\right)$$

0.410651

Critical Wall Shear	V = 1.027 kip / ft , (shear at a distance "d" from the bottom of the wall)
Factored Critical Wall Shear	V_u = 1.438 kip / ft
Base Horz Wall Reaction	Reaction = 3.273 kip /ft ,tri press coef = 0.2330 ,uniform press coef = 0.2674
Foundation Ring Tension	F = 57.28 kip F_u = 80.19 kip , A_s (in^2) = 1.48

nominal design shear strength, $\phi V_c = \phi *2* f'_c \sqrt{bd} =$ 13.661 k / ft

notes:
1). Reference: "Circular Concrete Tanks without Prestressing", Portland Cement Association, 1993.
2). Intermediate coefficient values from the PCA reference are found by quadratic interpolation to enhance accuracy.
3). Maximum allowable concrete tensile stress. For seismic conditions, engineer may consider up to 1.33 x static. 0.1 * f 'c = 0.400 ksi static X 1.33 = 0.532 ksi seismic
4). Concrete tension, $f_c = (C*E_s*A_s + T) / (A_c + n*A_s)$,use C=0.0003
5). T = coef*(tri. pressure)*R + coef*(uni. pressure)*R , M = coef*(tri. pressure)*H^2 + coef*(uni. pressure)*H^2

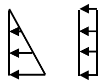
Engineers...Working Wonders With Water™

BY:	C. Che	**DATE:** Sep-17	**CLIENT:** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:			Interior Liquid Load Case		

$H^2 / (D*t_w) = 4.114$

STEEL TYPE	DISTANCE FROM TOP OF FLUID		*** SEISMIC LOAD CASE *** PINNED BASE CIRCULAR WALL					
	Distance (% H)	Distance (feet)	Coefficients		Concrete Tensile stress (ksi)	unfactored Hoop Tension, T (kip / ft)	factored Hoop T_u (kip / ft)	Hoop Steel Req'd. (in^2 / ft)
			triangular loading	uniform loading				
HOOP STEEL	0.0 H	0.00	0.0130	1.0130	0.021	2.525	3.536	0.07
	0.1 H	1.20	0.1338	1.0338	0.040	4.732	6.625	0.12
	0.2 H	2.40	0.2506	1.0506	0.058	6.861	9.605	0.18
	0.3 H	3.60	0.3658	1.0658	0.075	8.955	12.538	0.23
	0.4 H	4.80	0.4693	1.0693	0.091	10.814	15.139	0.28
	0.5 H	6.00	0.5476	1.0476	0.102	12.165	17.031	0.32
	0.6 H	7.20	0.5842	0.9842	0.106	12.675	17.745	0.33
	0.7 H	8.40	0.5599	0.8599	0.100	11.960	16.744	0.31
	0.8 H	9.60	0.4540	0.6540	0.081	9.600	13.441	0.25
	0.9 H	10.80	0.2606	0.3606	0.046	5.477	7.668	0.14
	1.0 H	12.00	0.0000	0.0000	0.000	0.000	0.000	0.00

STEEL TYPE	Distance (% H)	Distance (feet)	Coefficients		unfactored Moment M (ft-kip / ft)	factored Moment M_u (ft-kip / ft)	Vertical Steel Req'd. for Bending (in^2/ft)
			triangular loading	uniform loading			
VERT STEEL	0.0 H	0.00	0.00000	0.00000	0.000	0.000	0.00
	0.1 H	1.20	0.00008	0.00008	0.014	0.019	0.00
	0.2 H	2.40	0.00061	0.00061	0.100	0.141	0.00
	0.3 H	3.60	0.00146	0.00146	0.241	0.338	0.01
	0.4 H	4.80	0.00306	0.00306	0.507	0.710	0.02
	0.5 H	6.00	0.00540	0.00540	0.895	1.253	0.03
	0.6 H	7.20	0.00796	0.00796	1.320	1.848	0.05
	0.7 H	8.40	0.01051	0.01051	1.743	2.440	0.06
	0.8 H	9.60	0.01149	0.01149	1.904	2.666	0.07
	0.9 H	10.80	0.00902	0.00902	1.495	2.094	0.05
	1.0 H	12.00	0.00000	0.00000	0.000	0.000	0.21



pressure loadings

triangular = 1.022 ksf

uniform = 0.129 ksf

radius, R = 17.5

fluid, H = 12

wall thk., t_w= 12

$$A_{(req'd)} = \frac{T_u}{\phi f_y}$$

$$R_u = \frac{M_u}{\phi b d^2}$$

$$A_s = \frac{0.85 f_c' bd}{f_y}\left(1 - \sqrt{1 - \frac{2 R_u}{0.85 f_c'}}\right)$$

0.205243

Critical Wall Shear	V = 1.122 kip / ft , (shear at a distance "d" from the bottom of the wall)
Factored Critical Wall Shear	V_u = 1.570 kip / ft
Base Horz Wall Reaction	Reaction = 1.864 kip /ft ,tri press coef = 0.1349 ,uniform press coef = 0.1349
Foundation Ring Tension	F = 32.62 kip F_u = 45.67 kip , A_s (in^2) = 0.85

nominal design shear strength, ϕV_c = $\phi * 2 * f'_c \sqrt{bd}$ = 13.661 k / ft

notes: 1). Reference: "Circular Concrete Tanks without Prestressing", Portland Cement Association, 1993.

2). Intermediate coefficient values from the PCA reference are found by quadratic interpolation to enhance accuracy.

3). Maximum allowable concrete tensile stress. For seismic conditions, engineer may consider up to 1.33 x static. 0.1 * f 'c = 0.400 ksi static X 1.33 = 0.532 ksi seismic

4). Concrete tension, $f_c = (C*E_s*A_s + T) / (A_c + n*A_s)$,use C=0.0003

5). T = coef*(tri. pressure)*R + coef*(uni. pressure)*R , M = coef*(tri. pressure)*H^2 + coef*(uni. pressure)*H^2

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:** Willamette River WTP	**SHEET:**
CHKD:		**DESCRIPTION:**		Area 11 - Sludge Thickener	**JOB NO:** 10721A.10
DESIGN TASK:				Interior Liquid Load Case	

hoop $A_{s\,(req'd)} = T_u / (\phi * f_y)$ $A_{s\,(min)} = \rho * b * t_w$

SUMMARY OF HOOP & VERTICAL STEEL REQUIREMENTS THE INTERNAL WATER LOADING CASES

	Distance from top of fluid (ft)	Hydrostatic Case		Seismic Case		controlling $A_{s\,(req'd)}$ (in^2/ft)	$A_{s\,(min)}$ (in^2/ft)	Bar number	Bar spacing (in)	total for 2 curtains $A_{s(provided)}$ (in^2/ft)
		Fixed Base T_u (kip / ft)	Pinned Base T_u (kip / ft)	Fixed Base T_u (kip / ft)	Pinned Base T_u (kip / ft)					
HOOP STEEL	0.00	3.057	0.659	4.930	3.536	0.09	0.43	**5**	**12**	0.62
	1.20	8.116	6.766	7.405	6.625	0.15	0.43	**5**	**12**	0.62
	2.40	12.885	12.678	9.724	9.605	0.24	0.43	**5**	**12**	0.62
	3.60	17.211	18.505	11.787	12.538	0.34	0.43	**5**	**12**	0.62
	4.80	20.560	23.738	13.290	15.139	0.44	0.43	**5**	**12**	0.62
	6.00	22.031	27.698	13.743	17.031	0.51	0.43	**5**	**12**	0.62
	7.20	21.073	29.547	12.828	17.745	0.55	0.43	**5**	**12**	0.62
	8.40	17.303	28.319	10.347	16.744	0.52	0.43	**5**	**12**	0.62
	9.60	10.923	22.964	6.449	13.441	0.43	0.43	**5**	**12**	0.62
	10.80	3.800	13.181	2.222	7.668	0.24	0.43	**5**	**12**	0.62
	12.00	0.000	0.000	0.000	0.000	0.00	0.43	**5**	**12**	0.62

	Distance from top of fluid (ft)	Hydrostatic Case		Seismic Case		controlling $A_{s\,(req'd)}$ (in^2/ft)	$A_{s\,(min)}$ (in^2/ft)	Bar number	Bar spacing (in)	each face $A_{s(provided)}$ (in^2/ft)
		Fixed Base M_u (ft-kip / ft)	Pinned Base M_u (ft-kip / ft)	Fixed Base M_u (ft-kip / ft)	Pinned Base M_u (ft-kip / ft)					
VERT STEEL	0.00	0.000	0.000	0.000	0.000	0.00	0.22	**5**	**12**	0.31
	1.20	0.070	0.020	0.069	0.019	0.00	0.22	**5**	**12**	0.31
	2.40	0.342	0.147	0.327	0.141	0.01	0.22	**5**	**12**	0.31
	3.60	0.641	0.353	0.626	0.338	0.02	0.22	**5**	**12**	0.31
	4.80	1.081	0.742	1.048	0.710	0.03	0.22	**5**	**12**	0.31
	6.00	1.538	1.309	1.479	1.253	0.04	0.22	**5**	**12**	0.31
	7.20	1.812	1.932	1.730	1.848	0.05	0.22	**5**	**12**	0.31
	8.40	1.644	2.551	1.534	2.440	0.06	0.22	**5**	**12**	0.31
	9.60	0.577	2.786	0.463	2.666	0.07	0.22	**5**	**12**	0.31
	10.80	-1.874	2.188	-1.954	2.094	0.05	0.22	**5**	**12**	0.31
	12.00	-6.361	0.000	-6.330	0.000	0.16	0.22	**5**	**6**	0.62

SUMMARY OF FOUNDATION HOOP STEEL REQUIRED

Foundation Hoop Forces	Foundation Ring Tension				$A_{(req'd)} = \frac{F_u}{\phi\, f_y}$ maximum $A_{s\,(req'd)}$ (in^2)	Bar number	total number of Bars in 2 layers	$A_{s(provided)}$ (in^2)
	Hydrostatic Case		Seismic Case					
	Fixed Base (kip)	Pinned Base (kip)	Fixed Base (kip)	Pinned Base (kip)				
Foundation Ring Tension, F =	36.64	21.22	57.28	32.62				
F_u = (load factor)*F =	141.44	81.89	80.19	45.67	2.62	**5**	**10**	3.10

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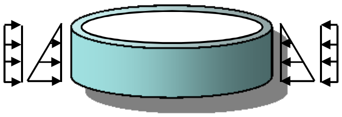
BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:					External Soil Load Case		

External Soil Compression Loading:

uniform soil surcharge pressure = **0.100** ksf
soil height from base, H_s = **7** ft.
lateral at-rest soil density = **0.055** k / ft^3
max triangular soil pressure = 0.385 ksf
Tank diameter, D = 35 ft.
Tank wall height, H = 13.67 ft.
Wall thickness, t_w = 12 in.
H_s^2 / (D*t_w) = 1.400

Concrete load factor for hoop compression = **1.6**
Concrete load factor for moments = **2.25**
Concrete load factor for shears = **1.6**
Depth to vert reinforcing, d =tw-3 = 9 in.
Reinforcement strength, fy = 60 ksi
Concrete strength, f 'c = 4 ksi



*** FORCES RESULTING FROM EXTERNAL SOIL COMPRESSION ***

STEEL TYPE | **DISTANCE FROM TOP OF SOIL** | **FIXED BASE CIRCULAR WALL**

STEEL TYPE	Distance (% H_s)	Distance (feet)	Coefficients triangular loading	Coefficients uniform loading	unfactored Hoop Compression, P (kip / ft)	factored Hoop Compression, P_u (kip / ft)	Ultimate Hoop Compression $\phi Pu = 0.85\phi(0.85 f'_c{*}A_g)$ (kip / ft)
HOOP COMPRESSION	0.0 H_s	0.00	0.2756	1.2429	4.032	6.451	291.31
	0.1 H_s	0.70	0.2713	1.1170	3.782	6.052	291.31
	0.2 H_s	1.40	0.2621	0.9814	3.483	5.574	291.31
	0.3 H_s	2.10	0.2516	0.8476	3.179	5.086	291.31
	0.4 H_s	2.80	0.2303	0.7051	2.785	4.456	291.31
	0.5 H_s	3.50	0.2028	0.5613	2.348	3.757	291.31
	0.6 H_s	4.20	0.1630	0.4143	1.823	2.917	291.31
	0.7 H_s	4.90	0.1161	0.2696	1.254	2.007	291.31
	0.8 H_s	5.60	0.0635	0.1391	0.671	1.074	291.31
	0.9 H_s	6.30	0.0194	0.0396	0.200	0.320	291.31
	1.0 H_s	7.00	0.0000	0.0000	0.000	0.000	291.31

STEEL TYPE	Distance (% H_s)	Distance (feet)	Coefficients triangular loading	Coefficients uniform loading	unfactored Moment M (ft-kip / ft)	factored Moment M_u (ft-kip / ft)	Vertical Steel Req'd. for Bending (in^2/ft)	minimum flexural steel at max face (in^2/ft)
VERT STEEL	0.0 H_s	0.00	0.00000	0.00000	0.000	0.000	0.00	0.22
	0.1 H_s	0.70	0.00115	0.00100	0.027	0.060	0.00	0.22
	0.2 H_s	1.40	0.00421	0.00323	0.095	0.214	0.01	0.22
	0.3 H_s	2.10	0.00766	0.00521	0.170	0.383	0.01	0.22
	0.4 H_s	2.80	0.01065	0.00576	0.229	0.516	0.01	0.22
	0.5 H_s	3.50	0.01178	0.00365	0.240	0.540	0.01	0.22
	0.6 H_s	4.20	0.01026	-0.00325	0.178	0.400	0.01	0.22
	0.7 H_s	4.90	0.00424	-0.01525	0.005	0.012	0.00	0.22
	0.8 H_s	5.60	-0.00761	-0.03549	-0.317	-0.714	-0.02	0.22
	0.9 H_s	6.30	-0.02675	-0.06538	-0.825	-1.856	-0.05	0.22
	1.0 H_s	7.00	-0.05500	-0.10089	-1.532	-3.447	-0.09	0.22

Note: P = coef*(tri. pressure)*R + coef*(uni. pressure)*R , M = coef*(tri. pressure)*H_s^2 + coef*(uni. pressure)*H_s^2

Critical Wall Shear	V = 1.238 kip / ft , (shear at a distance "d" from the bottom of the wall)
Factored Critical Wall Shear	V_u = 1.980 kip / ft ϕV_c = 10.25
Base Horz Wall Reaction	Reaction = 1.185 kip /ft ,soil coef = 0.3275 ,uniform press coef = 0.4315
Foundation Ring Compression	F = 20.7 kip

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BY:	C. Che	**DATE:** Sep-17	**CLIENT:** Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**	Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:			External Soil Load Case		

$H_s^2 / (D*t_w) =$ 1.400 soil height, H_s = 7 ft

***** FORCES RESULTING FROM EXTERNAL SOIL COMPRESSION *****

STEEL TYPE | **DISTANCE FROM TOP OF SOIL** | **PINNED BASE CIRCULAR WALL**

STEEL TYPE	Distance (% H_s)	Distance (feet)	Coefficients triangular loading	Coefficients uniform loading	unfactored Hoop Compression, P (kip / ft)	factored Hoop Compression, P_u (kip / ft)	Ultimate Hoop Compression $\phi Pu = 0.85\phi(0.85 f'_c*A_g)$ (kip / ft)
HOOP COMPRESSION	0.0 H_s	0.00	0.3089	1.3089	4.372	6.995	291.31
	0.1 H_s	0.70	0.3279	1.2279	4.358	6.973	291.31
	0.2 H_s	1.40	0.3510	1.1510	4.379	7.007	291.31
	0.3 H_s	2.10	0.3659	1.0659	4.330	6.929	291.31
	0.4 H_s	2.80	0.3716	0.9716	4.204	6.727	291.31
	0.5 H_s	3.50	0.3631	0.8631	3.957	6.331	291.31
	0.6 H_s	4.20	0.3350	0.7305	3.535	5.657	291.31
	0.7 H_s	4.90	0.2854	0.5854	2.947	4.715	291.31
	0.8 H_s	5.60	0.2095	0.4095	2.128	3.405	291.31
	0.9 H_s	6.30	0.1109	0.2109	1.116	1.786	291.31
	1.0 H_s	7.00	0.0000	0.0000	0.000	0.000	291.31

STEEL TYPE	Distance (% H_s)	Distance (feet)	Coefficients triangular loading	Coefficients uniform loading	unfactored Moment M (ft-kip / ft)	factored Moment M_u (ft-kip / ft)	Vertical Steel Req'd. for Bending (in^2/ft)	minimum flexural steel at max face (in^2/ft)
VERT STEEL	0.0 H_s	0.00	0.00000	0.00000	0.000	0.000	0.00	0.22
	0.1 H_s	0.70	0.00139	0.00139	0.033	0.074	0.00	0.22
	0.2 H_s	1.40	0.00506	0.00506	0.120	0.271	0.01	0.22
	0.3 H_s	2.10	0.01008	0.01008	0.239	0.539	0.01	0.22
	0.4 H_s	2.80	0.01609	0.01609	0.382	0.860	0.02	0.22
	0.5 H_s	3.50	0.02154	0.02154	0.512	1.152	0.03	0.22
	0.6 H_s	4.20	0.02571	0.02571	0.611	1.375	0.03	0.22
	0.7 H_s	4.90	0.02749	0.02749	0.653	1.470	0.04	0.22
	0.8 H_s	5.60	0.02470	0.02470	0.587	1.321	0.03	0.22
	0.9 H_s	6.30	0.01623	0.01623	0.386	0.868	0.02	0.22
	1.0 H_s	7.00	0.00000	0.00000	0.000	0.000	0.00	0.22

Note: P = coef*(tri. pressure)*R + coef*(uni. pressure)*R , M = coef*(tri. pressure)*H_s^2 + coef*(uni. pressure)*H_s^2

Critical Wall Shear	V = 2.919 kip / ft , (shear at a distance "d" from the bottom of the wall)
Factored Critical Wall Shear	V_u = 4.671 kip / ft ϕV_c = 10.25
Base Horz Wall Reaction	Reaction = 0.735 kip /ft , soil coef = 0.2119 ,uniform press coef = 0.2119
Foundation Ring Compression	F = 12.9 kip

Check maximum buckling load using a short cylinder of length "L" with radial critical buckling load P_{cr}:

t_w = 1 ft R = 17.5 ft, ,use L as the soil loaded shell height, L = 7 ft E = 3605.0 ksi

poisson ratio, ν = 0.2 use a factor of safety of 2.5 for buckling, see Roark 6th ed. Table 35 case 19

$P_{cr} = \{ 0.807*E*t_w^2/(L*R)*((1/(1-\nu^2))^3*(t_w^2/R^2))^{1/4}\} / 2.5 =$ 337.17 k/ft

max fixed base hoop compressive load, P = 4.032 k/ft < 337.17 OK

max pinned hoop base compressive load, P = 4.379 k/ft < 337.17 OK

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP
SHEET:					
CHKD:		**DESCRIPTION:**	Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:	External Soil Load Case				

vertical steel required for the external soil loading…

depth the the vertical steel, d = 9 in

min gross vert shrinkage/ temperature steel ratio, ρ = 0.00300

M_u = 2.25 * M

SUMMARY OF VERTICAL STEEL REQUIREMENTS FOR THE EXTERNAL SOIL LOADING CASE

	Distance from top of soil (ft)	External Soil Loading				controlling $A_{s\,(req'd)}$ (in^2/ft)	$A_{s\,(min)}$ (in^2/ft)	Bar number	Bar spacing (in)	each face $A_{s(provided)}$ (in^2/ft)
		Fixed Base M (ft-kip / ft)	Fixed Base M_u (ft-kip / ft)	Pinned Base M (ft-kip / ft)	Pinned Base M_u (ft-kip / ft)					
VERT STEEL	0.00	0.000	0.000	0.000	0.000	0.00	0.22	**5**	**12**	0.31
	0.70	0.027	0.060	0.033	0.074	0.00	0.22	**5**	**12**	0.31
	1.40	0.095	0.214	0.120	0.271	0.01	0.22	**5**	**12**	0.31
	2.10	0.170	0.383	0.239	0.539	0.01	0.22	**5**	**12**	0.31
	2.80	0.229	0.516	0.382	0.860	0.02	0.22	**5**	**12**	0.31
	3.50	0.240	0.540	0.512	1.152	0.03	0.22	**5**	**12**	0.31
	4.20	0.178	0.400	0.611	1.375	0.03	0.22	**5**	**12**	0.31
	4.90	0.005	0.012	0.653	1.470	0.04	0.22	**5**	**12**	0.31
	5.60	-0.317	-0.714	0.587	1.321	0.03	0.22	**5**	**12**	0.31
	6.30	-0.825	-1.856	0.386	0.868	0.05	0.22	**5**	**12**	0.31
	7.00	-1.532	-3.447	0.000	0.000	0.09	0.22	**5**	**12**	0.31

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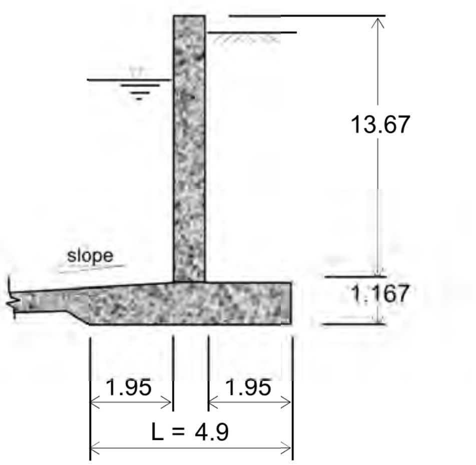
BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**			Area 11 - Sludge Thickener	**JOB NO:**	10721A.10
DESIGN TASK:					Ring Foundation		

Ringwall Foundation Design:

foundation projection on each side of wall, L_{fp} = **1.95** ft
max foundation thickness on the soil side, t_{fs} = **14** inch
foundation slope on the water side (i.e. 1:12) = **4** :12
soil density = **0.110** k / ft^3
allowable soil bearing pressure = **2** ksf
min foundation thickness on water side, t_{fw} = 6.20 inch
total foundation length, L = 2*(1.95)+(12/12) = 4.900 ft
tank wall thickness, t_w = 12 in
tank wall height = 13.67 ft
water height above top of foundation = 12 ft
soil height above top of foundation = 7 ft

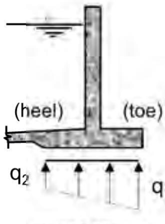


foundation loads:
wall wt. = 13.67*(12/12)*0.15 = 2.051 kip/ft
foundation slab wt. = 4.9*(14/12)*0.15 = 0.858 kip/ft
launder slab, wall, tough, grout = **0.27** kip/ft
water in trough = **0.0624** kip/ft
dome roof DL = **0.48** kip/ft
dome roof snow = **1.995** kip/ft
miscellaneous

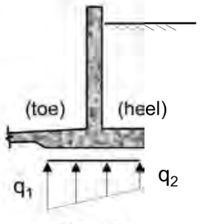
P_1 = wall + foundation + misc = 5.716 kip/ft
w_2 = water on foundation projection = 0.0624 * 12 = 0.749 ksf
P_2 = total water on foundation projection = 0.7488 * 1.95 = 1.460 kip/ft
w_3 = soil on foundation projection = 0.11 * 7 = 0.770 ksf
P_3 = total soil on foundation projection = 0.77 * 1.95 = 1.502 kip/ft

Conservatively design for the max wall moment for the fixed base wall and require that the full length of the foundation have contact with soil bearing (i.e. the kern fall within the middle third of the foundation, or other words e(max) = Lf / 6). Load cases of water and soil are checked independently of each other.

Refer to the circular wall and buried wall design tables for the max wall moments.
M_o = moment at center wall = (max wall moment) - $(L_{fp} + t_w)/2$ * (P_2 or P_3)
$P_o = P_1 + (P_2 \text{ or } P_3)$
$e = M_o / P_o$
kern = L / 6 = 0.8167 ft



water cases



soil case

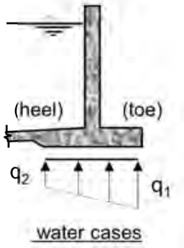
$$q_{1,2} = \frac{P_o}{L} * \left(1 \pm \frac{6\ e}{L}\right)$$

M_o = moment at center wall for the static water case = 2.827-((1.95+1)/2)*(1.46) = 0.673 ft-k/ft
M_o = moment at center wall for the static water + seismic case = 4.521-((1.95+1)/2)*(1.46) = 2.367 ft-k/ft
M_o = moment at center wall for the soil + LL surcharge case = 1.532-((1.95+1)/2)*(1.502) = -0.683 ft-k/ft

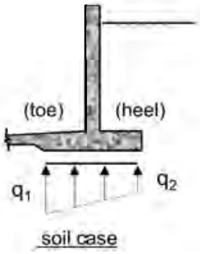
BY: C. Che **DATE:** Sep-17 **CLIENT:** Willamette River WTP **SHEET:**
CHKD: **DESCRIPTION:** Area 11 - Sludge Thickener **JOB NO:** 10721A.10
DESIGN TASK: Ring Foundation

foundation moments & shears…

$$q_{1,2} = \frac{P_o}{L} * \left(1 \pm \frac{6\,e}{L}\right)$$



water cases



soil case

$L =$ 4.9 ft
$e =$ M_o / P_o
$L_{(min)} = 6 * e_{(max)} =$ 6*0.33 = 1.979 ft
kern = L / 6 = 0.8167 ft

Soil Bearing Pressures at Maximum, Minimum, and Face of Wall Locations							
Load Case	M_o (ft-k/ft)	P_o (k/ft)	e (ft)	pressure q_1 (ksf)	pressure at face of wall on "q_1" side = q_{x1} (ksf)	pressure at face of wall on "q_2" side = q_{x2} (ksf)	pressure q_2 (ksf)
static water	0.673	7.177	0.094 e < kern	1.633	1.499	1.430	1.296
static water + seismic	2.367	7.177	0.330 e < kern	2.056	1.585	1.344	0.873
soil + LL surcharge	-0.683	7.218	-0.095 e < kern	1.644	1.508	1.438	1.302

net soil bearing pressures, $q_{net} = q_{gross}$ - insitu soil overburden. insitu soil overburden = 0.7 ksf

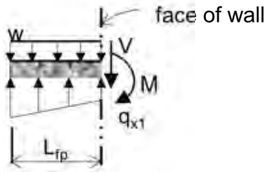
net soil bearing pressures, q_{net} = 2.056 - 0.7 = 1.356 ksf

Max net soil bearing is less than the allowable of 2 ksf, Okay.

moments and shears on the foundation projections:

$$M = \left(\frac{q_1}{3} + \frac{q_{x1}}{6} - \frac{w}{2}\right)\left(L_{fp}\right)^2$$

$$V = \left(\frac{q_1 + q_{x1}}{2} - w\right)L_{fp}$$



Example of Foundation Toe Projection Freebody

for water and soil cases on toe side, w = foundation wt = 0.175 = 0.175 ksf } toe
for the water cases on heel side, w = water above foundation + foundation wt = 0.749 + 0.175 = 0.924 ksf
for the soil case on heel side, w = soil above foundation + foundation wt = 0.77 + 0.175 = 0.945 ksf } heel

Foundation Moments and Shears										
		unfactored pressures					unfactored moments and shears			
						w	toe side		heel side	
Load Case	foundation projection (ft)	q_1 (ksf)	q_{x1} (ksf)	q_{x2} (ksf)	q_2 (ksf)	(toe or heel) (ksf)	M (ft-k/ft)	V (k/ft)	M (ft-k/ft)	V (k/ft)
static water	1.950	1.633	1.499	1.430	1.296	0.175 0.924	2.687	2.712	0.793	0.857
static water + seismic	1.950	2.056	1.585	1.344	0.873	0.175 0.924	3.278	3.209	0.202	0.360
soil + LL surcharge	1.950	1.644	1.508	1.438	1.302	0.175 0.945	2.706	2.731	0.766	0.829

BY:	C. Che	**DATE:**	Sep-17	**CLIENT:**	Willamette River WTP	**SHEET:**	
CHKD:		**DESCRIPTION:**		Area 11 - Sludge Thickener		**JOB NO:**	10721A.10
DESIGN TASK:		Ring Foundation					

foundation reinforcement…

Concrete load factor for moments = **2.25** use Mu = 2.25 * M

Concrete load factor for shears = **1.6** use Vu = 1.6 * V

minimum shrinkage/temp gross steel ratio, ρ = **0.00300**

d(top) = 14 - 3 - 0.5 = 10.5 in

d(bott) = 14 - 3 - 0.5 = 10.5 in

RINGWALL FOUNDATION STEEL

Location		max moments		d (in)	$A_{s\,(req'd)}$ (in^2/ft)	$A_{s\,(min)}$ (in^2/ft)	Bar number	Bar spacing (in)	$A_{s(provided)}$ (in^2/ft)	crack control Z
		M_{max} (ft-kip / ft)	M_u (ft-kip / ft)							
transverse steel	top steel (heel loads)	0.793	1.785	10.50	0.04	0.25	**5**	**12**	0.31	16
	bottom steel (toe loads)	3.278	7.376	10.50	0.16	0.25	**5**	**12**	0.31	65
hoop steel		total foundation hoop steel provided = 10 ~ #5 (distribute equally top & bottom) (refer to the circular wall design)								

CRACK CONTROL CRITERIA

Z < 95 for extreme exposures
Z < 115 for hydraulic structures
Z < 145 for exterior exposure
Z < 175 interior exposure

Foundation Shear: ϕ, Shear = 1

$V_{(max)}$ = 3.209 k/ft

V_u = 1.6 * 3.209 = 5.134 k/ft

nominal design shear strength, $\phi V_c = \phi * 2 * \sqrt{f'_c} * b * d_{min}$ = 15.938 k/ft

Vu ≤ øVc Okay

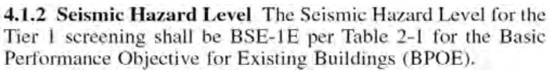
Area 12 - Sludge Dewatering Builidng
ASCE 41 Evaluation

Engineers...Working Wonders With Water™

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK					ASCE 41 (Tier 1 Screening) - Seismic		

SEISMIC HAZARD LEVEL & BASIC PERFORMANCE OBJECTIVE

Note:



4.1.2 Seismic Hazard Level The Seismic Hazard Level for the Tier 1 screening shall be BSE-1E per Table 2-1 for the Basic Performance Objective for Existing Buildings (BPOE).

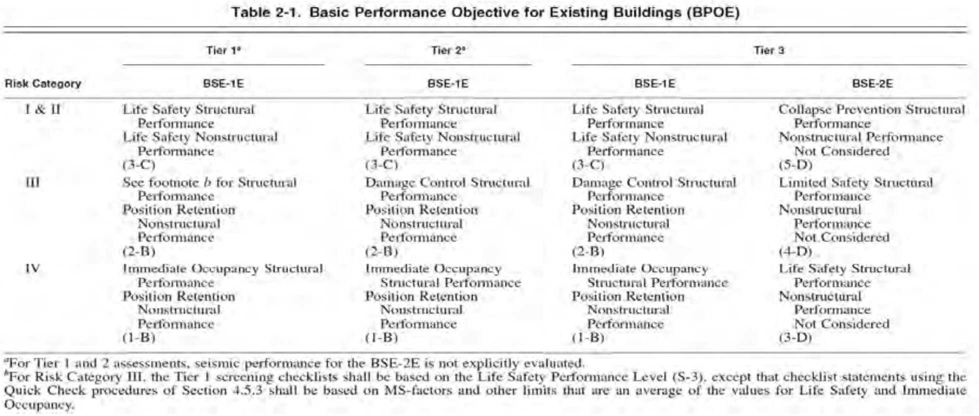


Table 2-1. Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1[a]	Tier 2[a]	Tier 3	
Risk Category	**BSE-1E**	**BSE-1E**	**BSE-1E**	**BSE-2E**
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III	See footnote *b* for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

[a] For Tier 1 and 2 assessments, seismic performance for the BSE-2E is not explicitly evaluated.

[b] For Risk Category III, the Tier 1 screening checklists shall be based on the Life Safety Performance Level (S-3), except that checklist statements using the Quick Check procedures of Section 4.5.3 shall be based on MS-factors and other limits that are an average of the values for Life Safety and Immediate Occupancy.

BUILDING PERIOD (SECTION 4.5.2.4)

building height, h_n = 31.00 ft

building period adjustment factor, C_t = 0.020

effective viscous damping ratio, β = 0.75

fundamental building period, T = 0.263 sec

SEISMIC PARAMETERS

Building Type = C2 Table 3-1

modification factor, C = 1.20 Table 4-8

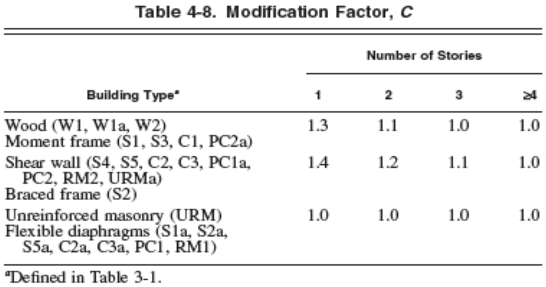


Table 4-8. Modification Factor, *C*

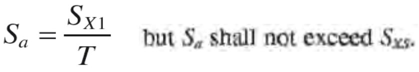
	Number of Stories			
Building Type[a]	**1**	**2**	**3**	**≥4**
Wood (W1, W1a, W2) Moment frame (S1, S3, C1, PC2a)	1.3	1.1	1.0	1.0
Shear wall (S4, S5, C2, C3, PC1a, PC2, RM2, URMa) Braced frame (S2)	1.4	1.2	1.1	1.0
Unreinforced masonry (URM) Flexible diaphragms (S1a, S2a, S5a, C2a, C3a, PC1, RM1)	1.0	1.0	1.0	1.0

[a] Defined in Table 3-1.

spectral acceleration at 1-sec for BSE-1E, S_{x1} = 0.372 g USGS Seismic Map

spectral acceleration at short period for BSE-1E, S_{xs} = 0.611 g USGS Seismic Map

spectral acceleration, S_a = 0.611 g



$$S_a = \frac{S_{X1}}{T}$$ but S_a shall not exceed S_{XS}.

base shear coefficient, V = 0.733 W Eq 4-1

Engineers...Working Wonders With Water™

BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 12 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening) - Building Weight & Base Shear

DEAD LOAD (Seismic Weight)

Roof Weight

Roofing = 10.00 psf
Metal Roof Deck = 3.00 psf
Steel Joist = 7.00 psf
Miscellaneous (MEP) = 10.00 psf
Total = 30.00 psf

Roof Length = 34.00 ft
Roof Width = 20.67 ft

Total Roof Weight = 21.08 kips

	Thick (in)	Trib Ht (ft)	Length (ft)			
Parapet Wall	8.00	1.50	112.00	=	16.80	kips
Wall Below	8.00	6.92	112.00	=	77.50	kips

Roof Seismic Weight = 115.38 kips

2nd Floor

12" Concrete Slab = 150.00 psf
Miscellaneous (MEP) = 10.00 psf
Low Roof Weight = 160.00 psf

Floor Length = 34.00 ft
Floor Width = 20.67 ft

Total Floor Weight = 112.43 kips

3-Centrifuges (35 kips each) 105.00 kips

	Thick (in)	Trib Ht (ft)	Length (ft)			
Wall Above	8.00	6.92	112.00	=	77.50	kips
Wall Below	12.00	9.00	70.67	=	95.40	kips

2nd Floor Seismic Weight = 390.33 kips

Seismic Weight & Base Shear

Base Shear Coefficient = 0.733 g
Total Seismic Weight = 506 kips
Design Base Shear = 371 kips

LIVE LOAD

Roof Live Load = 30.0 psf

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK					ASCE 41 (Tier 1 Screening) - Center of Mass		

DEAD LOAD (Seismic Weight)

Roof Weight

Roof Items	unif wt (psf)	Width (ft)	Length (ft)	W (kips)	x-C.M (ft)	y-C.M (ft)	W*x (kip-ft)	W*y (kip-ft)
Roof DL	30.00	20.67	34.00	21.08	17.67	11.00	373	232
	trib height	thick	length					
Walls	(ft)	(ft)	(ft)					
Parapet	1.50	0.67	112.00	16.80	17.67	11.00	297	185
Walls Below	6.92	0.67	112.00	77.50	17.67	11.00	1369	853
			Σ =	115.39			2039	1269

Origin at NW-Corner, x-C.M. = 17.67 ft

Origin at NW-Corner, y-C.M. = 11.00 ft

2nd Floor

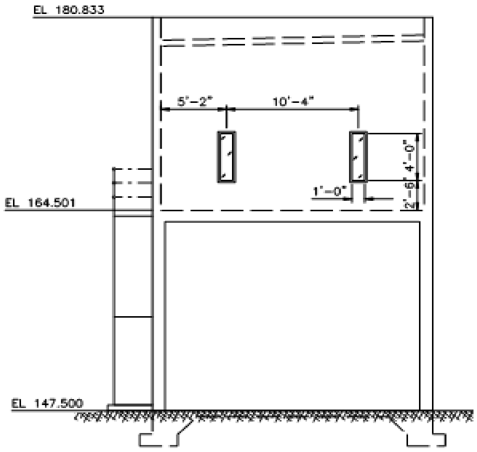
Floor Items	unif wt (psf)	Width (ft)	Length (ft)	W (kips)	x-C.M (ft)	y-C.M (ft)	W*x (kip-ft)	W*y (kip-ft)
12" Concrete Slab	150.00	20.67	34.00	105.42	17.67	11.00	1863	1160
Misc (MEP)	10.00	20.67	34.00	7.03	17.67	11.00	124	77
Floor Open 1	-150.00	5.00	12.00	-9.00	5.17	11.17	-47	-101
Floor Open 2	-150.00	1.83	1.83	-0.50	11.33	8.58	-6	-4
Floor Open 3	-150.00	1.83	1.83	-0.50	19.83	8.58	-10	-4
Floor Open 4	-150.00	1.83	1.83	-0.50	28.33	8.58	-14	-4
Cover Plate	20.17	5.00	12.00	1.21	5.17	11.17	6	14
Centrifuges								
Centrifuge 1				35.00	11.33	9.75	397	341
Centrifuge 2				35.00	19.83	9.75	694	341
Centrifuge 3				35.00	28.33	9.75	992	341
	trib height	thick	length					
Walls	(ft)	(ft)	(ft)					
Wall (above)	6.92	0.67	112.00	77.89	17.67	11.00	1376	857
Wall (below)	9.00	1.00	70.67	95.40	17.67	11.00	1686	1049
North Wall Opng	4.00	-0.67	1.00	-0.40	0.33	5.83	0	-2
North Wall Opng	4.00	-0.67	1.00	-0.40	0.33	16.17	0	-6
Sout Wall Opng	4.00	-0.67	1.00	-0.40	35.00	5.83	-14	-2
Sout Wall Opng	1.33	-0.67	1.33	-0.18	35.00	11.00	-6	-2
Sout Wall Opng	4.00	-0.67	1.00	-0.40	35.00	16.17	-14	-6
E-Wall Opng	7.17	-0.67	3.33	-2.40	2.67	21.67	-6	-52
			Σ =	377.25			7020	3995

Origin at NW-Corner, x-C.M. = 18.61 ft

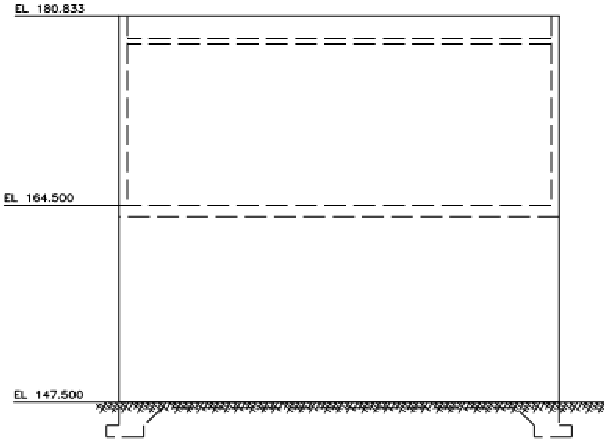
Origin at NW-Corner, y-C.M. = 10.59 ft

BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 12 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening) - Relative Rigidity

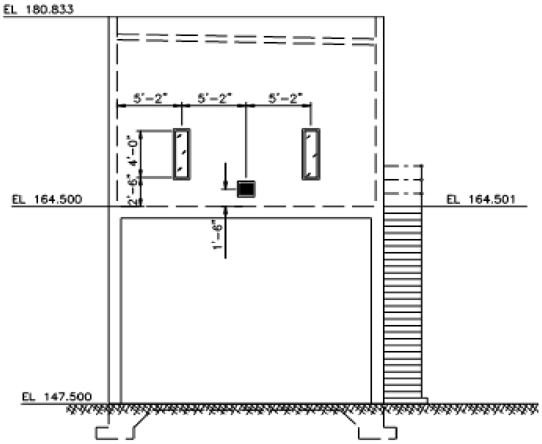
SOFT STORY CHECK (Relative Rigidity for Story Drift)



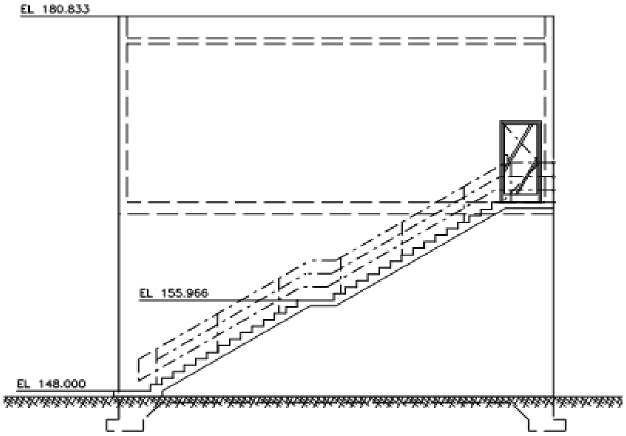
NORTH ELEVATION



WEST ELEVATION



SOUTH ELEVATION



EAST ELEVATION

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BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 12 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening) - Relative Rigidity

$P =$ 1000 kip -- applied unit force

$f'_c =$ 4000 psi -- concrete compressive strength
$E_{mc} =$ 519119.5 ksf -- modulus of elasticity
$E_v =$ 207647.8 ksf -- shear modulus

Cantilever at Top of Each Floor:

$$\delta_c = \frac{4P}{Et}\left[\left(\frac{H}{L}\right)^3 + 0.75\frac{H}{L}\right]$$

Fixed at Openings:

$$\delta_f = \frac{P}{Et}\left[\left(\frac{H}{L}\right)^3 + 3\frac{H}{L}\right]$$

	Thick (in)	Height (ft)	Length (ft)	I (ft^3)	Δ (in)	R 1/Δ	Δ_{net}	R_{story}		
					South Elevation					
2^{nd} - Roof	8.00	13.83	22.00	592	0.0998				*cantilever*	
opening(-)	-8.00	6.5	22.00	-592	-0.0316		0.07		*fix-fix*	
wall(+)	8.00	4	5.33	8	0.0927	10.79			*fix-fix*	
	8.00	4	9.33	45	0.0473	21.13			*fix-fix*	
	8.00	4	5.33	8	0.0927	10.79			*fix-fix*	
					ΣR =	42.70	0.02			
wall(+)	8.00	1.33	10.33	61	0.0135	74.26			*fix-fix*	
	8.00	1.33	10.33	61	0.0135	74.26			*fix-fix*	
					ΣR =	148.51	0.01		*fix-fix*	
wall(+)	8.00	1.17	22.00	592	0.0055	180.59	0.01		*fix-fix*	
						Wall Rigidity =>	0.10	9.62		
1^{st} - 2^{nd}	423.96	18	1.00	3	15.2986	0.07	15.30	0.07	*cantilever*	
						Stiffness Ratio: 1st to 2nd =		**1%**	**<---**	***NG***
					North Elevation					
2^{nd} - Roof	8.00	13.83	22.00	592	0.0998				*cantilever*	
opening(-)	-8.00	6.5	22.00	-592	-0.0316		0.07		*fix-fix*	
wall(+)	8.00	4	5.33	8	0.0927	10.79			*fix-fix*	
	8.00	4	9.33	45	0.0473	21.13			*fix-fix*	
	8.00	4	5.33	8	0.0927	10.79			*fix-fix*	
					ΣR =	42.70	0.02			
wall(+)	8.00	2.5	22.00	592	0.0119	84.23	0.01		*fix-fix*	
						Wall Rigidity =>	0.10	9.66		
1^{st} - 2^{nd}	423.96	18	1.00	3	15.2986	0.07	15.30	0.07	*cantilever*	
						Stiffness Ratio: 1st to 2nd =		**1%**	**<---**	***NG***

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BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 12 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening) - Relative Rigidity

West Elevation										
2nd - Roof	8.00	13.83	35.33	2450	0.0490	20.39	0.05	20.39	*cantilever*	
1st - 2nd	12.00	18	35.33	3675	0.0476	21.03	0.05	21.03	*cantilever*	
						Stiffness Ratio: 1st to 2nd =		**103%**	**<---**	***OK***
East Elevation										
2nd - Roof	8.00	13.83	35.33	2450	0.0490				*cantilever*	
opening(-)	-8.00	7.17	35.33	-2450	-0.0214		0.03		*fix-fix*	
wall(+)	8.00	7.17	31.00	1655	0.0245	40.84	0.02		*fix-fix*	
						Wall Rigidity =>	*0.05*	*19.18*		
1st - 2nd	12.00	18	35.33	3675	0.0476	21.03	0.05	21.03	*cantilever*	
						Stiffness Ratio: 1st to 2nd =		**110%**	**<---**	***OK***

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
CHKD BY		**DESCRIPTION**	Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
SHEET					
DESIGN TASK	ASCE 41 (Tier 1 Screening) - Weak Story				

WEAK STORY CHECK

f'c = 4000 psi

Longitudinal Direction

	1st Floor			2nd Floor		
Gridline	t_w (in)	L_{net} (ft)	$2(f'_c)^{0.5}t_wL_{net}$ (kips)	t_w (in)	L_{net} (ft)	$2(f'_c)^{0.5}t_wL_{net}$ (kips)
E-Wall	12.00	35.33	644	8.00	32.00	389
W-Wall	12.00	35.33	644	8.00	35.33	429
		Total =	1287		Total =	818

wall shear strength ratio of lower level to upper level = 157% <--- ***OK***

Transverse Direction

	1st Floor			2nd Floor		
Gridline	t_w (in)	L_{net} (ft)	$2(f'_c)^{0.5}t_wL_{net}$ (kips)	t_w (in)	L_{net} (ft)	$2(f'_c)^{0.5}t_wL_{net}$ (kips)
N-Wall	0.00	22.00	0	8.00	20.00	243
S-Wall	0.00	22.00	0	8.00	18.67	227
		Total =	0		Total =	470

wall shear strength ratio of lower level to upper level = 0% <--- ***NG***

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK					ASCE 41 (Tier 1 Screening) - Center of Rigidity		

CENTER OF RIGIDITY (Net Rigidity for Transfer of Diphragm Forces to Bottom of Wall)

Origin at Outside of N-W Wall Corner
x = Distance in N-S direction
y = Distance in E-W direction
Δ = Story drift per unit force
δ = Total Displacement per unit force

R_Δ = Rigidity of story drift
R_δ = Rigidity of Displacement

	R_{story} (1/in)	Δ_{story} (in)	δ (in)	$R_{x,wall}$	$R_{y,wall}$	x (N-S) (ft)	y (E-W) (ft)	$x*R_{wall}$	$y*R_{wall}$
South Elevation									
Roof	9.62	0.104	15.403	0.1	-	35.000	-	2.3	-
2nd	0.07	15.299	15.299	0.1	-	17.665	-	1.2	-
North Elevation									
Roof	9.66	0.104	15.402	0.1	-	0.330	-	0.0	-
2nd	0.07	15.299	15.299	0.1	-	17.665	-	1.2	-
West Elevation									
Roof	20.39	0.049	0.097	-	10.4	-	0.330	-	3.4
2nd	21.03	0.048	0.048	-	21.0	-	0.500	-	10.5
East Elevation									
Roof	19.18	0.052	0.100	-	10.0	-	21.670	-	217.4
2nd	21.03	0.048	0.048	-	21.0	-	21.500	-	452.1
			Σ 2nd =	0.1	20.4			2.3	220.8
			Σ 1st =	0.1	42.1			2.3	462.6

	C.R x-dir (ft)	***C.R y-dir (ft)***
Roof Diaphragm=	***17.665***	***10.832***
2nd Floor Diaphragm=	***17.665***	***11.000***

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK					ASCE 41 (Tier 1 Screening "Damage Control") - Shear Stress		

SEISMIC LOAD VERTICAL DISTRIBUTION

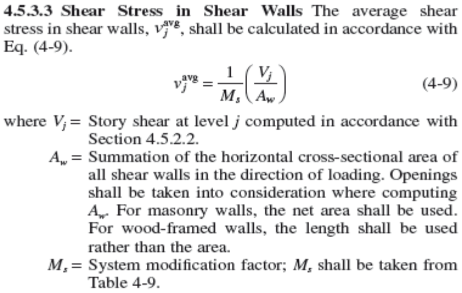
C_s = 0.733 g -- base shear coefficient

T = 0.263 sec -- building period

k = 1.00 -- building height exponential coefficient

Floors Level	Diaphragm Forces						Story Forces	
	w_x	h_x	$w_x*h_x^k$	$\frac{w_x*h_x^k}{\Sigma w_x*h_x^k}$	F_x / W_x	***$F_x = C_{vx} * V$***	V_x	M_x
	(kips)	(ft)	(kip-ft)			***(kips)***	(kips)	(kip-ft)
Roof	115	30.83	3546	0.36	1.14	***132***	0	0
2nd	390	16.50	6435	0.64	0.61	***239***	132	1885
1st							370	7993
Σ	505		9981	1.00		***370***		

Wall Shear Stress Check (Life Safety)



4.5.3.3 Shear Stress in Shear Walls The average shear stress in shear walls, v_j^{avg}, shall be calculated in accordance with Eq. (4-9).

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{A_w}\right) \qquad (4\text{-}9)$$

where V_j = Story shear at level j computed in accordance with Section 4.5.2.2.

A_w = Summation of the horizontal cross-sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration where computing A_w. For masonry walls, the net area shall be used. For wood-framed walls, the length shall be used rather than the area.

M_s = System modification factor; M_s shall be taken from Table 4-9.

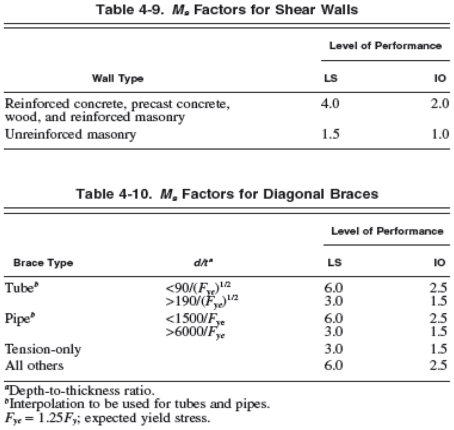


Table 4-9. M_s Factors for Shear Walls

Wall Type	Level of Performance LS	Level of Performance IO
Reinforced concrete, precast concrete, wood, and reinforced masonry	4.0	2.0
Unreinforced masonry	1.5	1.0

Table 4-10. M_s Factors for Diagonal Braces

Brace Type	d/t[a]	Level of Performance LS	Level of Performance IO
Tube[b]	$<90/(F_{ye})^{1/2}$ $>190/(F_{ye})^{1/2}$	6.0 3.0	2.5 1.5
Pipe[b]	$<1500/F_{ye}$ $>6000/F_{ye}$	6.0 3.0	2.5 1.5
Tension-only		3.0	1.5
All others		6.0	2.5

[a] Depth-to-thickness ratio.

[b] Interpolation to be used for tubes and pipes.

$F_{ye} = 1.25F_y$; expected yield stress.

$2*(f'_c)^{1/2} = 2*(4000)^{1/2}$ = 126 psi

M_s ("IO") = 3.0 <-- Damage Control (between "LS" & "IO")

		t_{wall} (in)	L_{wall} (ft)	A_{wall} (in^2)	*v_{shear}* (psi)	
2nd Floor	N-Wall	8.00	20.00	1920	-	
	S-Wall	8.00	18.17	1744	-	
			Σ	3664	11.96	***<= OK***
2nd Floor	E-Wall	8.00	32.00	3072	-	
	W-Wall	8.00	35.33	3392	-	
			Σ	6464	6.78	***<= OK***

		t_{wall} (in)	L_{wall} (ft)	A_{wall} (in^2)	*v_{shear}* (psi)	
1st Floor	N-Wall	0.00	0.00	0	-	
	S-Wall	0.00	0.00	0	-	
			Σ	0	########	***<= NG***
1st Floor	E-Wall	12.00	32.00	4608	-	
	W-Wall	12.00	35.33	5088	-	
			Σ	9696	12.73	***<= OK***

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**	Area 12 - Sludge Dewatering Building			**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 - Damage Control - Roof Diaph Shear in Transverse Direction					

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, K = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Seismic Load Vertical Distribution

spectral acceleration, S_a = 0.611 g
pseudo seismic coefficient, $C_s = C_1C_2C_mS_a$ = 0.855 g

building period, T = 0.263 sec
building height exponentional coefficient, k = 1.00

Floors Level	Diaphragm Force Distribution						Story Forces	
	w_x	h_x	$w_x{*}h_x^k$	$\frac{w_x{*}h_x^k}{\Sigma\, w_x{*}h_x^k}$	F_x / W_x	$F_x = C_{vx}{*}V$	V_x	M_x
	(kips)	(ft)	(kip-ft)			***(kips)***	(kips)	(kip-ft)
Roof	78	30.83	2405	0.29	1.38	***108***	0	0
2nd	356	16.50	5874	0.71	0.74	***263***	108	1546
1st							371	7671
Σ	434		8279	1.00		***371***		

Roof Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 34.00 ft
diaphragm depth, L_{diaph} = 20.67 ft

roof diaphragm force = 108 kips
diaph shear, $Q_{UD} = F_d / (2{*}L_{diaph})$ = 2613 plf

allowable diaphragm shear = 1069 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1710 plf
$m_1{*}\mathrm{K}{*}Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

chord force, $Q_{UD} = (F_d{*}L_{span}) / (8{*}L_{diaph})$ = 22210 lbs

strength reduction factor, ϕ = 1.00
Number of Bars = 4 bars
Bar Size = #5
Yield Stress f_y = 60,000 psi

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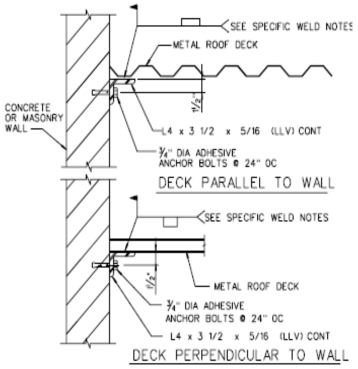
BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**		Area 12 - Sludge Dewatering Building		**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 - Damage Control - Roof Diaph Shear in Transverse Direction					

$A_{s,total}$ = 1.24 in^2
Tensile Capacity at Opng, ϕT_n = 74400 lbs
$m_2 * K * Q_{CE}$ = 269700 lbs



Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in

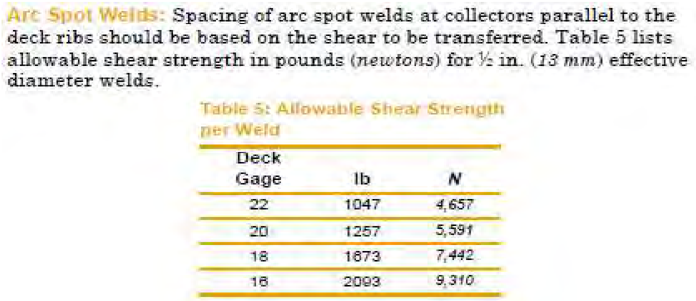
anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

anchor bolt shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 5226 lbs /bolt
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 1866 lbs /bolt

projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt
cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

strength reduction factor, ϕ = 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y$ = 15904 lbs /bolt steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddle weld shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 2613 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 933 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, C_{WELD} = 1.65 per IAPMO-ER #0217
KQ_{CL} = 2074 lbs /weld

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**	Area 12 - Sludge Dewatering Building			**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 - Damage Control - Roof Diaph Shear in Transverse Direction						

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.94	**<--**	***OK***	diaphragm shear
demand capcity ratio, DCR =	*0.08*	**<--**	***OK***	diaphragm chord
demand capcity ratio, DCR =	*0.31*	**<--**	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.35*	**<--**	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.08*	**<--**	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.12*	**<--**	***OK***	steel yielding
demand capcity ratio, DCR =	0.45	**<--**	***OK***	puddle weld strength

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CHKD BY		**DESCRIPTION**		Area 12 - Sludge Dewatering Building		**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 - Damage Control - Concrete Diaph in Transverse Direction					

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, K = 1.00 per Table 6-1

diaphragm shear, m_1-factor = 1.375 per Table 10-13 (between "IO" & "LS")
diaphragm chord, m_2-factor = 1.625 per Table 10-13 (between "IO" & "LS")

Roof Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 34.00 ft
diaphragm depth, L_{diaph} = 20.67 ft

concrete diaphragm force = 263 kips
diaph shear, $Q_{UD} = F_d / (2*L_{diaph})$ = 6.36 kips

f'_c = 4000 psi
diaph thick, t = 12 in

concrete shear capacity, Q_{CE} = 18.21 kips
$m_1*\mathrm{K}*Q_{CE}$ = 25.05 kips

Chord Force (Tier 2 - Deformation Controlled)

chord force, $Q_{UD} = (F_d*L_{span}) / (8*L_{diaph)}$ = 54.08 kips

strength reduction factor, ϕ = 1.00
Number of Bars = 4 bars
Bar Size = #5
Yield Stress f_y = 60 ksi
$A_{s,total}$ = 1.24 in^2
Tensile Capacity at Opng, ϕT_n = 74.40 kips
$m_2*\mathrm{K}*Q_{CE}$ = 120.90 kips

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = 0.25 <-- ***OK*** diaphragm shear
demand capcity ratio, DCR = *0.45* <-- ***OK*** diaphragm chord

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SHEET					
CHKD BY		**DESCRIPTION**	Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 - Damage Control - Roof Diaph Shear in Longitudinal Direction				

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, Κ = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Seismic Load Vertical Distribution

spectral acceleration, S_a = 0.611 g
pseudo seismic coefficient, $C_s = C_1C_2C_mS_a$ = 0.855 g

building period, T = 0.263 sec
building height exponentional coefficient, k = 1.00

Floors Level	Diaphragm Force Distribution						Story Forces	
	w_x	h_x	$w_x{*}h_x^k$	$\frac{w_x{*}h_x^k}{\Sigma\, w_x{*}h_x^k}$	F_x / W_x	$\boldsymbol{F_x = C_{vx}{*}V}$	V_x	M_x
	(kips)	(ft)	(kip-ft)			***(kips)***	(kips)	(kip-ft)
Roof	56	30.83	1727	0.26	1.41	***79***	0	0
2nd	302	16.50	4983	0.74	0.75	***227***	79	1130
1st							306	6182
Σ	358		6710	1.00		***306***		

Roof Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 20.67 ft
diaphragm depth, L_{diaph} = 34.00 ft

roof diaphragm force = 79.00 kips
diaph shear, $Q_{UD} = F_d / (2{*}L_{diaph})$ = 1162 plf

allowable diaphragm shear = 1069 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1710 plf
$m_1{*}Κ{*}Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

chord force, $Q_{UD} = (F_d{*}L_{span}) / (8{*}L_{diaph})$ = 6003 lbs

strength reduction factor, φ = 1.00
Number of Bars = 4 bars
Bar Size = #5
Yield Stress f_y = 60,000 psi

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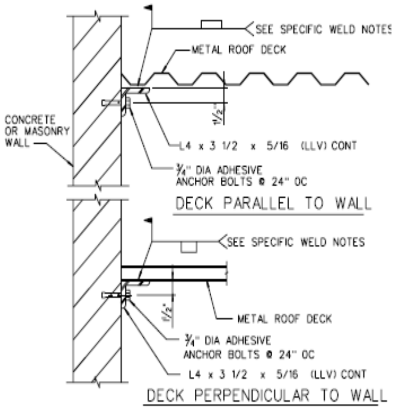
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 - Damage Control - Roof Diaph Shear in Longitudinal Direction					

$A_{s,total}$ = 1.24 in^2
Tensile Capacity at Opng, ϕT_n = 74400 lbs
$m_2 \cdot K \cdot Q_{CE}$ = 269700 lbs



Masonry & Steel Strength (Tier 2 - Force Controlled)

anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f_m = 1500 psi

anchor bolt shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 2324 lbs /bolt
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 830 lbs /bolt

projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt
cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

strength reduction factor, ϕ = 1.00
$KQ_{CL} = K\phi B_{vnb} = K*\phi*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt masonry breakout
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt masonry crushing
$KQ_{CL} = K\phi B_{vnpry} = K*\phi*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt anchor bolt pryout
$KQ_{CL} = K\phi B_{vns} = K*\phi*0.6*A_b*f_y$ = 15904 lbs /bolt steel yielding

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)

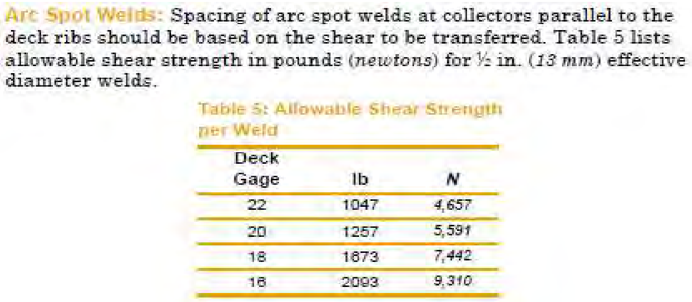

Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddle weld shear, $Q_E = V_{bolt} = (V / 2L_{diaph})*(s/12)$ = 1162 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 415 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, C_{WELD} = 1.65 per IAPMO- allowable multiplied by 1.4 for
KQ_{CL} = 2074 lbs /weld

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**	Area 12 - Sludge Dewatering Building			**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 - Damage Control - Roof Diaph Shear in Longitudinal Direction						

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.42	**<--**	***OK***	diaphragm shear
demand capcity ratio, DCR =	*0.02*	**<--**	***OK***	diaphragm chord
demand capcity ratio, DCR =	*0.14*	**<--**	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.16*	**<--**	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.03*	**<--**	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.05*	**<--**	***OK***	steel yielding
demand capcity ratio, DCR =	0.20	**<--**	***OK***	puddle weld strength

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CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK				ASCE 41 - Damage Control - Concrete Diaph in Longitudinal Direction			

DIAPHRAGM IN-PLANE SHEAR & CONNECTION

Knowledge factor, κ = 1.00 per Table 6-1

diaphragm shear, m_1-factor = 1.375 per Table 10-13 (between "IO" & "LS")
diaphragm chord, m_2-factor = 1.625 per Table 10-13 (between "IO" & "LS")

Roof Diaphragm Shear (Tier 2 - Deformation Controlled)

diaphragm span, L_{span} = 34.00 ft
diaphragm depth, L_{diaph} = 20.67 ft

concrete diaphragm force = 227 kips
diaph shear, $Q_{UD} = F_d / (2^*L_{diaph})$ = 5.49 kips

f'_c = 4000 psi
diaph thick, t = 12 in

concrete shear capacity, Q_{CE} = 18.21 kips
$m_1{}^*\kappa^*Q_{CE}$ = 25.05 kips

Chord Force (Tier 2 - Deformation Controlled)

chord force, $Q_{UD} = (F_d{}^*L_{span}) / (8^*L_{diaph})$ = 46.68 kips

strength reduction factor, ϕ = 1.00
Number of Bars = 4 bars
Bar Size = #5
Yield Stress f_y = 60 ksi
$A_{s,total}$ = 1.24 in^2
Tensile Capacity at Opng, ϕT_n = 74.40 kips
$m_2{}^*\kappa^*Q_{CE}$ = 120.90 kips

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = 0.22 <-- ***OK*** diaphragm shear
demand capcity ratio, DCR = *0.39* <-- ***OK*** diaphragm chord

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CHKD BY **DESCRIPTION** Area 12 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Joist Supports

WALL ANCHORAGE

4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \tag{4-13}$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

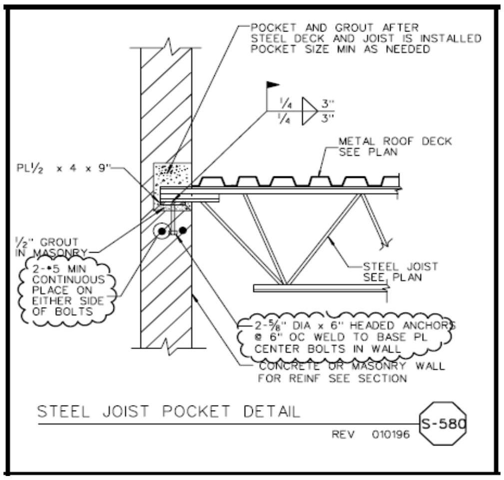
wall thickness, t_w = 8.00 in
wall height to diaphragm, h_w = 13.83 ft
parapet height, h_p = 1.50 ft

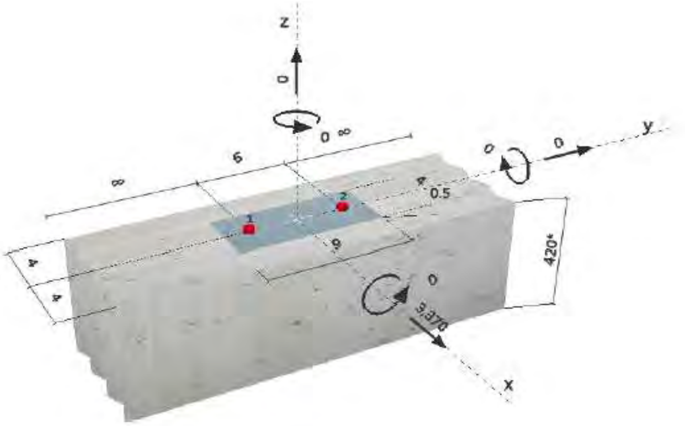
unit weight of wall, w_p = 150.00 pcf
Ψ ("IO") = 1.50 <-- Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

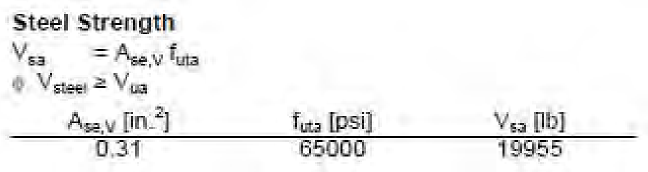
beam spacing = 5.67 ft
wall out-of-plane load = 771 lbs/ ft

wall anchorage force, T_c = 4370 lbs

Anchor Bolts







Steel Strength

$V_{sa} = A_{se,V} f_{uta}$

$\phi \ V_{steel} \geq V_{ua}$

$A_{se,V}$ [in.^{2}]	f_{uta} [psi]	V_{sa} [lb]
0.31	65000	19955

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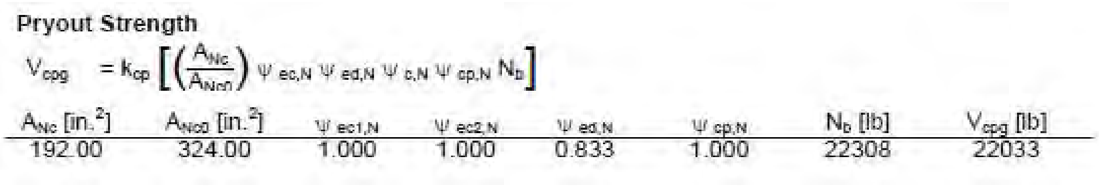
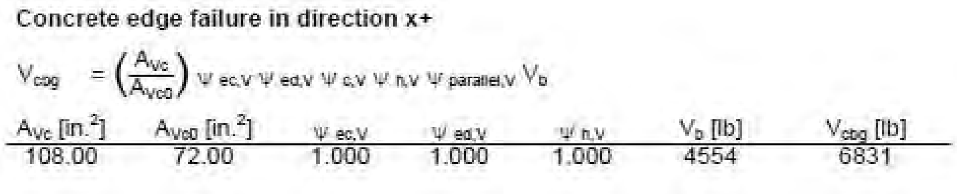
CHKD BY **DESCRIPTION** Area 12 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Joist Supports



Pryout Strength

$$V_{cpg} = k_{cp}\left[\left(\frac{A_{Nc}}{A_{Nc0}}\right)\psi_{ec,N}\,\psi_{ed,N}\,\psi_{c,N}\,\psi_{cp,N}\,N_b\right]$$

A_{Nc} [in.^{2}]	A_{Nc0} [in.^{2}]	$\psi_{ec1,N}$	$\psi_{ec2,N}$	$\psi_{ed,N}$	$\psi_{cp,N}$	N_b [lb]	V_{cpg} [lb]
192.00	324.00	1.000	1.000	0.833	1.000	22308	22033



Concrete edge failure in direction x+

$$V_{cbg} = \left(\frac{A_{Vc}}{A_{Vc0}}\right)\psi_{ec,V}\,\psi_{ed,V}\,\psi_{c,V}\,\psi_{h,V}\,\psi_{parallel,V}\,V_b$$

A_{Vc} [in.^{2}]	A_{Vc0} [in.^{2}]	$\psi_{ec,V}$	$\psi_{ed,V}$	$\psi_{h,V}$	V_b [lb]	V_{cbg} [lb]
108.00	72.00	1.000	1.000	1.000	4554	6831

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

V_{sa} = 39,910 lbs steel shear strength for 2-bolts
V_{cpg} = 22,033 lbs pryout strength
V_{cbg} = 6,831 lbs concrete edge failure

pryout overstrength factor, Ω_{cpg} = 2.5 concrete governed
concrete edge failure overstrength factor, Ω_{cbg} = 2.5 concrete governed

demand capcity ratio, DCR = *0.11* **<--** ***OK*** steel shear strength
demand capcity ratio, DCR = *0.50* **<--** ***OK*** pryout strength
demand capcity ratio, DCR = *1.60* **<--** ***NG*** concrete edge failure

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger						

WALL ANCHORAGE

4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \tag{4-13}$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

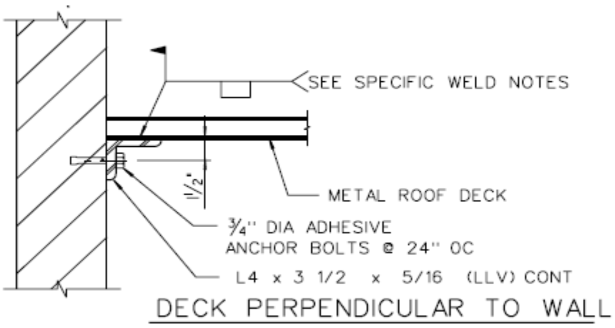
wall thickness, t_w = 8.00 in
wall height to diaphragm, h_w = 13.83 ft
parapet height, h_p = 1.50 ft

unit weight of wall, w_p = 150.00 pcf
Ψ ("IO") = 1.50 <-- Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

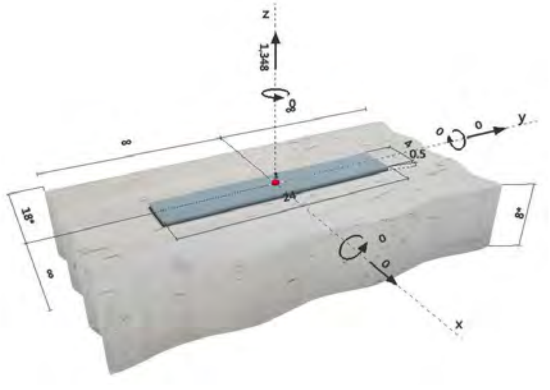
anchor bolt spacing = 24.00 in
wall out-of-plane load = 771 lbs/ ft

wall anchorage force, T_c = 1542 lbs /bolt

Anchor Bolts (Assumed 3.5" Min Embed)



DECK PERPENDICULAR TO WALL



Anchor Bolt Strength Parameters

anchor bolt diameter, d_a = 0.75 in
tensile stress area, A_{se} = 0.33 in^2
anchor bolt embed, h_{ef} = 3.50 in minimum embed assumed

specified anchor bolt strength, f_{uta} = 58,000 psi
concrete strength, f'_c = 4,000 psi

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**	Area 12 - Sludge Dewatering Building			**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger						

k_c = 17.00
λ = 1.00
N_b = 7,040 lbs /bolt

A_{Nc} = 110.25 in^2
A_{Nco} = 110.25 in^2

$\Psi_{ed,N}$ = 1.00
$\Psi_{c,N}$ = 1.00
$\Psi_{CP,N}$ = 1.00

steel strength, N_{sa} = 19,372 lbs /bolt
concrete pullout strength, N_{cb} = 7,040 lbs /bolt
concrete overstrength factor, Ω_{cb} = 2.5 concrete governed

Ledger Angle

yield strength, f_y = 36,000 psi
ledger angle thick, t = 0.31 in
moment arm, l_{arm} = 1.19 in distance from top of ledger to center of AB
effective width, b = 3.00 in
section modulus, S = 0.0488 in^3

shear stress = 1,645 psi

moment = 1,836 lb-in
flexural stress = 37,592 psi

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR = *0.08* **<--** ***OK*** steel strength
demand capcity ratio, DCR = *0.55* **<--** ***OK*** concrete strength

demand capcity ratio, DCR = *0.05* **<--** ***OK*** ledger shear
demand capcity ratio, DCR = *1.04* **<--** ***NG*** ledger flexural

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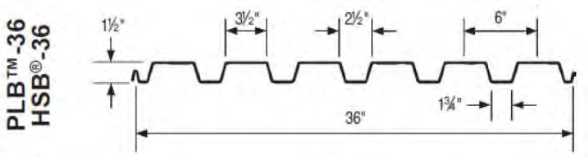
BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Area 12 - Sludge Dewatering Building **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck

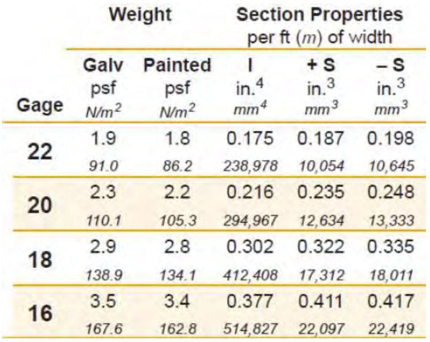
STEEL DECK PROPERTIES (ASTM A653, Grade 33)

Modulus of Elasticity, E = 29500 ksi

Yield Strength, F_y = 38 ksi

Ultimate Strength, F_u = 52 ksi





Gage	Weight Galv psf N/m²	Weight Painted psf N/m²	Section Properties per ft (m) of width I in.⁴ mm⁴	+S in.³ mm³	−S in.³ mm³
22	1.9 91.0	1.8 86.2	0.175 238,978	0.187 10,054	0.198 10,645
20	2.3 110.1	2.2 105.3	0.216 294,967	0.235 12,634	0.248 13,333
18	2.9 138.9	2.8 134.1	0.302 412,408	0.322 17,312	0.335 18,011
16	3.5 167.6	3.4 162.8	0.377 514,827	0.411 22,097	0.417 22,419

Steel Deck = HSB-36

Gage = 20

Deck Span, L = 5.67 ft

DESIGN LOAD (Service Level)

Roof Load, w = 30 psf *--- steel deck gravity*

Wall Out-of-Plane Load, F = 771 lb/ft *--- deck axial load*

Design Flexural Moment :

Neutral Axis, y_b = 0.919 in

M_{roof} = 1.447 kip-in /ft *--- moment due to gravity load = w * L^2 / 8*

M_{ecc} = 0.506 kip-in /ft *--- moment due to wall out-of-plane = (F/1.4) * yb*

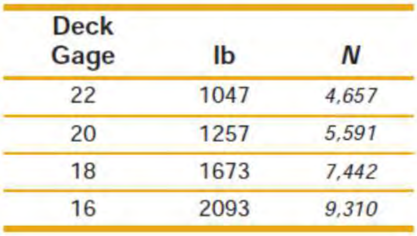
M_{total} = 1.953 kip-in /ft

ARC-SPOT WELD (WALL OUT-OF-PLANE)

Effective Weld Size Dia, d_e = 1/2 in

Weld Pattern = 5 per 36/sheet

Allowable Weld Capacity = 2.10 kip/ft **<= OK**



Deck Gage	lb	N
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

Allowable shear strength for 1/2" effective diameter puddle welds.

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck						

STEEL DECK ALLOWABLE COMPRESSION

Effective Length Factor, K = 1.00

Deck Thickness, t = 0.0359 in

Width of Top Flange, w = 3.50 in

Gross Section Area, A_g = 0.599 in^2/ft

radius of gyration, r = 0.601 in

KL/r = 113

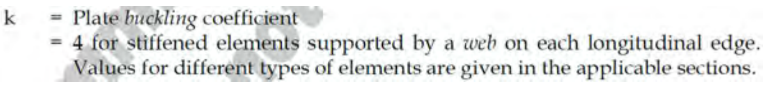
λ_c = 1.29

F_n = 18.85 ksi

Effective Width of Top & Bottom Flange Under Compression
(Assume Bottom Flange Fully Effective)

Ω_c = 1.8 --- *factor of safety*

k = 4



k = Plate buckling coefficient
= 4 for stiffened elements supported by a *web* on each longitudinal edge. Values for different types of elements are given in the applicable sections.

Poisson's Ratio = 0.300

F_{cr} = 11.22

λ = 1.296

ρ = 0.641

Effective Flange Width, b = 2.242 in --- *effective flange width =* ρw

Effective Section Area, A_e = 0.554 in^2/ft --- *effective section area*

P_n / Ω_c = 5.80 kip /ft **<= OK** --- $A_e * F_n / \Omega_c$

STEEL DECK ALLOWABLE TENSION

Gross Section Area, A_g = 0.599 in^2/ft

Ω_{T1} = 1.67

T_{n1} / Ω_{T1} = 13.63 kip /ft **<= OK** --- $A_g * F_y / \Omega_{T1}$

Ω_{T2} = 2.00

T_{n2} / Ω_{T2} = 15.57 kip /ft **<= OK** --- $A_g * F_u / \Omega_{T2}$

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Area 12 - Sludge Dewatering Building	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck						

STEEL DECK ALLOWABLE BENDING

Ω_b = 1.67

S_+ = 0.235 in^3/ft --- *positive section modulus*

M_n / Ω_b = 5.35 kip-in /ft **<= OK** --- $S_+ * F_y / \Omega_b$

COMBINED LOAD INTERACTION

Bending-Tension Interaction:

DCR = 0.422 **<= OK**

Bending-Compression Interaction:

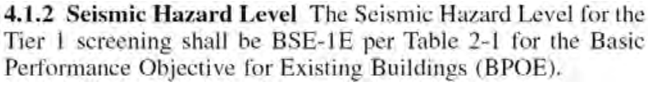
DCR = 0.498 **<= OK**

Areas 13, 18, 19 - Chemical / Admin / Ozone Building
ASCE 41 Evaluation

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Areas 13,18,19 - Buildings	**JOB NO.**	10721A.00
DESIGN TASK					ASCE 41 (Tier 1 Screening) - Seismic		

SEISMIC HAZARD LEVEL & BASIC PERFORMANCE OBJECTIVE

Note:



4.1.2 Seismic Hazard Level The Seismic Hazard Level for the Tier 1 screening shall be BSE-1E per Table 2-1 for the Basic Performance Objective for Existing Buildings (BPOE).

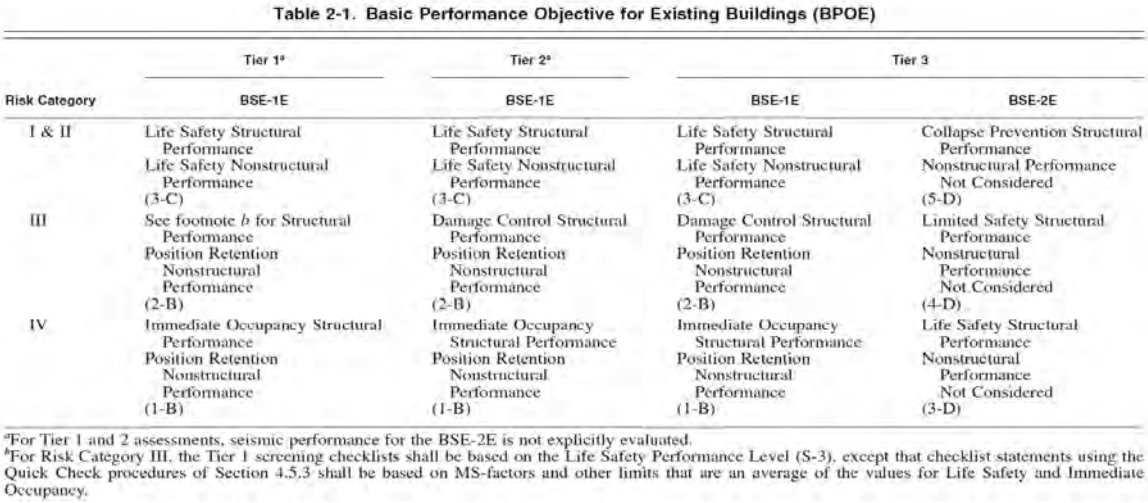


Table 2-1. Basic Performance Objective for Existing Buildings (BPOE)

	Tier 1[a]	Tier 2[a]	Tier 3	
Risk Category	BSE-1E	BSE-1E	BSE-1E	BSE-2E
I & II	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Life Safety Structural Performance Life Safety Nonstructural Performance (3-C)	Collapse Prevention Structural Performance Nonstructural Performance Not Considered (5-D)
III	See footnote *b* for Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Damage Control Structural Performance Position Retention Nonstructural Performance (2-B)	Limited Safety Structural Performance Nonstructural Performance Not Considered (4-D)
IV	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Immediate Occupancy Structural Performance Position Retention Nonstructural Performance (1-B)	Life Safety Structural Performance Nonstructural Performance Not Considered (3-D)

[a] For Tier 1 and 2 assessments, seismic performance for the BSE-2E is not explicitly evaluated.
[b] For Risk Category III, the Tier 1 screening checklists shall be based on the Life Safety Performance Level (S-3), except that checklist statements using the Quick Check procedures of Section 4.5.3 shall be based on MS-factors and other limits that are an average of the values for Life Safety and Immediate Occupancy.

BUILDING PERIOD (SECTION 4.5.2.4)

building height, h_n = 16.00 ft

building period adjustment factor, C_t = 0.020

effective viscous damping ratio, β = 0.75

fundamental building period, T = 0.160 sec

SEISMIC PARAMETERS

Building Type = RM1 Table 3-1

modification factor, C = 1.00 Table 4-8

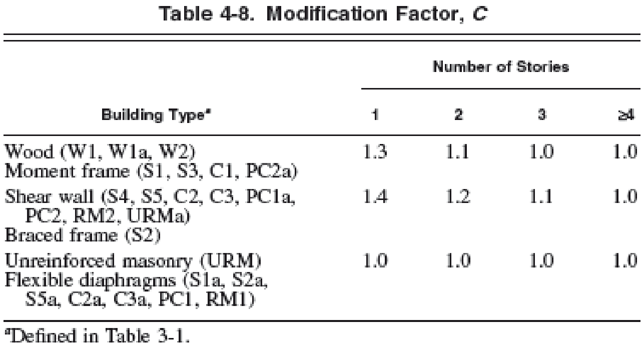


Table 4-8. Modification Factor, *C*

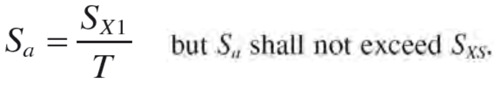
	Number of Stories			
Building Type[a]	1	2	3	≥4
Wood (W1, W1a, W2) Moment frame (S1, S3, C1, PC2a)	1.3	1.1	1.0	1.0
Shear wall (S4, S5, C2, C3, PC1a, PC2, RM2, URMa) Braced frame (S2)	1.4	1.2	1.1	1.0
Unreinforced masonry (URM) Flexible diaphragms (S1a, S2a, S5a, C2a, C3a, PC1, RM1)	1.0	1.0	1.0	1.0

[a] Defined in Table 3-1.

spectral acceleration at 1-sec for BSE-1E, S_{x1} = 0.372 g USGS Seismic Map

spectral acceleration at short period for BSE-1E, S_{xs} = 0.611 g USGS Seismic Map

spectral acceleration, S_a = 0.611 g



$$S_a = \frac{S_{X1}}{T} \quad \text{but } S_a \text{ shall not exceed } S_{XS}.$$

base shear coefficient, V = 0.611 W Eq 4-1

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CHKD BY		**DESCRIPTION**			Areas 13,18,19 - Buildings	**JOB NO.**	10721A.00
DESIGN TASK			ASCE 41 (Tier 1 Screening) - Building Weight & Base Shear				

DEAD LOAD (Seismic Weight)

Roof Weight

Roofing	=	5.00	psf
Metal Roof Deck	=	3.00	psf
Steel Joist	=	7.00	psf
Miscellaneous (MEP)	=	5.00	psf
	Total =	20.00	psf
Total Roof Area	=	13255.00	sq.ft
	Total Roof Weight =	265.10	kips

	UW (psf)	Trib Ht (ft)	Length (ft)			
Area 13	84.00	8.00	209.34	=	140.68	kips
Area 18	84.00	8.00	247.32	=	166.20	kips
Area 19	84.00	8.00	130.00	=	87.36	kips
				Roof Seismic Weight =	***659.34***	***kips***

Seismic Weight & Base Shear

Base Shear Coefficient	=	0.611	g
Total Seismic Weight	=	659	kips
Design Base Shear	=	403	kips

LIVE LOAD

Roof Live Load	=	20.0	psf

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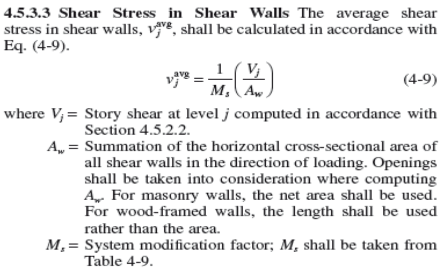
CHKD BY		**DESCRIPTION**			Areas 13,18,19 - Buildings	**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Shear Stress					

SEISMIC LOAD VERTICAL DISTRIBUTION

Wall Shear Stress Check



4.5.3.3 Shear Stress in Shear Walls The average shear stress in shear walls, v_j^{avg}, shall be calculated in accordance with Eq. (4-9).

$$v_j^{avg} = \frac{1}{M_s}\left(\frac{V_j}{A_w}\right) \tag{4-9}$$

where V_j = Story shear at level j computed in accordance with Section 4.5.2.2.

A_w = Summation of the horizontal cross-sectional area of all shear walls in the direction of loading. Openings shall be taken into consideration where computing A_w. For masonry walls, the net area shall be used. For wood-framed walls, the length shall be used rather than the area.

M_s = System modification factor; M_s shall be taken from Table 4-9.

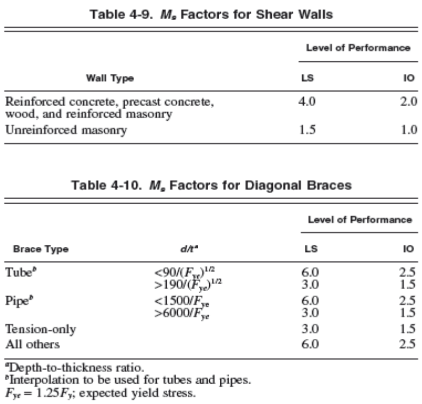


Table 4-9. M_s Factors for Shear Walls

	Level of Performance	
Wall Type	LS	IO
Reinforced concrete, precast concrete, wood, and reinforced masonry	4.0	2.0
Unreinforced masonry	1.5	1.0

Table 4-10. M_s Factors for Diagonal Braces

		Level of Performance	
Brace Type	d/t[a]	LS	IO
Tube[b]	$<90/(F_{ye})^{1/2}$ $>190/(F_{ye})^{1/2}$	6.0 3.0	2.5 1.5
Pipe[b]	$<1500/F_{ye}$ $>6000/F_{ye}$	6.0 3.0	2.5 1.5
Tension-only		3.0	1.5
All others		6.0	2.5

[a] Depth-to-thickness ratio.
[b] Interpolation to be used for tubes and pipes.
$F_{ye} = 1.25F_y$; expected yield stress.

$v_{s,allow}$ = 70 psi
M_s = 3.0 <-- Damage Control (between "LS" & "IO")

	t_{wall} (in)	$L_{net,\ wall}$ (ft)	A_{wall} (in^2)	*V* *(kips)*	*v_{shear}* *(psi)*	
Walls in NS-Dir	7.63	271.19	24814	*403.00*	*5.41*	***<= OK***
Walls in EW-Dir	7.63	266.00	24339	*403.00*	*5.52*	***<= OK***

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BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Areas 13,18,19 - Buildings **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in NS-Dir

DIAPHRAGM IN-PLANE SHEAR CONNECTION

Knowledge factor, K = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3
effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")
diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

spectral acceleration, S_a = 0.611 g
building seismic weight, W = 659 kips

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 564 kips
total length of diaph support in NS-Dir, $L_{support}$ = 366 ft "Combined Total Length of Supports"
diaph shear, $Q_{UD} = F_d / L_{support}$ = 1539 plf

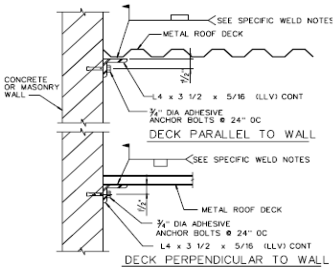
allowable diaphragm shear = 1069 plf per IAPMO-ER #0217
conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217
diaph shear capacity, Q_{CE} = 1710 plf
$m_1 \cdot K \cdot Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

Note: Chord force okay by inspection

Masonry & Steel Strength (Tier 2 - Force Controlled)



anchor bolt size, d_b = 0.750 in
anchorage spacing, s = 24.00 in
anchor bolt effective embed, l_b = 3.50 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

anchor bolt shear, $Q_E = V_{bolt} = (V / L_{support})*(s/12)$ = 3078 lbs /bolt
$Q_{UF} = Q_E / (J*C_1*C_2)$ = 1099 lbs /bolt

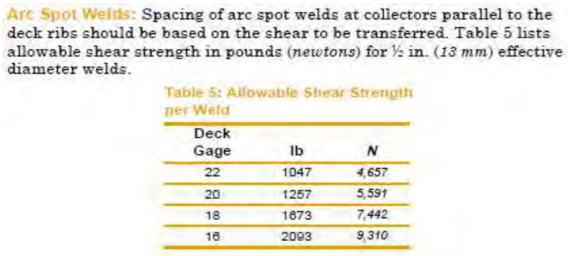
projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt
projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt
cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

$\phi B_{vnb} = 1.0*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt **OK** masonry breakout
$\phi B_{vnpry} = 1.0*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt **OK** masonry crushing
$\phi B_{vnpry} = 1.0*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt **OK** anchor bolt pryout
$\phi B_{vns} = 1.0*0.6*A_b*f_y$ = 15904 lbs /bolt **OK** steel yielding

BY: C. Che **DATE** Sep-17 **CLIENT** Wilamette River WTP **SHEET**
CHKD BY **DESCRIPTION** Areas 13,18,19 - Buildings **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 - Damage Control - Diaphragm Shear in NS-Dir

DIAPHRAGM IN-PLANE SHEAR CONNECTION

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddel weld shear, $Q_E = V_{bolt} = (V / L_{support})*(s/12) =$ 1539 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2) =$ 550 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, $C_{WELD} =$ 1.65 per IAPMO-ER #0217
strength of puddle weld = 2074 lbs /weld

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.55	<--	***OK***	diaphragm shear
demand capcity ratio, DCR =	*0.18*	<--	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.21*	<--	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.05*	<--	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.07*	<--	***OK***	steel yielding
demand capcity ratio, DCR =	0.26	<--	***OK***	puddle weld strength

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BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Areas 13,18,19 - Buildings	**JOB NO.**	10721A.00
DESIGN TASK				ASCE 41 - Damage Control - Diaphragm Shear in EW-Dir			

DIAPHRAGM IN-PLANE SHEAR CONNECTION

Knowledge factor, K = 1.00 per Table 6-1

seismic modification factors, C_1C_2 = 1.40 per Table 7-3

effective mass factor, C_m = 1.00 per Table 7-4

diaphragm shear, m_1-factor = 1.625 per Table 9-4 (between "IO" & "LS")

diaphragm chord, m_2-factor = 3.625 per Table 9-4 (between "IO" & "LS")

force-delivery reduction factor, J = 2.00 per Sec. 7.5.2.1.2

Diaphragm Shear (Tier 2 - Deformation Controlled)

spectral acceleration, S_a = 0.611 g

building seismic weight, W = 659 kips

pseudo seismic force, $V = F_d = C_1C_2C_mS_aW$ = 564 kips

total length of diaph support in NS-Dir, $L_{support}$ = 291 ft "Combined Total Length of Supports"

diaph shear, $Q_{UD} = F_d / L_{support}$ = 1937 plf

allowable diaphragm shear = 1069 plf per IAPMO-ER #0217

conversion factor for strength design, $C_{buckling}$ = 1.60 per IAPMO-ER #0217

diaph shear capacity, Q_{CE} = 1710 plf

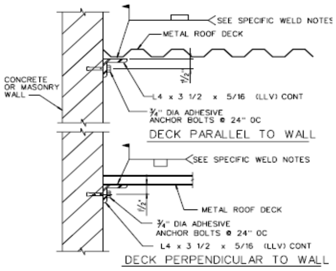
$m_1 * \mathrm{K} * Q_{CE}$ = 2779 plf

Note: Diaph shear capacity from Verco HSB-36 (20GA; 6'-0" span; weld pattern 36/5; TSW @ 12")

Chord Force (Tier 2 - Deformation Controlled)

Note: Chord force okay by inspection

Masonry & Steel Strength (Tier 2 - Force Controlled)



anchor bolt size, d_b = 0.750 in

anchorage spacing, s = 24.00 in

anchor bolt effective embed, l_b = 3.50 in

anchor bolt yield stress, f_y = 36.00 ksi

masonry compressive strength, f'_m = 1500 psi

anchor bolt shear, $Q_E = V_{bolt} = (V / L_{support})*(s/12)$ = 3874 lbs /bolt

$Q_{UF} = Q_E / (J*C_1*C_2)$ = 1384 lbs /bolt

projected area of anchor bolt shear, A_{pv} = 38.48 in^2 lbs /bolt

projected area of anchor bolt tension, A_{pt} = 76.97 in^2 lbs /bolt

cross section area of anchor bolt, A_b = 0.44 in^2 lbs /bolt

$\phi B_{vnb} = 1.0*4*A_{pv}*(f'_m)^{0.5}$ = 5962 lbs /bolt **OK** masonry breakout

$\phi B_{vnpry} = 1.0*1050*(f'_m*A_b)^{1/4}$ = 5327 lbs /bolt **OK** masonry crushing

$\phi B_{vnpry} = 1.0*8*A_{pt}*(f'_m)^{0.5}$ = 23848 lbs /bolt **OK** anchor bolt pryout

$\phi B_{vns} = 1.0*0.6*A_b*f_y$ = 15904 lbs /bolt **OK** steel yielding

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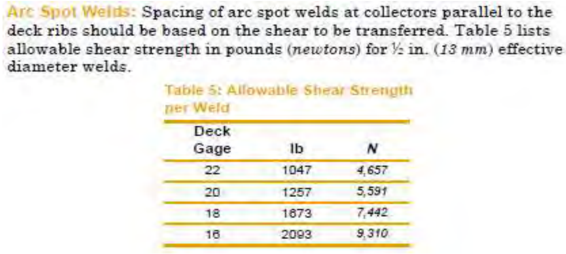
CHKD BY		**DESCRIPTION**			Areas 13,18,19 - Buildings	**JOB NO.**	10721A.00
DESIGN TASK				ASCE 41 - Damage Control - Diaphragm Shear in EW-Dir			

DIAPHRAGM IN-PLANE SHEAR CONNECTION

Boundary Puddle Weld Strength (Tier 2 - Force Controlled)



Arc Spot Welds: Spacing of arc spot welds at collectors parallel to the deck ribs should be based on the shear to be transferred. Table 5 lists allowable shear strength in pounds (*newtons*) for ½ in. (*13 mm*) effective diameter welds.

Table 5: Allowable Shear Strength per Weld

Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

effective puddle weld diameter = 0.500 in
puddle weld spacing = 12.00 in

puddel weld shear, $Q_E = V_{bolt} = (V / L_{support})*(s/12) =$ 1937 lbs /weld
$Q_{UF} = Q_E / (J*C_1*C_2) =$ 692 lbs /weld

allowable strength of weld = 1257 lbs /weld
conversion factor for strength design, $C_{WELD} =$ 1.65 per IAPMO-ER #0217
strength of puddle weld = 2074 lbs /weld

Numerical Acceptance Criteria

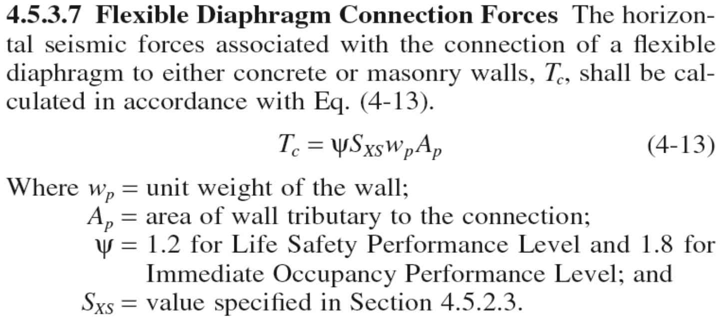
acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	0.70	<--	***OK***	diaphragm shear
demand capcity ratio, DCR =	*0.23*	<--	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.26*	<--	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.06*	<--	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.09*	<--	***OK***	steel yielding
demand capcity ratio, DCR =	0.33	<--	***OK***	puddle weld strength

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP
CHKD BY		**DESCRIPTION**	Areas 13,18,19 - Buildings	**JOB NO.**	10721A.00
DESIGN TASK	ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Joist Supports				

SHEET

WALL ANCHORAGE FORCE



4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \qquad (4\text{-}13)$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

wall height to diaphragm, h_w = 16.00 ft
parapet height, h_p = 2.00 ft

unit weight of wall, w_p = 84.00 psf
Ψ ("IO") = 1.50 <-- Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

beam spacing = 6.00 ft
wall out-of-plane load = 770 lbs/ ft

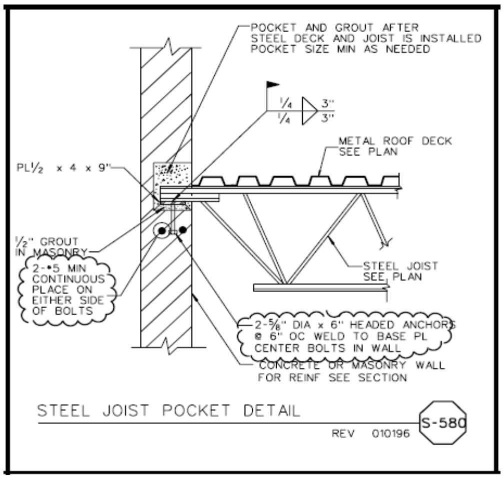
wall anchorage force, T_c = 4619 lbs

Masonry & Steel Strength

number of anchor bolts = 2
anchor bolt size = 0.625 in
anchor bolt embed = 6.00 in
anchor bolt edge distance = 3.81 in
anchorage spacing = 6.00 in

anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

projected area of anchor bolt shear, A_{pv} = 46 in^2
projected area of anchor bolt tension, A_{pt} = 137 in^2
cross section area of anchor bolt, A_b = 0.31 in^2



$\phi B_{vnb} = 1.0 * 4 * A_{pv} * (f'_m)^{0.5}$ = 7,074 lbs masonry breakout
$\phi B_{vnpry} = 1.0 * 1050 * (f'_m * A_b)^{1/4}$ = 9,726 lbs masonry crushing
$\phi B_{vnpry} = 1.0 * 8 * A_{pt} * (f'_m)^{0.5}$ = 42,525 lbs anchor bolt pryout
$\phi B_{vns} = 1.0 * 0.6 * A_b * f_y$ = 13,254 lbs steel yielding

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DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Joist Supports					

WALL ANCHORAGE FORCE

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	*0.65*	**<--**	***OK***	masonry breakout
demand capcity ratio, DCR =	*0.47*	**<--**	***OK***	masonry crushing
demand capcity ratio, DCR =	*0.11*	**<--**	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.35*	**<--**	***OK***	steel yielding

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CHKD BY **DESCRIPTION** Areas 13,18,19 - Buildings **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger

WALL ANCHORAGE FORCE

4.5.3.7 Flexible Diaphragm Connection Forces The horizontal seismic forces associated with the connection of a flexible diaphragm to either concrete or masonry walls, T_c, shall be calculated in accordance with Eq. (4-13).

$$T_c = \psi S_{XS} w_p A_p \qquad (4\text{-}13)$$

Where w_p = unit weight of the wall;
A_p = area of wall tributary to the connection;
ψ = 1.2 for Life Safety Performance Level and 1.8 for Immediate Occupancy Performance Level; and
S_{XS} = value specified in Section 4.5.2.3.

wall height to diaphragm, h_w = 16.00 ft
parapet height, h_p = 2.00 ft

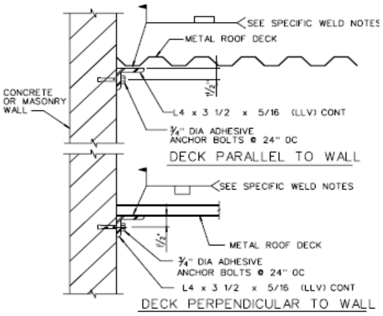
unit weight of wall, w_p = 84.00 psf
Ψ ("IO") = 1.50 <-- Damage Control (between "LS" & "IO")
S_{XS} = 0.611 g

anchor bolts spacing = 24.00 in
wall out-of-plane load = 770 lbs/ ft

wall anchorage force, T_c = 1540 lbs /bolt

Masonry & Steel Strength

anchor bolt size = 0.750 in
anchor bolt embed = 3.50 in
anchor bolt edge distance = 3.81 in
anchorage spacing = 6.00 in



anchor bolt yield stress, f_y = 36.00 ksi
masonry compressive strength, f'_m = 1500 psi

projected area of anchor bolt tension, A_{pt} = 38 in^2
cross section area of anchor bolt, A_b = 0.44 in^2

$\phi B_{vnpry} = 1.0*4*A_{pt}*(f'_m)^{0.5}$ = 5,962 lbs anchor bolt pryout
$\phi B_{vns} = 1.0*A_b*f_y$ = 15,904 lbs steel yielding

Ledger Angle

yield strength, f_y = 36,000 psi
ledger angle thick, t = 0.31 in
moment arm, l_{arm} = 1.19 in distance from top of ledger to center of AB
effective width, b = 3.00 in
section modulus, S = 0.0488 in^3

shear stress = 1,642 psi

moment = 1,832 lb-in
flexural stress = 37,525 psi

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DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Ledger					

WALL ANCHORAGE FORCE

Numerical Acceptance Criteria

acceptance criteria (max allowable DCR) = 1.00

demand capcity ratio, DCR =	*0.26*	**<--**	***OK***	anchor bolt pryout
demand capcity ratio, DCR =	*0.10*	**<--**	***OK***	steel yielding
demand capcity ratio, DCR =	*0.05*	**<--**	***OK***	ledger shear
demand capcity ratio, DCR =	*1.04*	**<--**	***NG***	ledger flexural

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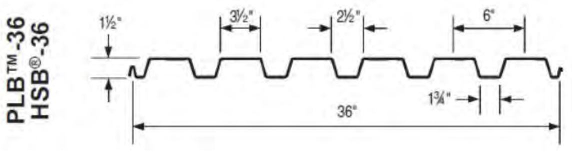
CHKD BY **DESCRIPTION** Areas 13,18,19 - Buildings **JOB NO.** 10721A.00
DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck

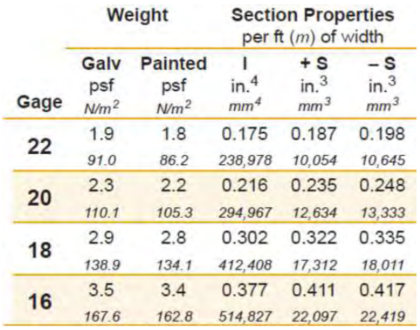
STEEL DECK PROPERTIES (ASTM A653, Grade 33)

Modulus of Elasticity, E = 29500 ksi

Yield Strength, F_y = 38 ksi

Ultimate Strength, F_u = 52 ksi





Gage	Weight Galv psf *N/m²*	Weight Painted psf *N/m²*	Section Properties per ft (*m*) of width I in.^{4} *mm*^{4}	Section Properties per ft (*m*) of width + S in.^{3} *mm*^{3}	Section Properties per ft (*m*) of width – S in.^{3} *mm*^{3}
22	1.9 *91.0*	1.8 *86.2*	0.175 *238,978*	0.187 *10,054*	0.198 *10,645*
20	2.3 *110.1*	2.2 *105.3*	0.216 *294,967*	0.235 *12,634*	0.248 *13,333*
18	2.9 *138.9*	2.8 *134.1*	0.302 *412,408*	0.322 *17,312*	0.335 *18,011*
16	3.5 *167.6*	3.4 *162.8*	0.377 *514,827*	0.411 *22,097*	0.417 *22,419*

Steel Deck = HSB-36

Gage = 20

Deck Span, L = 6 ft

DESIGN LOAD (Service Level)

Roof Load, w = 30 psf *--- steel deck gravity*

Wall Out-of-Plane Load, F = 770 lb/ft *--- deck axial load*

Design Flexural Moment :

Neutral Axis, y_b = 0.919 in

M_{roof} = 1.620 kip-in /ft *--- moment due to gravity load = w * L2 / 8*

M_{ecc} = 0.506 kip-in /ft *--- moment due to wall out-of-plane = (F/1.4) * yb*

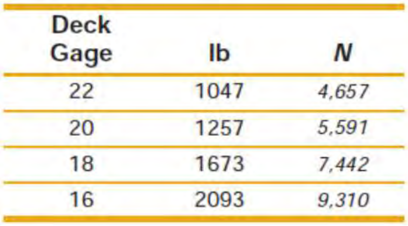
M_{total} = 2.126 kip-in /ft

ARC-SPOT WELD (WALL OUT-OF-PLANE)

Effective Weld Size Dia, d_e = 1/2 in

Weld Pattern = 5 per 36/sheet

Allowable Weld Capacity = 2.10 kip/ft **<= OK**



Deck Gage	lb	*N*
22	1047	*4,657*
20	1257	*5,591*
18	1673	*7,442*
16	2093	*9,310*

Allowable shear strength for 1/2" effective diameter puddle welds.

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DESIGN TASK ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck

STEEL DECK ALLOWABLE COMPRESSION

Effective Length Factor, K = 1.00

Deck Thickness, t = 0.0359 in

Width of Top Flange, w = 3.50 in

Gross Section Area, A_g = 0.599 in^2/ft

radius of gyration, r = 0.601 in

KL/r = 120

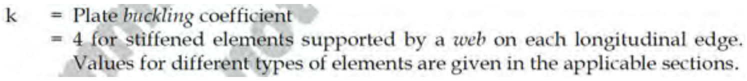
λ_c = 1.37

F_n = 17.33 ksi

Effective Width of Top & Bottom Flange Under Compression
(Assume Bottom Flange Fully Effective)

Ω_c = 1.8 --- *factor of safety*

k = 4



k = Plate *buckling* coefficient
= 4 for stiffened elements supported by a *web* on each longitudinal edge. Values for different types of elements are given in the applicable sections.

Poisson's Ratio = 0.300

F_{cr} = 11.22

λ = 1.243

ρ = 0.662

Effective Flange Width, b = 2.318 in --- *effective flange width =* ρw

Effective Section Area, A_e = 0.557 in^2/ft --- *effective section area*

P_n / Ω_c = 5.36 kip /ft **<= OK** --- $A_e * F_n / \Omega_c$

STEEL DECK ALLOWABLE TENSION

Gross Section Area, A_g = 0.599 in^2/ft

Ω_{T1} = 1.67

T_{n1} / Ω_{T1} = 13.63 kip /ft **<= OK** --- $A_g * F_y / \Omega_{T1}$

Ω_{T2} = 2.00

T_{n2} / Ω_{T2} = 15.57 kip /ft **<= OK** --- $A_g * F_u / \Omega_{T2}$

BY:	C. Che	**DATE**	Sep-17	**CLIENT**	Wilamette River WTP	**SHEET**	
CHKD BY		**DESCRIPTION**			Areas 13,18,19 - Buildings	**JOB NO.**	10721A.00
DESIGN TASK		ASCE 41 (Tier 1 Screening "Damage Control") - Wall Anchorage at Metal Deck					

STEEL DECK ALLOWABLE BENDING

Ω_b = 1.67

S_+ = 0.235 in^3/ft --- *positive section modulus*

M_n / Ω_b = 5.35 kip-in /ft **<= OK** --- $S_+ * F_y / \Omega_b$

COMBINED LOAD INTERACTION

Bending-Tension Interaction:

DCR = 0.454 **<= OK**

Bending-Compression Interaction:

DCR = 0.541 **<= OK**

Appendix C

SURGE TRANSIENT ANALYSIS AND PRE-DESIGN RECOMMENDATIONS TECHNICAL MEMORANDUM

City of Wilsonville & City of Sherwood

Willamette River Water Treatment Plant 2017 Master Plan Update

TECHNICAL MEMORANDUM

SURGE TRANSIENT ANALYSIS AND PRE-DESIGN RECOMMENDATIONS

FINAL | January 2018

City of Wilsonville and City of Sherwood

Willamette River Water Treatment Plant

2017 Master Plan Update

TECHNICAL MEMORANDUM

SURGE TRANSIENT ANALYSIS AND PRE-DESIGN RECOMMENDATIONS

REGISTERED PROFESSIONAL ENGINEER

83991 PE

OREGON

JUNE 24, 2013

ANDREW M. NISHIHARA

EXPIRES: 12-31-2018

CHRISTOPHER T. MICHALOS

REGISTERED

No. 10000120

STATE OF INDIANA

PROFESSIONAL ENGINEER

EXPIRES: 07-31-2018

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Abbreviations

cfs	cubic feet per second
ft	Feet
ft^3	Cubic foot
ft/s	Feet per second
HGL	Hydraulic Grade Line
$lb\text{-}ft^2$	Pound force square foot
mgd	million gallons per day
psi	pounds per square inch
WR^2	Rotating Inertia of pump and motor
WRWTP	Willamette River Water Treatment Plant

SURGE TRANSIENT ANALYSIS AND PRE-DESIGN RECOMMENDATIONS

1.1 Introduction

The objective of the transient analysis is to confirm the results identified in the *Hydraulic Transient Analysis – City of Wilsonville* Technical Memorandum prepared by MWH (August 2011) using the City of Wilsonville's revised distribution model and incorporating current water demand and recent piping network modifications. The 2011 modeling efforts evaluated numerous scenarios with WRWTP flow rates up to 15 million gallons per day (mgd). Modeling results indicated that a minimum 750 cubic foot (ft^3) (5,600 gallon) surge tank located at the WRWTP is recommended to prevent negative pressure formation within the distribution system due to power loss at the WRWTP when the City of Wilsonville demand exceeds 10 mgd (Sherwood excluded) and/or 12.5 mgd with Sherwood.

The City of Wilsonville's 2017 Innovyze Infowater hydraulic model was provided to Stantec for this hydraulic transient analysis. Based upon discussions with the City of Wilsonville, the *2011_MDDW48, Existing Demand with Priority 1 Improvements* Model Scenario was used to model the demand scenarios presented in Table 1 for the analyses. In addition, the model was used to determine if a surge tank is required assuming no Sherwood Demand.

Table 1 Summary of Hydraulic Transient Analysis Demand Scenarios

Scenario	WRWTP Flow Rate (MGD)	Wilsonville Demand (MGD)	Sherwood Demand (MGD)
1	12.5	12.5	0
2	15	15	0
3	15	10	5
4	20	15	5
5	25	17.5	7.5
6	30	22.5	7.5

1.1.1 Model Development

The InfoWater hydraulic model, provided by the City of Wilsonville, was used along with InfoSurge to perform the transient analysis. The transmission main to Sherwood was added to the model utilizing information from the 2011 model and the City of Sherwood Water Supply Improvement Project Transmission Pipeline Drawings prepared by Murray Smith and Associates, dated June 2009. The model file received from the City of Wilsonville included the four existing high service pumps; two additional high service pumps were added to the model at the WRWTP to represent increased pumping capacity for model runs at higher flows. Pump station pipe lengths and elevations were also adjusted in the model to match the WRWTP as-built drawings.

Assumptions and Methodologies

The following general assumptions and boundary conditions were used in the transient model development and throughout the analysis:

- A global wave speed of 3,600 feet per second (ft/s) was applied to the distribution network to represent the average wave speed of rigid pipe materials such as ductile iron pipe, steel, and concrete.
- Pump discharge check valves were modeled with a closing time of 0.01 seconds to provide near instantaneous closure upon flow reversal.
- Pump curves included as part of the model were not verified.
- A total rotating inertia of pump and motor (WR^2) of 277.6 pound force square-foot ($lb\text{-}ft^2$) was estimated to represent the combined pump and motor inertia based upon the pump curve provided in the model.
- Surge mitigation devices will be sized to maintain positive pressures in the distribution system during the downsurge in order to minimize potential contaminant intrusion.
- Utilized model demand scenario 2011_MDDW48, Existing Demand with Priority 1 Improvements.
- Base model demands were scaled to meet the proposed demands provided in Table 1. Demands were not adjusted or biased geographically within the distribution system.
- Simultaneous power failure of all pumps occur 10 seconds into the model run in order to establish steady state conditions.
- The Sherwood Pipeline is hydraulically connected to the Wilsonville Distribution Network for all model scenarios, even when there is no flow to Sherwood.

1.2 Surge Mitigation Devices

Surge mitigation devices considered for this analysis included hydropneumatic tank(s) and vacuum relief valves. Surge anticipation valves were not recommended because they will not prevent vapor cavity formation and collapse in the system resulting from the downsurge. Pump flywheels were not considered since the existing pumps are close coupled vertical turbine pumps, which would not accept a flywheel.

A hydropneumatic tank, also known as surge arrestor or surge tank, is a pressurized tank with the lower portion of the tank filled with water and the upper portion containing pressurized air. When a power failure occurs at the pumps, water begins to flow from the hydropneumatic tank into the system to make up for the drop in flow at the pumps. The compressed air in the hydropneumatic tank begins to expand as the water level in the tank drops. Because air is compressible, the corresponding drop in pressure within the tank is not as large as at the pumps. Water is delivered from the tank until the water column in the system comes to rest, the flow then reverses and flows back into the tank raising the pressure and compressing the air until flow stops. If the pressure in the tank is larger than the system, the air then expands delivering water back into the system. The pressure and flow continue to cycle until they are damped by friction.

A polytropic gas constant of 1.2 was used to represent actual expansion and contraction of the hydropneumatic tank's air volume. The air volume set point in the tank typically ranges from 40 to 60 percent of the total volume of the tank. The minimum water volume of the tank during the downsurge was assumed to be limited to 15 to 20 percent of the total tank volume to ensure a wet seal over the tank outlet pipe during the transient event.

Vacuum relief valves are used to allow air to enter the pipeline whenever the pipeline pressure falls below atmospheric pressure. The vacuum valve is fitted with an external air release valve to exhaust air from the pipeline at a controlled rate when the pipeline regains pressure. Vacuum relief valves were considered as a secondary mitigation device since they would allow other potential contaminants to enter the system when activated during a surge event.

1.3 Hydraulic Transient Analysis and Results

1.3.1 No Sherwood Demand (Scenarios 1 and 2)

The 2011 transient analysis indicated that a hydropneumatic tank was recommended when the City of Wilsonville demand exceeds 10.0 mgd (No Sherwood Demand). Therefore, the hydraulic transient model was first analyzed at demands of 12.5 mgd and 15 mgd to determine the maximum City of Wilsonville distribution system demand that would require a hydropneumatic tank to mitigate transients resulting from power loss at the WRWTP.

The minimum calculated pressure during a power loss event for 12.5 mgd and 15 mgd system demands are presented in Figures 1 and 2, respectively. Results show that minimum downsurge pressures fall below 20 pounds per square inch (psi) along the west and northwest sections of the Wilsonville distribution network and along the Sherwood pipeline for a 12.5 mgd demand; and the affected area within the Wilsonville distribution network increases at a 15 mgd demand. Although these areas are affected by the downsurge, it is important to determine the magnitude and duration of the downsurge. Pressure history following power loss for Model Junctions 3860, 4116, 4604, 4610, 4618, and 4622 are presented for both the 12.5 and 15 mgd demands in Figures 3 through 8. Model Junction 3860 is located along the future Wilsonville pipeline to the future Wilsonville Reservoir; Model Junction 4116 is located within the Wilsonville distribution system along SW Graham's Ferry Rd. Model Junctions 4604, 4610, 4618, and 4622 represent high points along the Sherwood Transmission Pipeline (at existing vacuum valve locations). Full vacuum conditions were calculated at Model Junction 3860 (future Wilsonville pipeline to future reservoir) and downsurge pressure approaching zero is estimated at Model Junction 4116. Results also show that the existing vacuum valves at Model Junctions 4604, 4610, 4618, and 4622 mitigate the downsurge along the Sherwood pipeline.

Even though there is no flow to Sherwood under Scenarios 1 and 2, the Sherwood Pipeline remains hydraulically connected to the Wilsonville transmission and distribution system via the setup of the operational controls for the Sherwood Pipeline, and is therefore subject to downsurge during hydraulic transients. Initial operational testing of the 24-inch control valve at the Tooze Road vault (which controls flow into the Sherwood pipeline) resulted in only a 3 psi differential, which was inadequate to provide water to Sherwood. Therefore, the control valve was operationally set to remain open in order to maintain adequate pressure and flow in the Sherwood Pipeline. Actual rate of flow is currently controlled by an Altitude Valve on the Sherwood Pipeline near the Snyder Park Reservoir. However, the current operational control strategy was established before the final segment of the Wilsonville Transmission pipeline was in place, and the weak pressure differential driving the control strategy was a differential between the Wilsonville distribution system pressure and the Sherwood pipeline.

Now that the Wilsonville Transmission line (operating at a higher pressure) is in place and connected, an operational change to the control valve setup at Tooze Road (i.e. control valve remains fully closed when no flow is being sent to Sherwood) was evaluated using the hydraulic transient model by assuming the Sherwood pipeline was disconnected from the Wilsonville distribution system. The effect of the downsurge on the Wilsonville distribution system was evaluated assuming a 15 mgd demand in the Wilsonville distribution system with the Tooze Rd control valve closed. The results are presented in Figure 9 and show that large sections of the

Wilsonville distribution system are affected by the downsurge resulting from power loss at the WRWTP. Results confirmed that a hydropneumatic tank is recommended as system demands approach 12.5 mgd (no Sherwood demand).

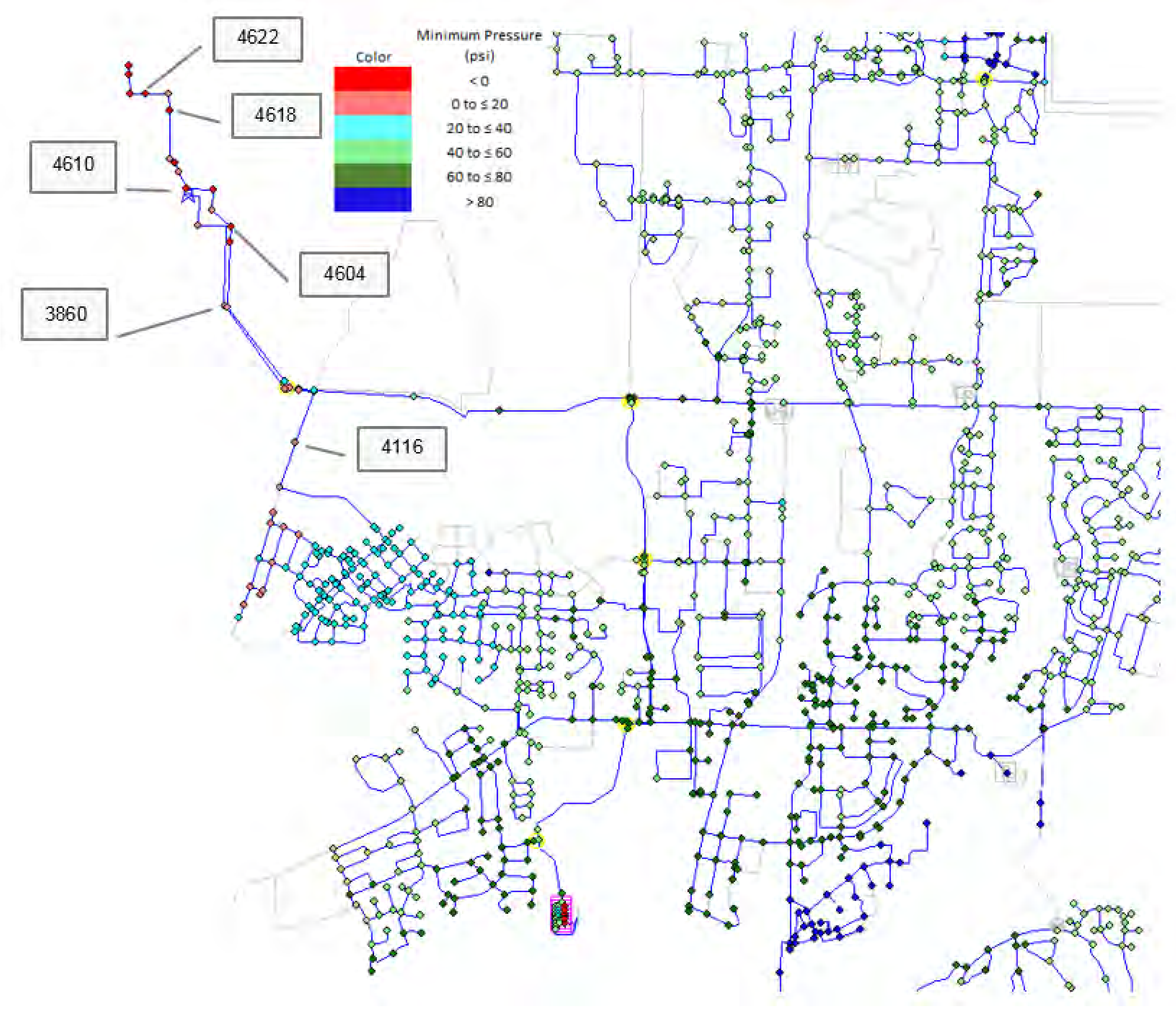

Figure 1 12.5 MGD WRWTP Flow – No Flow to Sherwood

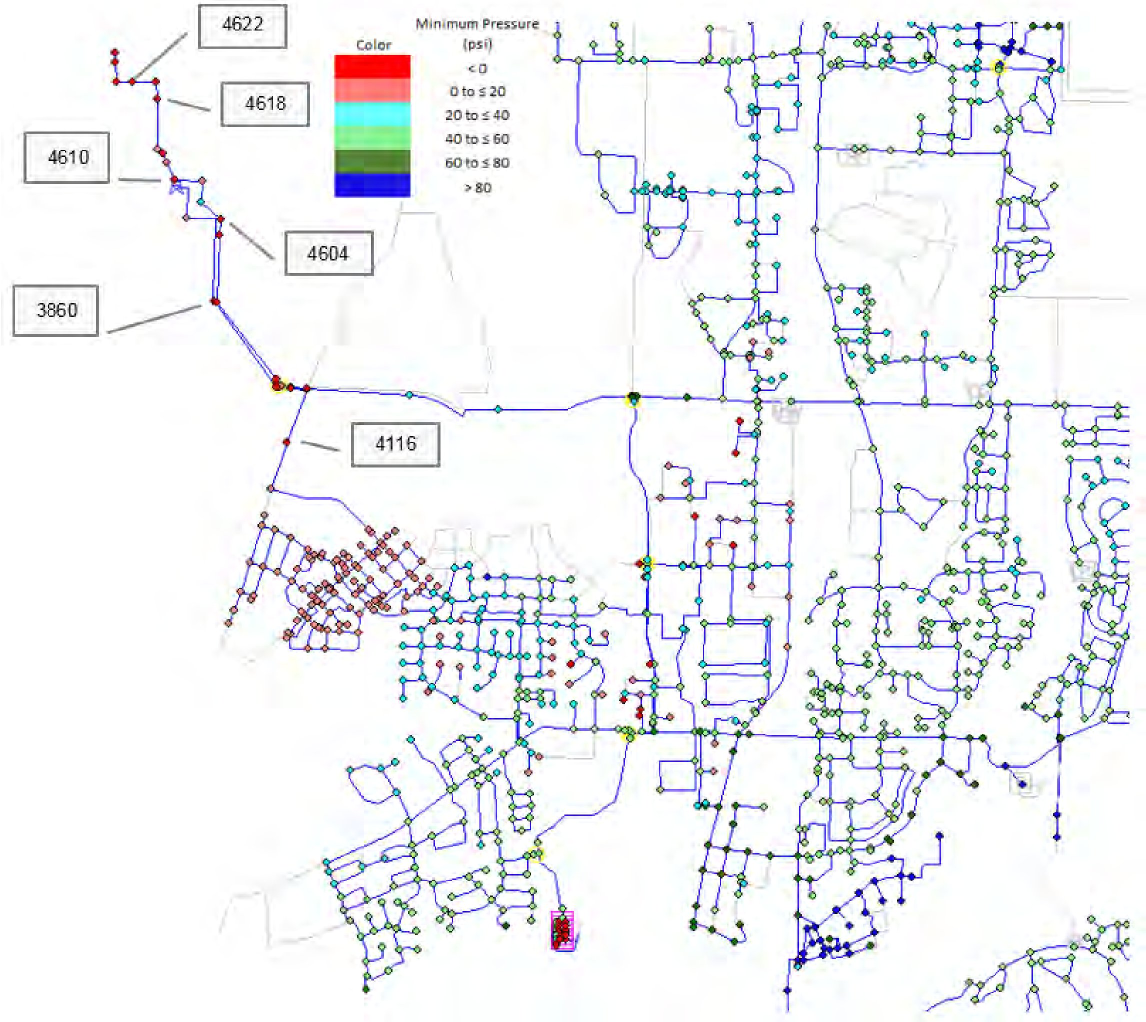

Figure 2 15.0 MGD WRWTP Flow – No Flow to Sherwood

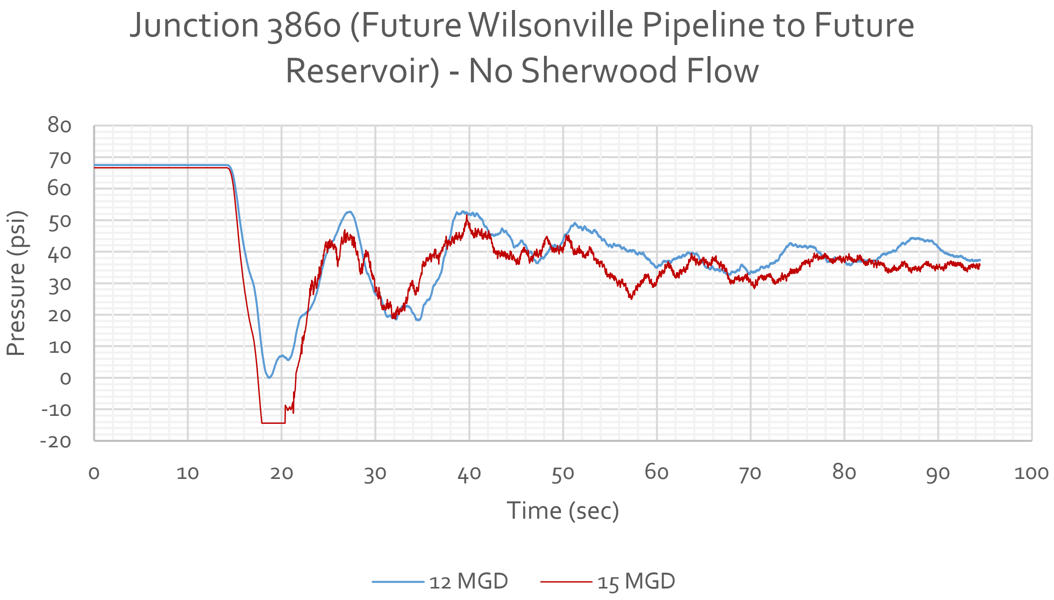

Figure 3 Pressure History Model Junction 3860 – No Flow to Sherwood

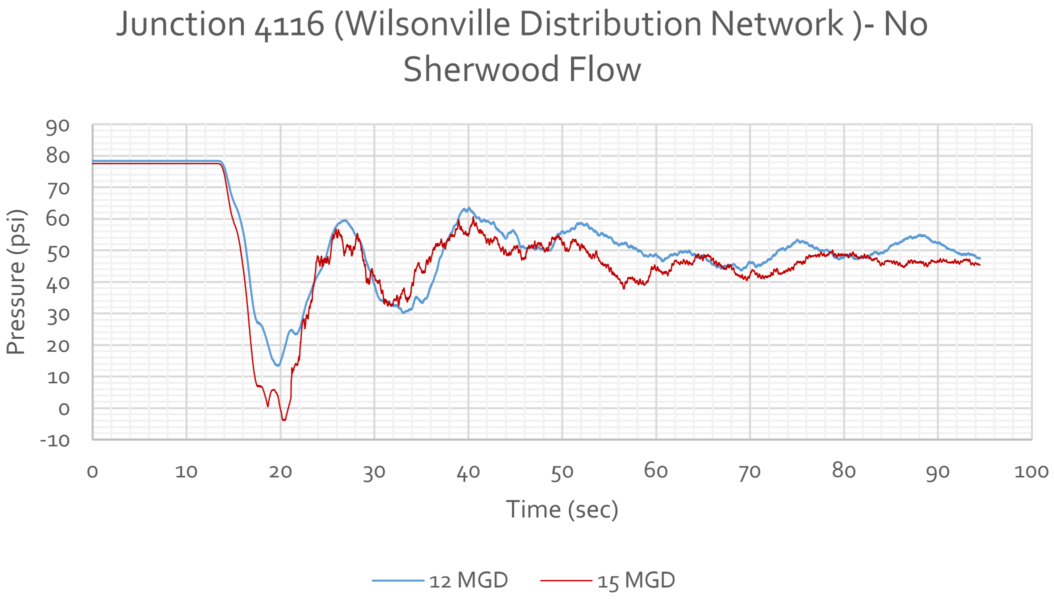

Figure 4 Pressure History Model Junction 4116 – No Flow to Sherwood

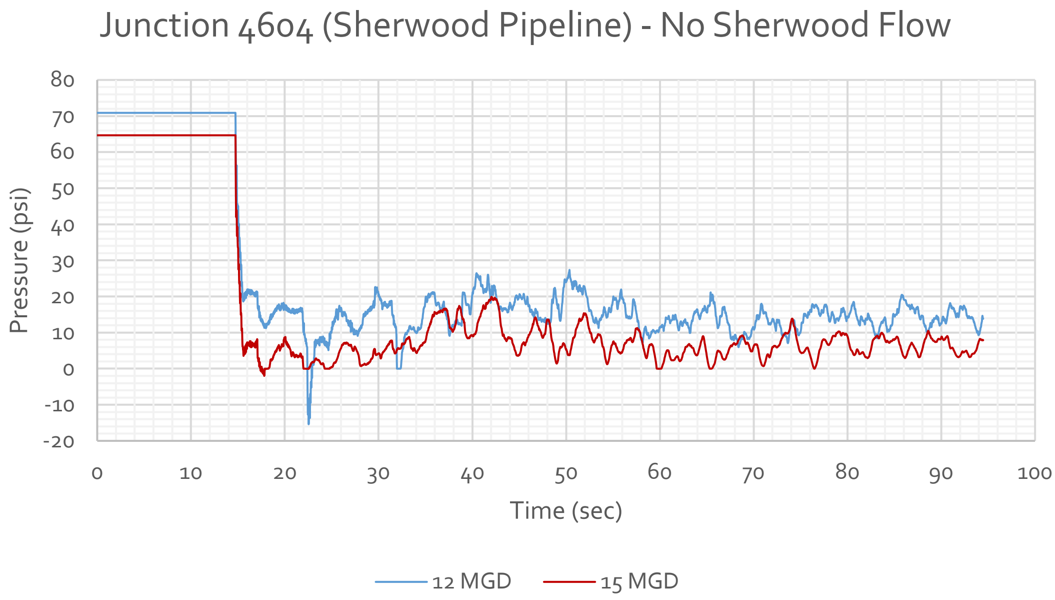

Figure 5 Pressure History Model Junction 4604 – No Flow to Sherwood

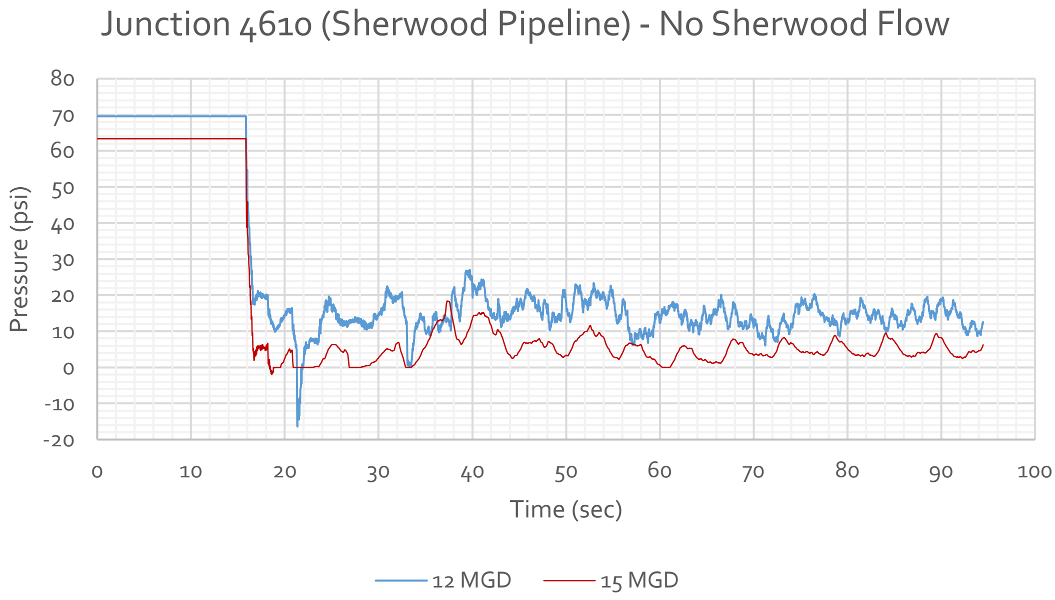

Figure 6 Pressure History Model Junction 4610 – No Flow to Sherwood

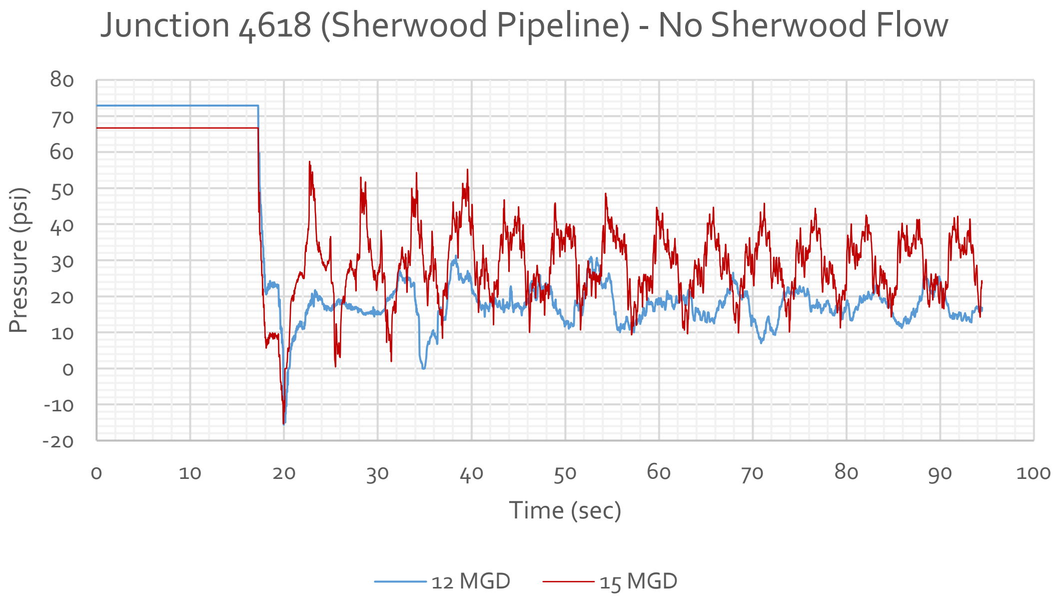

Figure 7 Pressure History Model Junction 4618 – No Flow to Sherwood

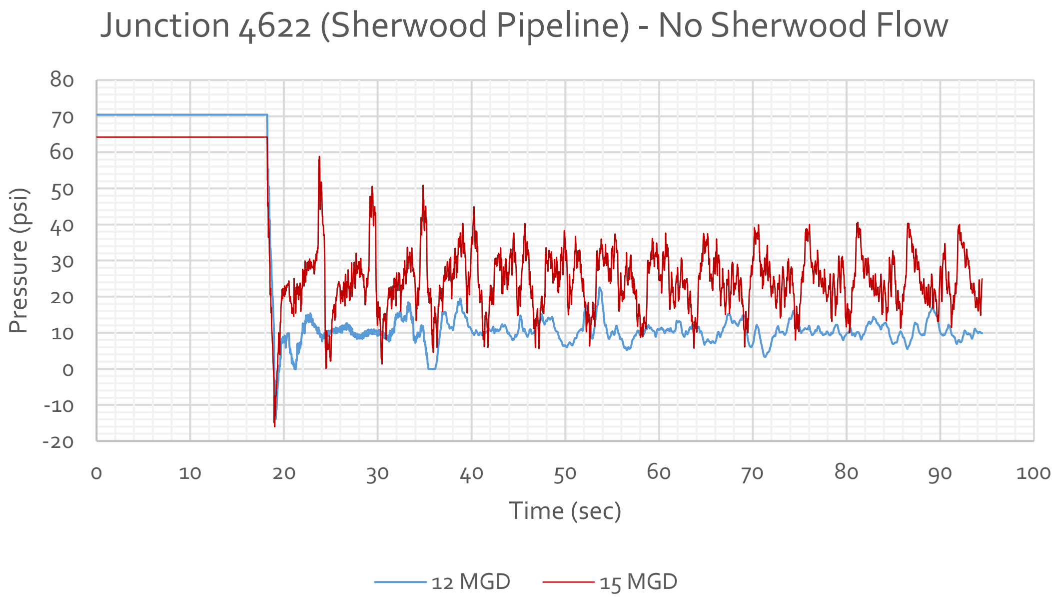

Figure 8 Pressure History Model Junction 4618 – No Flow to Sherwood

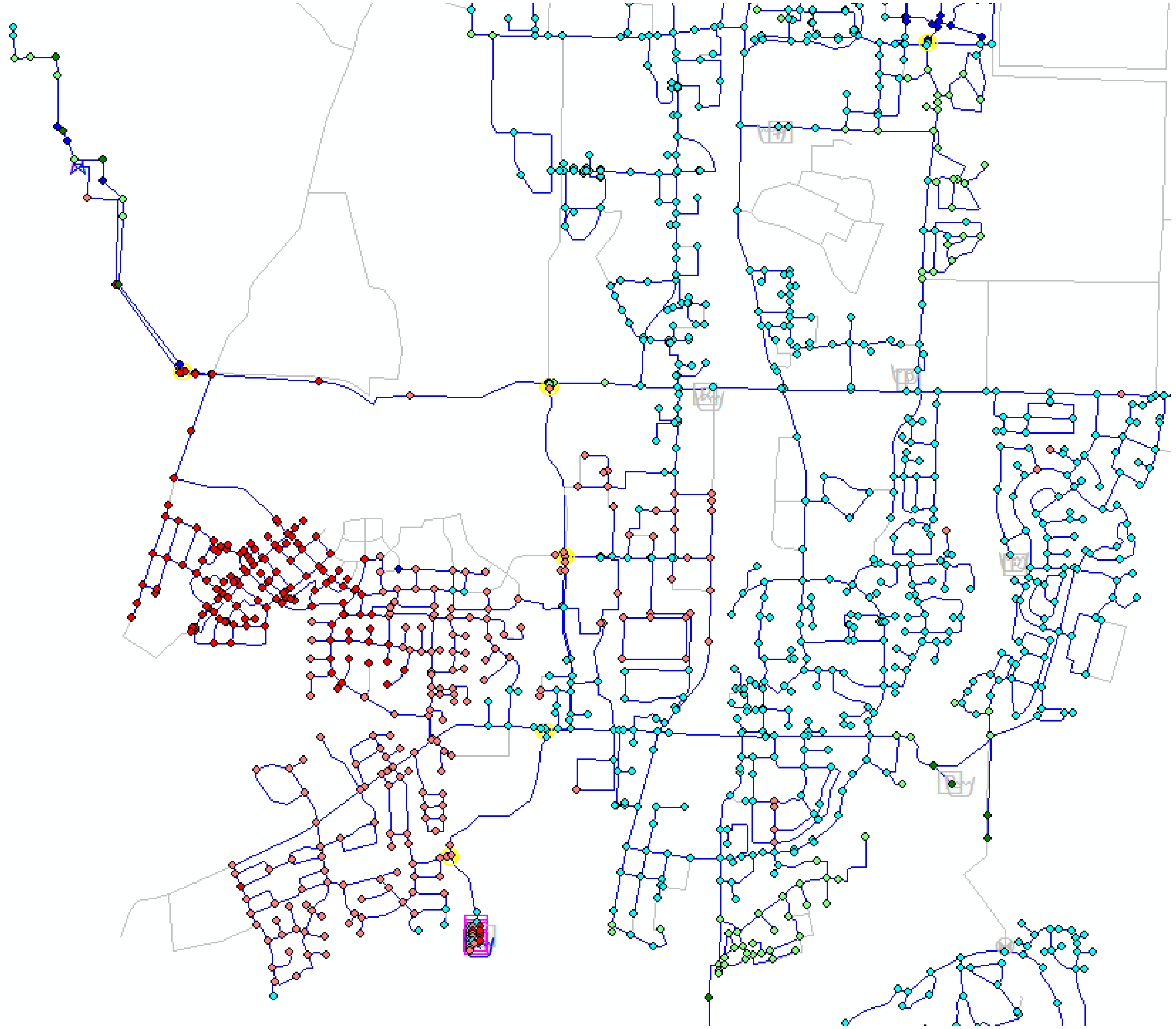

Figure 9 15.0 MGD WRWTP Flow – (Sherwood Pipeline Disconnected from Wilsonville System)

1.3.2 Hydropneumatic Tank Sizing (Scenarios 3 to 6)

A hydropneumatic tank was recommended to mitigate the downsurge resulting from power failure at the WRWTP for demands of 12.5 mgd or greater. Therefore, the model was used to determine the size of hydropneumatic tank required for each scenario identified in Table 1. For each scenario, model runs were evaluated varying the tank volume, air volume, and size of the connecting pipe until an optimized solution was achieved. Hydropneumatic tank sizing was evaluated assuming a 24-inch diameter pipe connected to the upstream end of the discharge header and air volume assumed to be 50 percent of the total volume. Table 2 summarizes the findings of the analysis.

Table 2 Summary of Hydropneumatic Tank Sizing

Scenario	WRWTP Flow Rate (mgd)	Wilsonville Demand (mgd)	Sherwood Demand (mgd)	Minimum Tank Size (ft^3)
1	12.5	12.5	0	N/A [1]
2	15	15	0	N/A [1]
3	15	10	5	750
4	20	15	5	1,000
5	25	17.5	7.5	1,250
6	30	22.5	7.5	1,500

Notes:

(1) Scenario was evaluated to determine maximum demand before surge mitigation is recommended.

Results for the same model junctions identified in the previous section (Model Junctions 3860 and 4116 for Wilsonville, and 4604, 4610, 4618, and 4622 for Sherwood) are provided for Scenarios 3 to 6 in Figures 10 to 15. As shown in Figures 10 and 11, the proposed tank sizing (identified in Table 2) adequately protects the Wilsonville Distribution System. Distribution system maps showing the results with surge tank in place were not presented since the proposed hydropneumatic tank was sized to protect the distribution system.

Results presented in Figures 12 to 15 show that the existing vacuum valves along with the proposed surge tank sizing mitigate the downsurge along the Sherwood pipeline. Figure 16 presents the minimum HGL along the Sherwood pipeline during the downsurge for Scenario 6. It should be noted that utilizing vacuum valves to mitigate the downsurge allows air and potential contaminants to enter the transmission pipeline during the surge event; in addition, trapped air must be exhausted through the air release valves in order to restore the operational capacity of the pipeline. This potential operational risk should be discussed with the City of Sherwood.

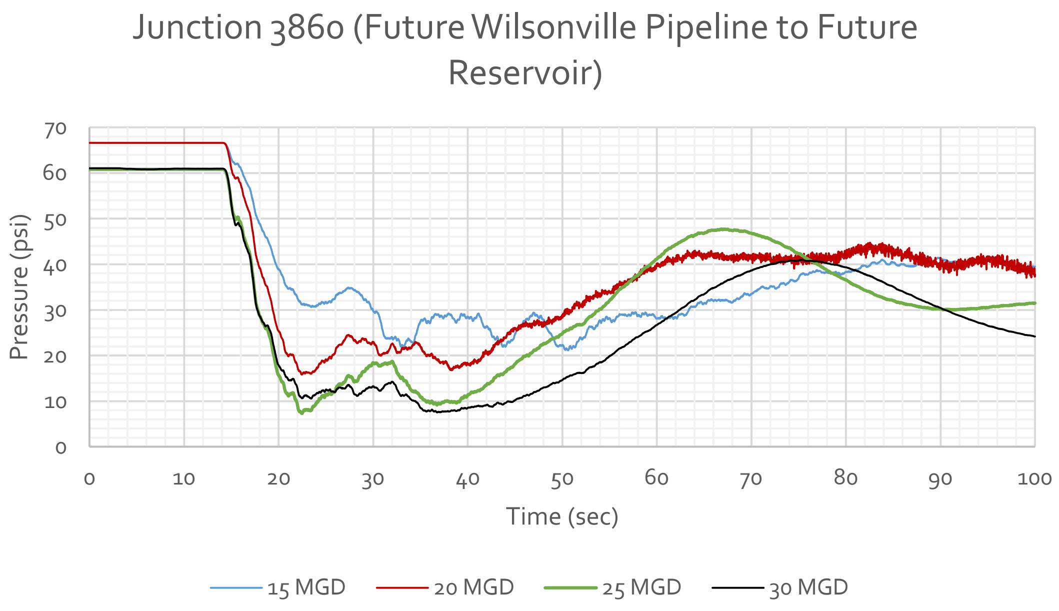

Figure 10 Pressure History Model Junction 3860 – Surge Protection

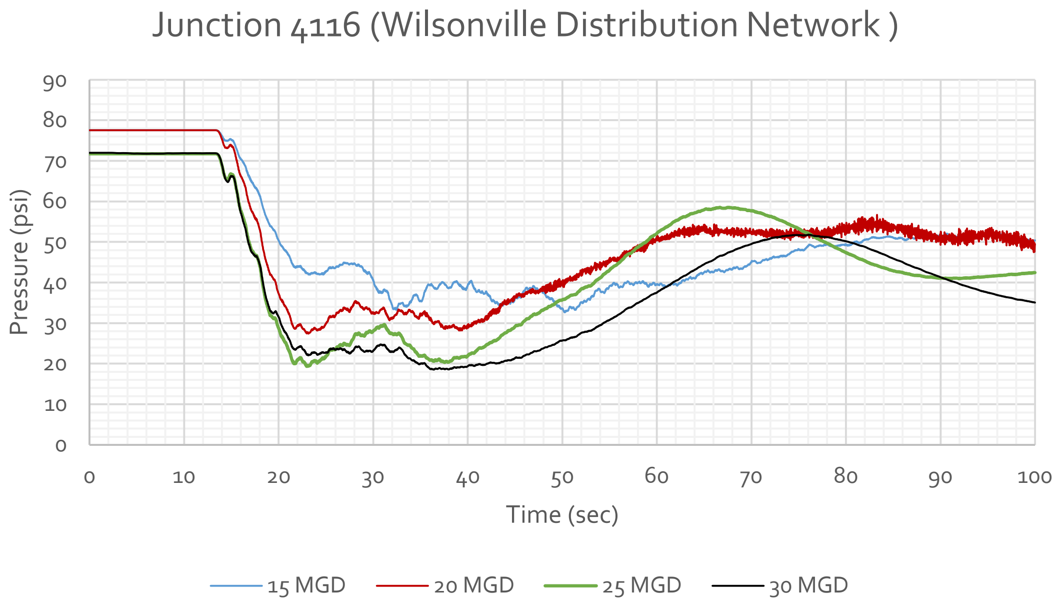

Figure 11 Pressure History Model Junction 4116 – Surge Protection

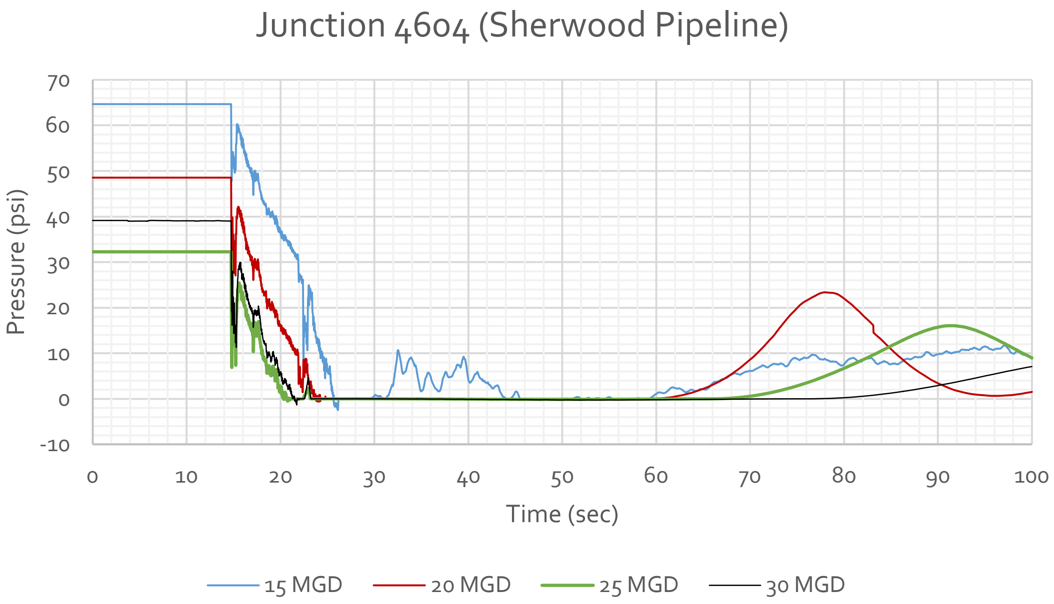

Figure 12 Pressure History Model Junction 4604 – Surge Protection

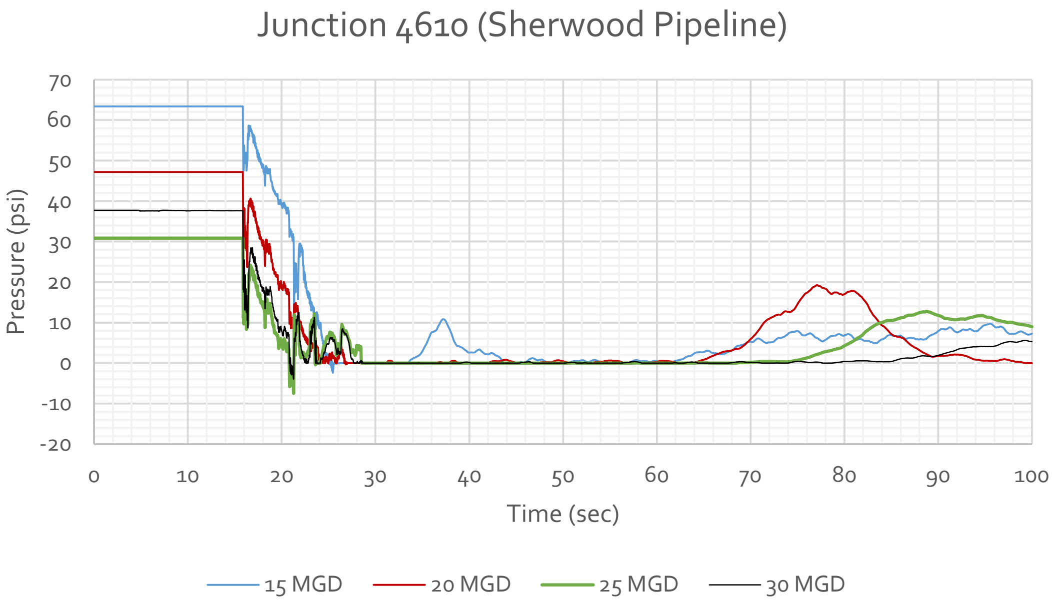

Figure 13 Pressure History Model Junction 4610 – Surge Protection

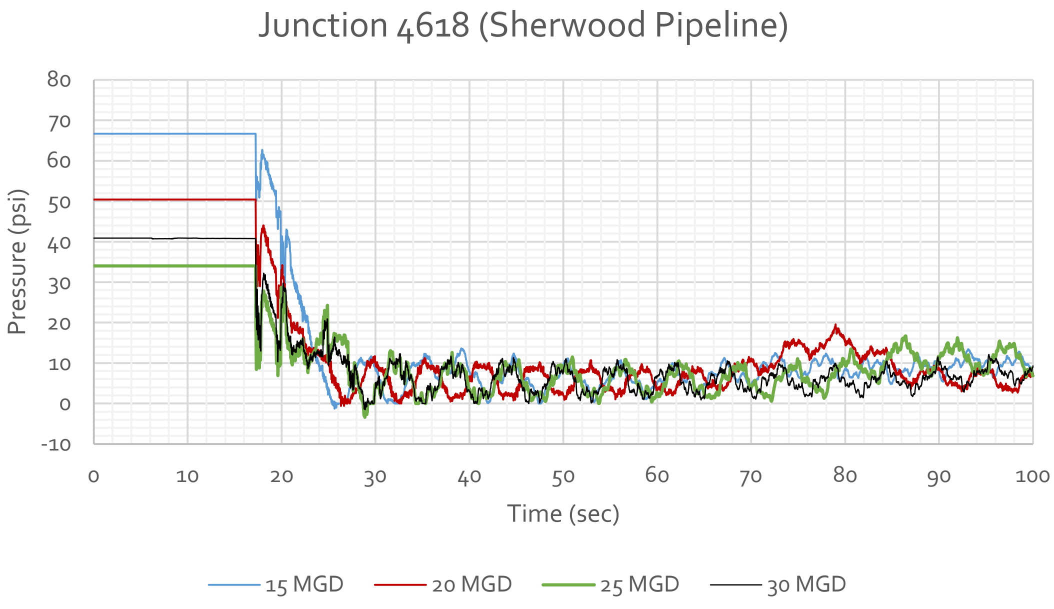

Figure 14 Pressure History Model Junction 4618 – Surge Protection

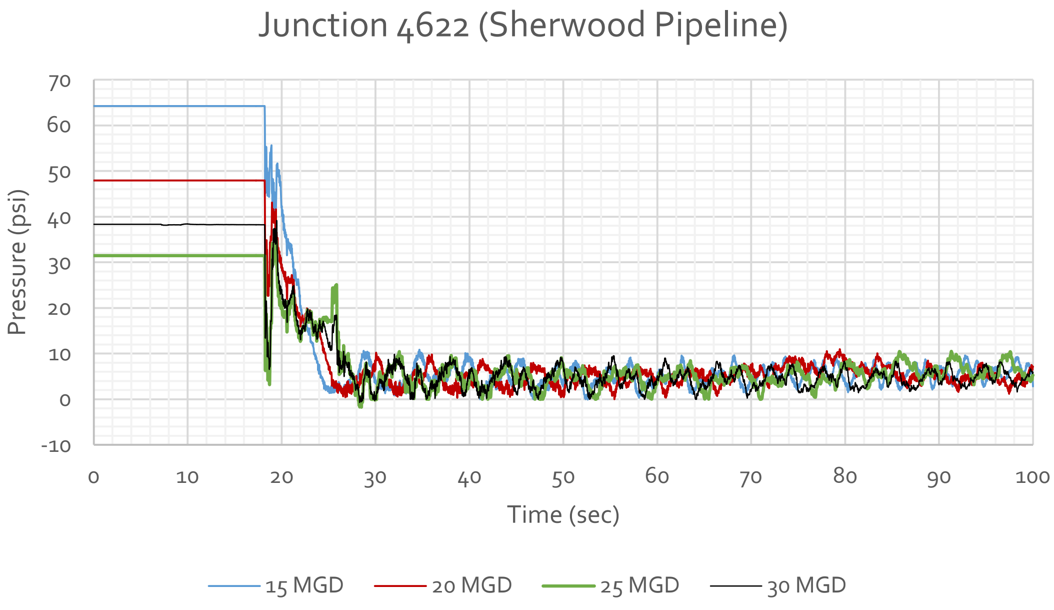

Figure 15 Pressure History Model Junction 4622 – Surge Protection

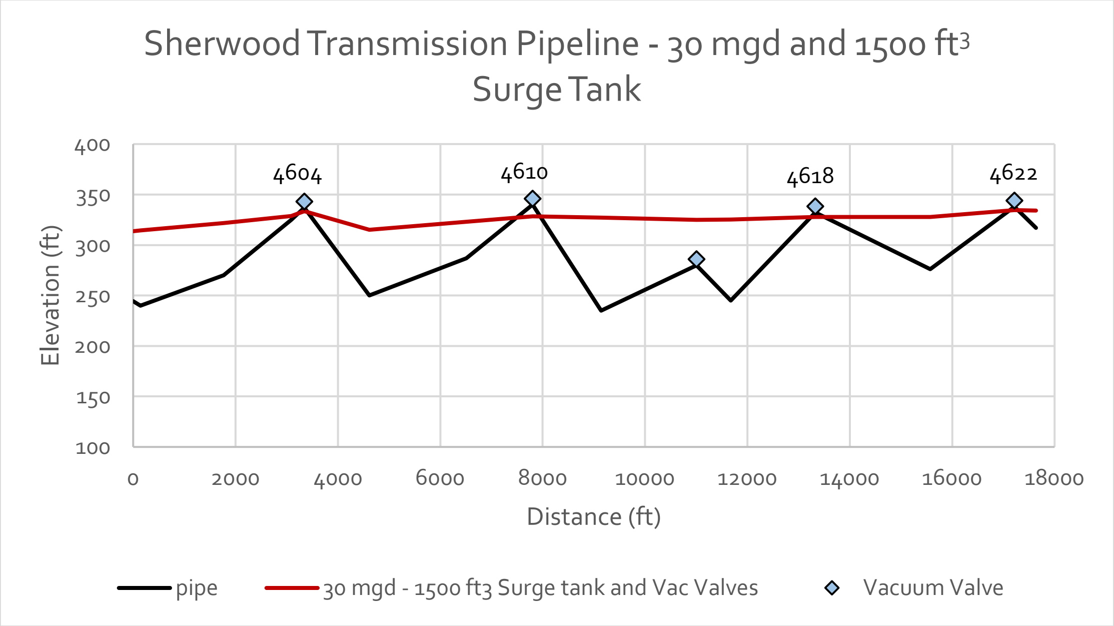

Figure 16 Elevation Profile – Sherwood Transmission Pipeline

1.4 Summary and Recommendations

Modeling results determined that a hydropneumatic tank located at the WRWTP is recommended when the City of Wilsonville's demand approaches 12.5 mgd, confirming the results from previous studies.

The hydraulic transient model was used to size the hydropneumatic tank required for each scenario identified in Table 1. Results are summarized in Table 2 and show that a 750 ft^3 hydropneumatic tank is recommended for a WRWTP flow of 15 mgd; recommended tank sizing increases by 250 ft^3 with each 5 mgd increase in flow at the WRWTP to 1500 ft^3 at 30 mgd. Hydropneumatic tank sizing was evaluated assuming a 24-inch diameter pipe connected to the upstream end of the discharge header and air volume 50 percent of the total tank volume.

The hydropneumatic tank can be configured in either a vertical or horizontal position; or as a conventional or bladder type tank. In a conventional hydropneumatic tank, the air is in direct contact with the water and an air compressor is required to regulate the air volume during operation. A bladder type tank stores the water within an expandable NSF 61-approved bladder. The bladder prevents the air from dissolving into the water and generally requires periodic inspection to verify the correct air precharge pressure in the tank and does not require a dedicated air compressor. The minimum water volume remaining in the tank during the downsurge should be limited to 15 to 20 percent of the tank volume to prevent potential extrusion of the bladder from the tank. The bladder requires periodic inspection and may need replacement every 15 to 20 years. It should be noted that a conventional tank also requires periodic inspection, maintenance, and electrical costs associated with the operation of the air compressor.

Budgetary equipment costs for various hydropneumatic tank sizes with comments are summarized in Table 3. Because the cost to provide a 1,500 ft^3 tank is only 35 percent more than a 750 ft^3 tank, installation of the 1,500 ft^3 tank is recommended. This will provide enhanced near-term surge protection and eliminate the need for additional construction in the future as demands increase.

Table 3 Summary of Budgetary Hydropneumatic Tank Costs (2017$)

Size	Budgetary Cost ($)	Comments
500 ft^3	100,000	Would be implemented with a 1,000 ft^3 tank when demands exceed 20 mgd.
750 ft^3	145,000	Could implement two 750 ft^3 tanks. Would want to install both today to protect demands exceeding 15 mgd.
1000 ft^3	170,000	Could implement single tank and build additional storage in the future.
1500 ft^3	195,000	Allows protection under build-out conditions. Incremental initial cost increase compared to other alternatives.

The proposed tank sizing adequately protects the Wilsonville Distribution system for each demand scenario; the existing vacuum valves along with the proposed surge tank sizing mitigate the downsurge along the Sherwood pipeline .Utilizing vacuum valves to mitigate the downsurge allows air and potential contaminants to enter the transmission pipeline during the surge event. Trapped air must be exhausted through the air release valves in order to restore the operational capacity of the pipeline. This potential operational risk should be discussed with the City of Sherwood.

Based upon the findings of the hydraulic transient analysis, surge mitigation recommendations for the WRWTP and City of Wilsonville Distribution System and Sherwood Pipeline include:

- A 1,500 ft^3 (11,220 gallon) hydropneumatic tank connected to the station discharge header by a 24-inch diameter pipe. A 1,500 ft^3 hydropneumatic tank is recommended based upon the budgetary costs provided above.
- Initial gas set point of 50 percent of total tank volume (750 ft^3).
- A bladder-style tank is recommended to reduce need for additional air piping and handling equipment to be routed to surge tank; will help minimize operations and maintenance impacts.
- Potential tank sizes (1,500 ft^3) include 10.0-ft diameter by 20.0-ft long; 11.0-ft diameter by 16.0-ft long; or 12.0-ft diameter by 13.5-ft long; the tank can be oriented in either the horizontal or vertical position. A horizontal, 11.0-ft diameter tank was carried forward in initial design to minimize vertical impact and to avoid extending too far horizontally away from the building. Upon review of the initial design, it was decided to revise the tank to a vertical configuration due to space considerations in the context of future build-out capacity.

Appendix D

CAPITAL COSTS ESTIMATES

- *Opinion-of-Probable-Construction Cost (OPCC)*
- *Cost Factoring Workbook*
- *Technical Memorandum – Modifications to OPCC*

OPCC OVERVIEW

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Overview

Project	**Willamette River WTP Master Plan**			*OPCC Completed*	30-Nov-17	*Total OPCC Cost-USD*	VARIES BY CIP SCOPE
Location	Wilsonville, OR			*Project Number*	30503765	*Prime Contractor*	GENERAL CONTRACTOR as CM
Overview	Capacity upgrades, R&R, seismic/life safety retrofits, & electrical			*Cost Code Number*	61000001	*Project Bid & Delivery*	BID/BUILD
Contact	Eric Ward	*Avg Daily Flow (MGD)*	15.00	*OPCC Prepared By*	Jim Ward	*Pre-Construction*	INCLUDED
Phone	(503) 220-5431	*Max Daily Flow (MGD)*	30.00	*OPCC Version #*	002	*Construction Duration*	TBD

OPCC Modeling Philosophy & Methodology

This proprietary model, developed on an Excel platform, is the primarily tool for preparing class 4-5 Opinion-of-Probable-Construction-Cost (OPCC) estimates, and follows the general principles within the AACE, International Recommended Practices publication # 18R-97. The absence of mature design deliverables and a comprehensive scope identity as typically encountered early in a project pursuit or design effort has driven the establishment of this model which continues to provide historically reliable and surprisingly detailed cost estimates through a "BASIS-OF-ESTIMATE" and "FORCED DETAIL" methodology of building an initial foundation of “estimatable” scope. After generating this "go-by" work, the model internally produces baseline costs through utilization of cost-analyses and parametric functions, manipulation of both historical and equipment size/capacity data, and traditional unit-cost methodologies using values of quantity, count, dimension, service, productivity, and/or end-use. These bare costs are then further “conditionalized" and "localized" based upon a combination of both perceived and known site/work issues as chosen within an "ASSUMPTIONS" section particular to each division of work. These subsequent direct costs are initially determined for the three primary installation elements of labor (MH$), materials & construction equipment (M&CE$), and major process/procured equipment items (EQ$), and are summarized into a user-defined work breakdown structure for adjustment with select burdens & mark-ups. All supporting costs needed for completing the estimate are also applied, with the valuation based upon years of observed and proven ratios and/or percentages.

Glossary of Potential OPCC Sheets

BASIS-OF-ESTIMATE CHECKLIST: Matrix identifying the primary OPCC scope & project delivery issues, with an initial indication of either being included or excluded in the OPCC

BASIS-OF-ESTIMATE CLARIFICATIONS: Clarifications/ exceptions related specifically to the project scope and issues concerning content, execution, & constructability

OPCC MODEL CLARIFICATIONS: Clarifications/exceptions related specifically to the OPCC modeling & internal functionality

MODEL LABOR RATE STANDARDS: Development of the DIV manhour rates based on the initial baseline source, add-ons, anticipated tradesmen ratios, and work schedule

WORK BREAKDOWN STRUCTURE: Breakdown of the project OPCC in either requested or arbitrary area/scope levels and presented in both direct costs and cost-of-work (i.e. to Owner)

WBS DIRECT COST DISTRIBUTION: Report presenting the OPCC direct costs (i.e. divs 1-17 sheet costs) by both WBS and CSI division categories

WBS COST-OF-WORK DISTRIBUTION: Report presenting the OPCC cost-of-work (i.e. fully burdened costs) by both WBS and CSI division categories

WBS MANHOURS DISTRIBUTION: Report presenting the OPCC installation manhours by both WBS and CSI division categories

WBS QUANTITY-OF-WORK DISTRIBUTION: Report presenting the OPCC major construction quantities by both WBS and CSI division categories

OPCC SUMMARY: Where cost-of work build-up occurs (i.e. installing Contractor's market price), along with the Prime Contractor's costs including staff, fee, insurance, engineering, and bonds

WBS COST BUILD-UP SUMMARY: Another view of how the overall project cost is built-up & developed starting from the Prime and Subcontractor(s) direct costs

PRELIMINARY SCHEDULE: Basic bar-chart presentation of the WBS line items, along with monthly projections of the cashflow and construction manpower loading

INSTALLATION OVERVIEW: Assignments of the construction baseline standards, assumptions, and localizing factors, including a bare cost roll-up of the CSI worksheets

DIV 1 (01) PRIME CONTRACTOR STAFF: Development of the anticipated Prime Contractor staff labor, travel/living needs, and camp costs (where applicable)

DIV 1 (01) GENERAL REQUIREMENTS: Development of the anticipated general conditions needs and tradesmen camp costs (where applicable)

DIV 2 (02 & 31-35) COMMON SITEWORK: Development of the "common" (i.e. typically self-performed) site/civil construction items by type, dimension, & quantity, along with allowances

DIV 2 (02 & 31-35) SPECIALTY SITEWORK: Development of the "specialty" (i.e. typically subcontracted) site/civil construction items by type, dimension, & quantity, along with allowances

DIV 2 (33) WELL WORK: Development of the subcontracted well construction items by type, dimension, & quantity, along with allowances

DIV 3 (03) CONCRETE: Development of the cast-in-place concrete construction items by type, dimension, & quantity, along with CY, tons of rebar, & allowances

DIV 4 (04) MASONRY: Development of the CMU work items by type, dimension, & quantity, along with SF & allowances

DIV 5 (05) MISCELLANEOUS METALS: Development of the misc metal items by type, dimension, & quantity, along with tons & allowances

DIVS 5-8 (05-08) BUILDINGS & COMPONENTS: Development of building and/or component structures by type, dimension, & quantity, along with tons, SF, & allowances

DIVS 9-10 (09-10) FINISHES: Development of the field-applied finishes by type, dimension, & quantity, along with SF & allowances

DIVS 13 (33) FIELD-ERECTED TANKS: Development of the field-erected metal tanks & components by type, dimension, & quantity, along with tons, SF, gallons, & allowances

DIVS 13 (33) SHOP-FABRICATED TANKS: Development of the shop-fabricated metal tanks & components by type, dimension, & quantity, along with tons, gallons, & allowances

DIVS 11-17 (40-45) PROCESS EQUIPMENT: Development of the project-specific process & mechanical equipment breakdown, including all related items, by size/capacity & quantity

DIV 15 (21-23) MECHANICAL INSTALLATION: Development of the mechanical installation work by parametrics, dimension, & quantity data, along with allowances

DIVS 16-17 (25-28 & 33) ELECTRICAL INSTALLATION: Development of the electrical installation by parametrics, dimension, & quantity data, along with allowances

DIVS 16-17 (25-28 & 33) ELECTRICAL EQUIPMENT: Development of the electrical equipment including switchboards, MCC's, transformers, control panels, and process control systems

MODEL COMMODITY STANDARDS: Construction commodity items listing with costs currently utilized in the OPCC model and based on monthly updates from ENR

O&M FORECAST CLARIFICATIONS: Clarifications/ exceptions related specifically to both the cost development and basis of the operation & maintenance details

O&M FORECAST SUMMARY: Roll-up of the initial operations & electrical power basis forecasts and development of the subsequent life cycle costs and net present value

O&M FORECAST DETAIL - OPERATIONS: Development of the process & mechanical operating costs for the OPCC project scope including an initial life-cycle cost

O&M FORECAST DETAIL - ELECTRICAL POWER: Development of the electrical operating KWH and cost for the OPCC project scope including an initial life-cycle cost

MWH CONSTRUCTORS

BASIS-OF-ESTIMATE CHECKLIST

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Version	Date	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	002	30-Nov-17	30503765

Basis-of-Estimate Items

		OPCC Status		
#	Work Scope & Estimate Content	INCLUDED As OPCC Scope	EXCLUDED But By Others	EXCLUDED Or Not Required
1	*This OPCC version # 002 replaces all previous estimates in their entirety for this specific project and/or scope*	✓		
2	*Estimator review of the project site and/or work area, either via a physical walk-through or photographic/video records*			✓
3	*Class 4 Opinion-of-Probable-Operating-Cost (OPOC) estimate with operating & maintenance forecasts*			✓
4	*July 2017 Means Construction Cost Indexes for Portland, OR utilized for initial baselining of local costs*	✓		
5	*September 2017 ENR Construction Economics data utilized for initial baselining of commodity costs*	✓		
6	*Labor rates established by the current STATE prevailing wages website for Wilsonville , OR*	✓		
7	*15% ESTIMATE contingency for potential issues related to Estimator judgements, take-offs, omissions, etc.*	✓		
8	*15% SCOPE contingency for potential growth related to design changes, preferences, regulatory issues, etc.*	✓		
9	*OPCC based upon a physical notice-to-proceed construction start on or about July 2018*	✓		
10	*Composite escalation to mid-point of construction established per individual APR's for MH, M&CE, and EQ*		✓	
11	*Taxes, including (but not limted to) sales, gross-receipts, professional, use, and/or Value-Added*			✓
12	*General conditions allowances in DIV 1 for the work reasonably anticipated but not currently quantifiable*	✓		
13	*General allowances in DIVS 2-17 for the related support work reasonably anticipated but not currently quantifiable*	✓		
14	*Duties, tariffs, and/or import & export fees including any related expenses*			✓
15	*Commissions and/or royalties including any related expenses*			✓
16	*Liquidated damages including any related expenses*			✓
17	*Prime Contractor to be a GENERAL CONTRACTING & CM firm*	✓		
18	*Prime Contractor solicited, bid, & contracted based upon BID/BUILD with PRE-CONSTRUCTION*	✓		
19	*Prime Contractor to pre-plan work sequencing, equipment pre-purchase, and/or early site mobilization as needed*	✓		
20	*Prime Contractor to provide staff (re: DIV 1) for the project management & construction oversight needs*	✓		
21	*Prime Contractor to self-perform select construction work and/or equipment procurement scope*	✓		
22	*Prime Contractor to provide Construction Manager-at-Risk (i.e. CMAR) services*	✓		
23	*Prime Contractor to provide Guaranteed Maximum Pricing (i.e. GMP)*	✓		
24	*Prime Contractor to have direct contractual & reporting responsibilities to OWNER or OWNER'S Rep*	✓		
25	*Prime Contractor to provide a safety program including management, training, reporting, & mitigation responsibilities*	✓		
26	*Prime Contractor to provide a QA/QC program including testing, inspecting, reporting, & mitigation responsibilities*	✓		
27	*Oversight/management of the Prime Contractor by OWNER'S 2nd-party representative*			✓
28	*Oversight/management of the Prime Contractor by OWNER'S 2nd-party safety and/or QC professional*			✓
29	*Local market cost increase allowance due to anticipated issues with the regional economy and bid conditions*			✓
30	*Construction fair market pricing that anticipates competitive market conditions (i.e. 4+ qualified bidders)*	✓		
31	*Construction labor primarily at local Prevailing Wage/Davis Bacon rates*	✓		
32	*40-hour work week, based upon an anticipated schedule of (5)-8 hr days Mon-Fri*	✓		
33	*Multiple-shift construction schedule*			✓
34	*Reduction of the construction duration due to an overtime work schedule*			✓
35	*Installation manhour rate adjustments due to anticipated issues with labor pool, location, and/or work conditions*			✓
36	*Installation manpower productivity adjustments due to anticipated issues with labor pool, location, and/or work conditions*			✓
37	*Installation manhour productivity adjustments due to PHASED Demo & Rehab Project*	✓		
38	*Remote site rotation allowance for eligible tradesmen, supervision, & Prime Contractor field staff*			✓
39	*Remote travel & camp allowance for eligible tradesmen, supervision, and/or Prime Contractor staff*			✓
40	*Project engineering & design services*	✓		
41	*Geotechnical testing, engineering, & design services*	✓		
42	*Engineering support services during construction & start-up*	✓		
43	*Supply & installation per standards typically anticipated for Municipal/Governmental work*	✓		
44	*OCIP (i.e. Owner-controlled-insurance-program) covering all insurance & bond costs at all tiers for this project*			✓

MWH CONSTRUCTORS

BASIS-OF-ESTIMATE CHECKLIST

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Version	Date	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	002	30-Nov-17	30503765

Basis-of-Estimate Items

		OPCC Status		
#	Work Scope & Estimate Content	INCLUDED As OPCC Scope	EXCLUDED But By Others	EXCLUDED Or Not Required
45	*Property acquisitions, leases, easements, right-of-ways, and related fees, costs, & schedule impacts*			✓
46	*Financing, leasing, legal services, and related fees, costs, & schedule impacts*			✓
47	*Work permits, inspections, and related fees, costs, & schedule impacts*			✓
48	*Water-use permits, inspections, and related fees, costs, & schedule impacts*			✓
49	*Environmental/ecological permits, inspections, and related fees, costs, & schedule impacts*			✓
50	*Cultural/preservation work permits, inspections, and related fees, costs, & schedule impacts*			✓
51	*Effluent discharge (i.e. NPDES, POTW, etc.) permits, inspections, and related fees, costs, & schedule impacts*	✓		
52	*Water/wastewater/air sampling, collection, analysis, and/or pilot treatability studies*			✓
53	*Building and trades-work construction permits, inspections, and related fees & costs*	✓		
54	*Work anticipated within an existing treatment area assessed to have Above & Below Grade Issues*	✓		
55	*Consideration for both moderate congestion and moderate spread of existing yard and/or systems infrastructure*	✓		
56	*Hazardous materials/work conditions requiring personal protection and equipment*			✓
57	*High-work conditions requiring personal fall protection equipment*			✓
58	*Clean-room work conditions requiring personal protection and equipment*			✓
59	*Underwater work requiring diver(s) with surface support team and equipment*			✓
60	*Weather (i.e. precipitation) and/or temperature considerations during execution of the work*	✓		
61	*Disadvantaged and/or minority business enterprise considerations for select work*	✓		
62	*System/process oversight of operations and maintenance during start-up & training*	✓		
63	*System/process operations and maintenance during functional and/or performance testing*		✓	
64	*System/process operations and maintenance from commissioning & forward*		✓	
65	*Supply and/or procurement of major EQ items within DIVS 5-15*	✓		
66	*Domestic (US) overland shipping of procured items to project site*	✓		
67	*Stretch-wrapping of select EQ (excluding permanent materials) for shipping and/or on-site storage*	✓		
68	*Crating of select EQ (excluding permanent materials) for shipping and/or on-site storage*			✓
69	*Containerization of select EQ (excluding permanent materials) for shipping and/or on-site storage*			✓
70	*Primary excavation issue of Dust Control considered within the construction area(s)*	✓		
71	*Secondary excavation issue of Unstable Soil considered within the construction area(s)*	✓		
72	*0.40-0.80 (x G) Peak acceleration consideration for construction of buildings & structures*	✓		
73	*Category IV - Essential facility risk consideration for construction of buildings & structures*	✓		
74	*Zone II - 160 MPH wind consideration for construction of buildings & structures*	✓		
75	*Minimum of 1,800 PSF uniform soil-bearing capacity in construction area(s)*		✓	
76	*Minimum of 200 PCI uniform soil modulus of subgrade in construction area(s)*		✓	
77	*Maximum of 0.500 INCH uniform soil settlement potential in construction area(s)*		✓	
78	*Maximum of 0.250 INCH differential soil settlement potential in construction area(s)*		✓	
79	*Slurry walls for select areas, excavation, and/or structures*			✓
80	*Deep foundations for select structures*			✓
81	*Soil pre-loading and/or over-excavation with recompaction (of excavated material) for select areas*			✓
82	*Shoring, lagging, and/or cribbing for select areas, excavations, and/or structures*	✓		
83	*Steel sheet piling for select areas, excavations, and/or structures*			✓
84	*Saw-cutting and/or core-drilling within select areas*	✓		
85	*Potholing and/or utility locating within select areas*	✓		
86	*Traffic controls within select areas*	✓		
87	*Erosion controls within select areas*	✓		
88	*Dewatering due to excessive surface run-on, aquifers/springs, and/or high water table within select areas*	✓		

BASIS-OF-ESTIMATE CHECKLIST

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Version	Date	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	002	30-Nov-17	30503765

Basis-of-Estimate Items

		OPCC Status		
#	Work Scope & Estimate Content	INCLUDED As OPCC Scope	EXCLUDED But By Others	EXCLUDED Or Not Required
89	*Removal/disposal of existing native topsoil, vegetation, trees, and/or fencing within select areas*	✓		
90	*Removal/disposal of existing EQ, piping, electrical, structures, rubble, and/or debris within select areas*	✓		
91	*Relocation of existing utilities, ductbank, utilidors, chases/tunnels, pipe, and/or conduit/wiring*			✓
92	*Remediation due to hazardous materials within select areas*			✓
93	*Remediation due to cultural (i.e. historical, archaeological, etc.) content within select areas*			✓
94	*Landscaping, irrigation, seeding, sodding, mulching, plantings, and/or restoration within select areas*			✓
95	*Temporary fencing system for safety/security/privacy purposes around select site/construction areas*	✓		
96	*Permanent fencing system for safety/security/privacy purposes around select system/project areas*			✓
97	*Asphalt paving, patching, and/or repairing of select road, parking, and miscellaneous areas*			✓
98	*Curb & gutter system for select road, parking, and/or landscaping areas*			✓
99	*Outdoor lighting units for select areas*	✓		
100	*Concrete-filled steel pipe bollards/guardposts for protecting select equipment, area(s), and/or structure(s)*			✓
101	*Secondary containment for select areas, tanks, and/or structures*			✓
102	*Secondary containment of select piping systems*			✓
103	*Emergency diesel generator(s) including automatic transfer switching and on-board fuel system(s)*	✓		
104	*Emergency power sized only for idling select critical processes, freeze protection, & minimum lighting*	✓		
105	*Paralleling gear for multiple emergency generators*			✓
106	*Double-walled bulk diesel storage tank system with level indication and transfer pumping*	✓		
107	*Sealing, waterproofing, and/or chemical-resistant finish for select field-constructed surfaces*	✓		
108	*Coating and/or galvanizing of select steel building and canopy structural components*	✓		
109	*LEED construction (with certification) of select building structures and/or components*			✓
110	*Usage cost of utilities (i.e. electric, water, natural gas, sewerage, etc.) utilized during construction*		✓	
111	*Assistance in removal, abatement, and/or disposal of existing fluids, sludges, and residuals*		✓	
112	*PPE stations and placarding of project hazards including noise, moving machinery, and chemicals*	✓		
113	*Heat, light, ventilation, entry switches, utility outlets, and/or sump pumps for select vault structures*			✓
114	*Fire protection systems, materials, equipment, and/or placarding within select areas*			✓
115	*Grounding and/or lightning protection systems, materials, and/or equipment within select areas*	✓		
116	*Concrete strength (28 day minimum) provided at 4,500 PSI (7-8 sacks/CY)*	✓		
117	*Type II (lo heat & sulfate resist) cement utilized in structural concrete*	✓		
118	*A615-Plain Steel (qty in tons) reinforcement bar utilized in structural concete*	✓		
119	*Aluminum Structure & Grate primarily utilized for personnel accessways*	✓		
120	*Piping and/or wiring supports primarily utilizing 304 SS Strut & Structural Shapes*	✓		
121	*Local safety disconnect switches for select motorized equipment*	✓		
122	*Local HOA and/or ON-OFF control stations for select equipment*	✓		
123	*Combination eyewash and shower stations (including tempered water system/supply) in select areas*	✓		
124	*ADA (Americans with Disabilities Act) accessibility in select areas*			✓
125	*Valved end-connections and/or by-passes for select in-line instrumentation and control valves*			✓
126	*Solenoid-controlled water stations for select sealwater and/or flushwater systems*	✓		
127	*Stairway access & perimeter handrailing for select building interior elevated spaces*			✓
128	*Ductwork system for select equipment and/or tankage*			✓
129	*Ductwork system for select areas and/or structures*			✓
130	*Coating of select pipe, fittings, and valves*	✓		
131	*Heat-tracing of select pipe, fittings, & valves*			✓
132	*Insulation & jacketing of select pipe, fittings, & valves*			✓

MWH CONSTRUCTORS

BASIS-OF-ESTIMATE CHECKLIST

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Version	Date	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	002	30-Nov-17	30503765

Basis-of-Estimate Items

#	Work Scope & Estimate Content	OPCC Status INCLUDED As OPCC Scope	EXCLUDED But By Others	EXCLUDED Or Not Required
133	*Heat-tracing of select tankage*			✓
134	*Insulation of select tankage*			✓
135	*Architectural treatments and/or finishes similar for all building structures*	✓		
136	*Permanent overhead crane/hoist system(s) that are stand-alone and/or integrated to select structure(s)*			✓
137	*Field-erected tank(s) with either field-applied coating(s) or factory-applied finish(es)*			✓
138	*Scope-wide safety management system with communications/PA and health & safety monitoring*			✓
139	*Scope-wide security management system with access controls and intrusion monitoring*			✓
140	*Scope-wide surveillance management system with video monitoring & archiving*			✓
141	*Access to the work area considered as Slightly Difficult throughout the project execution*	✓		
142	*Patching, repairing, and/or restoring of select existing local infrastructure utilized during work*	✓		
143	*Location for stockpiling, spreading, and/or disposal of surplus soil < 5 mile radius from ISBL*	✓		
144	*Location for stockpiling, spreading, and/or disposal of clearing & grubbing waste < 5 mile radius from ISBL*	✓		
145	*Location for stockpiling, spreading, or disposal of demolition waste < 5 mile radius from ISBL*	✓		
146	*Payment of fee(s) associated with soil and waste stockpiling, spreading, and/or disposal*	✓		
147	*Continuous free & clear access, easement, and/or right-of-way to work area*		✓	
148	*Oversize, overweight, and/or drop-deck trailer accessibility to work area*		✓	
149	*Public and/or main access roads which are suitable and available throughout construction*		✓	
150	*Material and equipment laydown, staging, and/or storage area(s) within 100' of work area*		✓	
151	*Parking area(s) for installation personnel within 100' of work area*		✓	
152	*15 KV primary power supply/tie-in location (with sufficient ampacity) within 100' of work area*		✓	
153	*15 KV back-up power supply/tie-in location (with sufficient ampacity) within 100' of work area*			✓
154	*Hydro-test water supply (with sufficient pressure & volume) or tie-in location within 100' of work area*		✓	
155	*Disposal location for hydro-test fluids within 100' of work area*		✓	
156	*Potable water supply (with sufficient pressure & volume) or tie-in location within 100' of work area*		✓	
157	*Utility and/or fire protection water supply (with sufficient pressure & volume) or tie-in location within 100' of work area*		✓	
158	*Sanitary waste piping tie-in location (with sufficient capacity) within 100' of work area*			✓
159	*Compressed and/or instrument air supply (with sufficient pressure & volume) or tie-in location within 100' of work area*			✓
160	*Steam and/or fossil fuel supply (with sufficient pressure & volume) or tie-in location within 100' of work area*			✓
161	*Influent and/or effluent piping (of sufficient size) or tie-in location within 100' of work area*			✓
162	*Return and/or recycle piping (of sufficient size) or tie-in location within 100' of work area*			✓
163	*Treatment chemical supply (of sufficient size & concentration) or tie-in location within 100' of work area*		✓	
164	*Landline and/or high-speed internet service (of sufficient bandwidth) or tie-in location within 100' of work area*		✓	
165	*High-speed wireless internet service availability (with sufficient speed & bandwidth) within 100' of work area*		✓	
166	*Integration of existing power, process, and site (i.e. safety, security, and/or surveillance) controls to new systems*		✓	
167	*Integration of new power controls to existing systems*	✓		
168	*Integration of new process controls to existing systems*	✓		
169	*Integration of new site controls (i.e. safety, security, and/or surveillance) to existing systems*			✓
170	*Remote monitoring, alarm, & control of new process and/or site management systems*			✓
171	*Local set-aside of equipment and/or piping, electrical, metals, and miscellaneous materials subject to demolition*	✓		
172	*Salvaging/recovery of equipment and/or piping, electrical, metals, and miscellaneous materials subject to demolition*		✓	

END

MWH CONSTRUCTORS

BASIS-OF-ESTIMATE CLARIFICATIONS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Date	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	30-Nov-17	002	30503765

B-O-E Clarifications

1 This OPCC has been assigned a Class 4 (i.e. SCREENING or FEASIBILITY) level status per our judgment of the level of project definition, expected accuracy range, and other characteristics per AACE International Recommended Practice # 18R-97. The estimating methodologies primarily utilized within a class 4 OPCC typically involves equipment and size factoring, parametrics, and complex modeling techniques

2 ***NOTE: The accuracy range limits for this specific OPCC class are defined by AACE International as follow: Low = (-)15% to (-)30%, and High = (+)20% to (+)50%, with a 90% confidence that the actual cost will fall within the bounds of these ranges after application of the appropriate contingencies.***

3 This OPCC, including any evaluation of the Client's project budget, represents our best judgment as a professional familiar with the construction industry. Unless and to the extent otherwise indicated by us, such opinion or evaluation is based upon current market rates for labor, materials and equipment. Furthermore, this OPCC is based on stable market conditions that exhibit predictable supply/demand relationships and does not attempt to capture the impacts of hyper-inflationary or deflationary market cycles. Client further acknowledges that this OPCC is a "snapshot in time" and that the reliability of the OPCC will degrade over time.

4 ***NOTE: A combination of "ESTIMATE "and "SCOPE" contingencies has been included in this OPCC for covering not only the potential issues related to any Estimator judgements, take-offs, or omissions, but also providing for the potential project growth due to design changes/revisions, undefined regulatory considerations, Owner preferences, and general unknowns that could arise over the duration of the project.***

5 ***The following scope deliverable(s) provided by Others form the initial basis of the cost development in this current OPCC version:***

a. Carollo WTP Expansion Cost Estimate Excel spreadsheet and 20/30 MGD planning summaries received via email 16Oct17
b. MWH Record project drawings (335 PDF sheets) dated January 2003 received via email file link 26Oct17
c. Carollo PowerPoint Workshop # 3 received via email file link 26Oct17
d. Carollo PowerPoint Workshop # 5 received via email file link 26Oct17
e. Carollo Electrical Upgrade Figures (5 PDF sheets) received via email 01Nov17
f. Carollo Site Utilidor Figure (1 PDF sheet) received via email 01Nov17
g. Carollo Cost Estimate Comments containing Item Additions and Item Confirmation spreadsheets received via email 17Nov17
h. Various scope clarification emails, telecons, and/or discussions up through 20Nov17

6 ***The Prime Contractor is anticipated to self-perform the following installation scope in this OPCC:***

a. DIV 1 General Conditions
b. DIV 1 Site Staffing for Project Management & Construction Oversight
c. DIV 2 Common Sitework
d. DIV 3 Concrete
e. DIV 4 Masonry
f. DIV 5 Install Miscellaneous Metals EQ
g. DIVS 5-8 Buildings & Components

7 ***Additionally, the Prime Contractor is anticipated to procure the following buy-outs direct from the Fabricators, Manufacturers, and/or Vendors:***

a. DIV 5 Miscellaneous Metals Items
b. DIVS 11-15 Process and Mechanical Equipment Items

8 ***Specific items that have been provided in the OPCC include the following:***

a. Cost items presume a signficant amount will be executed together/simultaneously (especially seismic) and therefore reflect the appropriate Prime burdens
b. Process mechanical items being replaced are anticipated to have the local valves, I&C, and electrical wiring/controls replaced as well
c. The entire FWPS roof membrane & insulation is removed for adding the E-W wall roof anchors, and is fully replaced as part of the deficient decking replacement
d. The following structures are anticipated for the 30 MGD expansion:
    i. (1) 19' wide ActiFlo flow channel and end gallery
    ii. (1) 10' wide ozonation flow channel and 14½' wide parallel/shared gallery (for future 2nd flow channel)
    iii. (2) 20' x 23' filter cells and 16' wide common/shared gallery

9 ***The primary change(s) reflected in this current OPCC from the previous version include:***

a. Added (16) CIP items per an "Additions" spreadsheet
b. Confirmation that installation labor rates are per Oregon BOLI July 2017 publication data for Clackamas County and Estimator's best judgement thereof
c. Adjustment of Prime Contractor's staffing forecast
d. Contingency increased from 20% to 30% (15% estimate +15% scope)
e. Added (16) CIP items per an "Additions" spreadsheet
f. The strainers added to (17) chemical metering pump suctions are 1½" Ø clear PVC Y-strainers with tru-union connections
g. Ventilation improvements are currently represented with gross allowances based on SF pending further scope identification/definition
h. Dry chlorine handling and mix/transfer system anticipates reusing existing in-place storage tanks, feed pumps, and related piping/I&C
i. All existing site lighting upgrades involve replacing the lighting head as well as the pole (where applicable)
k. The following scope items have been deleted from the OPCC:
    i. GAC filter media replacements (4 at 4X)
    ii. Chemical metering pump replacements (17 at 2X)

10 ***END***

MWH CONSTRUCTORS

OPCC MODEL CLARIFICATIONS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Date	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	30-Nov-17	002	30503765

Model Clarifications

1	***NOTE: If utilized in this OPCC, prevailing wage rates and/or overtime work are in anticipation of securing the highest quality/skilled tradesmen for this project, and considers that the availability of this talent could otherwise be compromised depending on the current labor market conditions of the area.***
2	The MODEL LABOR RATE STANDARDS sheet is provided to highlight the methodology behind development of the single blended rate which is then applied within each CSI division. The fringe benefits rate is anticipated to cover those paid by the employer and/or union such as vacation, pension, training, advancement funds, and health & welfare contributions. For any overtime work, the applicable overtime factor (i.e. multiplier) is applied to the MH base rate, while the fringe benefits cost is applied straight-up against each MH worked.
3	The designation of the PRIME CONTRACTOR has a direct bearing on the final OPCC cost, so both the identification and a consensus regarding this entity in the OPCC is important. For example, a "typical" General Contractor as PRIME will require a cost structure that differs from that for other firms such as an EPCM provider.
4	The *"Assumptions"* section at the top of each DIV sheet should be referenced for identifying a portion of the "forced-detail" in the OPCC, including both perceived and known issues such as specific components, materials of construction, site concerns, and working conditions that could impact the cost basis of this OPCC.
5	The *"General Conditions Allowances"* section in the DIV 1 sheet, and the *"General Allowances"* section at the bottom of the DIVS 2-17 sheets, are all comprised of "potential" cost items initially based on the type & quantity of work occurring within each CSI division, with the intention of covering items that could be reasonably anticipated but cannot yet be defined and/or quantified. ***NOTE: The individual allowance section totals should be considered as more reliable and representative of an overall reserve being allowed rather than detailed consideration of each line item cost (or absence thereof) comprising these totals, any of which may or may not eventually be needed.***
6	The manhours developed for each work item reflects the total, whether it be executed by an "individual" or "crew", with the manhour rates depicted thoughout the OPCC having been developed to reflect a blend of the anticipated trade labor and supervision for each CSI division. If the MODEL LABOR RATE STANDARDS sheet is provided, the overall composite rate is provided for informational purposes only and reflects the weighting effect due to the actual divisions of work comprising the project. The individual blended DIV rates utilized include adjustments for any overtime and/or shift work identified in the INSTALLATION OVERVIEW sheet.
7	The BASIS-OF-ESTIMATE CHECKLIST sheet is provided as a quick reference of those scope, execution, and cost items *INCLUDED* in the OPCC, those *EXCLUDED* from the OPCC but anticipated as necessary and the responsibility of Others, and those *EXCLUDED* from the OPCC because they are believed to be unnecessary.
8	The DIV 1 costs are split up into separate sheets, with the DIV 1 PRIME CONTRACTOR STAFF sheet carried as part of the *"Prime Contractor"* section of the OPCC SUMMARY sheet, while the DIV 1 GENERAL REQUIREMENTS sheet costs are carried as part of the direct cost subtotal line within the *"Cost-of-Work"* section of the OPCC SUMMARY sheet. These separate DIV 1 sheet totals are also included as a line item in the WORK BREAKDOWN STRUCTURE sheet. This split is due to the anticipation that the general conditions would primarily be executed utilizing trades labor, construction tools/equipment, and consumable materials.
9	When multiple options or alternatives are presented in the WORK BREAKDOWN STRUCTURE sheet, these are solely for purposes of making a screening/feasibility decision based upon a ROM (i.e rough order-of-magnitude) cost comparison. ***NOTE: These costs are not to be considered as the final/true cost indicator of any individual option or alternative.***
10	The arbitrary allocation (per the check-mark indicator) in the WORK BREAKDOWN STRUCTURE sheet is performed primarily because the line items being allocated are typically not conducive to being accurately partitioned to any specific/individual WBS item, area, or process. Distribution of these allocations is dependent upon the WBS items selected to receive them, with those being excluded marked with an "X" indicator.
11	The DIV 15 sheet piping and DIVS 16-17 sheet raceway material selection drop-downs (1 thru 5) at the top, along with the anticipated percentage of utilization within the total installation, are intended to represent a generalized materials profile anticipated to occur across the project.
12	There may be instances where highly un-symmetrical or complex structures will be dimensionally and/or geometrically "smoothed" to establish more-simplified units that comply with the OPCC input cell templates, all in an attempt to maintain the overall component aspect ratios and overall size. This typically occurs in the DIV sheets utilizing dimensional data inputs.
13	The PRELIMINARY SCHEDULE sheet, if provided, attempts to present all the forecast and WBS totals in a means approximating the anticipated "normal" distribution over the job duration. Typically, the overall construction duration should be considered as more accurate than the individual WBS item durations.
14	The DIVS 5-8 BUILDINGS & COMPONENTS sheet includes a composite cost of all the structure scope required for the building shell and/or roof structure identified. All other building-related construction scope is costed elsewhere as required, such as sitework & excavation (re: DIV 2), concrete & foundations (re: DIV 3), masonry (re: DIV 4), miscellaneous metals (re: DIV 5), finishes (re: DIVS 9-10), mechanical, HVAC, fire protection, utilities, & plumbing (re: DIV 15), and electrical, HVAC, fire protection, utilities, & lighting (re: DIVS 16-17).
15	With exception of those process equipment budget costs provided by Others, all buy-out equipment costs in the DIVS 11-17 sheets are anticipated to be of US origin and have been derived either through best judgement of the Estimator or extrapolation of similar items from an independent equipment quote/purchase database. ***NOTE: Skidded equipment packages have been anticipated as assembled, pre-piped, pre-valved, pre-wired, pre-switched, and pre-painted by the Manufacturer to the fullest extent possible, and typically requiring only re-assembly of the required shipping breakdown, off-skid piping/wiring homeruns, and touch-up paint.***
16	The DIVS 11-17 EQUIPMENT sheets provide equipment line-item breakdowns of the subtotal for the *"Process Equipment Installation Summary"* sections at the top of the DIV 15 and DIVS 16-17 sheets. Each field-installed process/mechanical equipment item within the DIVS 11-17 EQUIPMENT sheets provides parametric costing for all necessary DIV 15 mechanical work such as off-load, handle, set, anchor, grout, and needed hangars/brackets/supports, pipe, fittings, manual valves, check valves, pressure gauges, and sample ports, and for all necessary DIVS 16-17 electrical equipment such as off-load, handle, set, anchor, grout, and needed hangars/brackets/supports, disconnect/safety switches, raceway, flex-conduit, fittings, wire, terminations, and grounding.
17	Percentages applied for the indirect costs are estimates based upon the scope of work, anticipated schedule, and risk allocation deemed necessary at the time of this submittal.
18	***END***
19	
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MWH
CONSTRUCTORS

MODEL LABOR RATE STANDARDS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

Labor Classification Rate Basis

Prevailing Wage/Davis Bacon

MH Avg Burden for Fringes	51%
MH Adder for Supervision	$2.00
Allowance for Incidental OT	
MH Allowance for Other	$0.00

Construction Work Schedule

(5)-8 hr days Mon-Fri

Base Labor Rate Source

☐ MEANS Construction Cost Indexing of 30-City Rates
☐ MEANS Annual Prevailing Labor Rates Publication
☑ STATE Prevailing Wage Determination Website

MH Rate Overtime Factors

Work Day Schedule

	Hours = 8	Hours > 8
Monday-Friday	1X Base	1½X Base
Saturday	1½X Base	2X Base
Sunday	2X Base	3X Base

Composite MH Rate (for information only)

Weighted Rate by Scope & Schedule

	Straight	Overtime
Direct Rate	$52.28	
*Fringes **	$17.66	
Base Rate	$34.62	

* Fringes are anticipated as those benefits paid by the employer and/or union such as vacation, pension, training, advancement funds, and health & welfare contributions

Labor Rates by DIV

DIVS 1-2: General Requirements & Sitework

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Operator (crane)	2	$57.99	$57.99	$115.98
Operator (medium)	2	$52.09	$52.09	$104.18
Driver (heavy)	2	$27.70	$27.70	$55.40
Operator (mechanic)	1	$57.99	$57.99	$57.99
Operator (oiler)	1	$49.86	$49.86	$49.86
Helper/Apprentice	1	$39.87	$39.87	$39.87
Laborer	2	$42.68	$42.68	$85.36
Supervision	2	$59.99	$59.99	$119.98
Totals	13			$628.62

Blended Rate Applied in these DIVS = $48.36

DIV 3: Concrete

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Carpenter	4	$52.88	$52.88	$211.52
Rodman	4	$60.87	$60.87	$243.48
Cement Finisher	3	$51.12	$51.12	$153.36
Operator (crane)	1	$57.99	$57.99	$57.99
Operator (medium)	1	$52.09	$52.09	$52.09
Helper/Apprentice	2	$39.87	$39.87	$79.74
Laborer	2	$42.68	$42.68	$85.36
Supervision	3	$62.87	$62.87	$188.61
Totals	20			$1,072.15

Blended Rate Applied in this DIV = $53.61

DIV 4: Masonry

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Bricklayer	6	$55.62	$55.62	$333.72
Stone Mason	2	$55.62	$55.62	$111.24
Operator (light)	1	$50.94	$50.94	$50.94
Helper/Apprentice	2	$39.87	$39.87	$79.74
Laborer	2	$42.68	$42.68	$85.36
Supervision	2	$41.87	$41.87	$83.74
Totals	15			$744.73

Blended Rate Applied in this DIV = $49.65

DIV 5: Miscellaneous Metals

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Welder/SS Worker	5	$60.87	$60.87	$304.35
Operator (crane)	1	$57.99	$57.99	$57.99
Operator (medium)	3	$52.09	$52.09	$156.27
Boilermaker	2	$57.26	$57.26	$114.52
Helper/Apprentice	2	$39.87	$39.87	$79.74
Supervision	2	$59.26	$59.26	$118.52
Totals	15			$831.39

Blended Rate Applied in this DIV = $55.43

DIVS 5-8: Buildings

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Welder/SS Worker	1	$60.87	$60.87	$60.87
Operator (crane)	4	$57.99	$57.99	$231.96
Operator (medium)	1	$52.09	$52.09	$52.09
Sheetmetal Worker	2	$59.20	$59.20	$118.40
Glazier	1	$54.97	$54.97	$54.97
Roofer (composition)	2	$48.32	$48.32	$96.64
Sprinkler Installer	1	$59.13	$59.13	$59.13
Helper/Apprentice	2	$39.87	$39.87	$79.74
Supervision	2	$61.13	$61.13	$122.26
Totals	16			$876.06

Blended Rate Applied in these DIVS = $54.75

DIVS 9-10: Finishes

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Painter (structural)	5	$39.43	$39.43	$197.15
Tile Layers	1	$37.13	$37.13	$37.13
Plasterer	1	$47.37	$47.37	$47.37
Painter (ordinary)	3	$35.38	$35.38	$106.14
Lather	1	$52.88	$52.88	$52.88
Helper/Apprentice	1	$39.87	$39.87	$39.87
Supervision	2	$41.87	$41.87	$83.74
Totals	14			$564.27

Blended Rate Applied in these DIVS = $40.31

MWH CONSTRUCTORS

MODEL LABOR RATE STANDARDS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Labor Rates by DIV

DIV 13: Field & Shop Tanks

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Welder/SS Worker				
Operator (crane)				
Operator (medium)				
Boilermaker				
Helper/Apprentice				
Supervision				

DIV 15: Piping & Mechanical

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Millwright	1	$40.00	$40.00	$40.00
Steamfitter/Pipefitter	7	$69.85	$69.85	$488.95
Plumber	2	$69.85	$69.85	$139.70
Boilermaker	1	$57.26	$57.26	$57.26
Insulator	1	$66.67	$66.67	$66.67
Operator (medium)	2	$52.09	$52.09	$104.18
Welder/SS Worker	1	$60.87	$60.87	$60.87
Helper/Apprentice	2	$39.87	$39.87	$79.74
Supervision	3	$59.26	$59.26	$177.78
Totals	**20**			**$1,215.15**

Blended Rate Applied in this DIV = $60.76

DIVS 16-17: Power and I&C

Potential Labor Trades	Anticpated Work Ratio	Initial State Prevail Rate	Final OPCC Direct Rate	TOTAL
Electrician	8	$63.58	$63.58	$508.64
Operator (light)	1	$50.94	$50.94	$50.94
Helper/Apprentice	2	$39.87	$39.87	$79.74
Supervision	2	$65.58	$65.58	$131.16
Totals	**13**			**$770.48**

Blended Rate Applied in these DIVS = $59.27

Overview of Composite Labor Rates Based on Work Schedule

		Monday thru Friday				Saturday				Sunday				Summary		
		Workday = 8 Hours		Workday > 8 Hours		Workday = 8 Hours		Workday > 8 Hours		Workday = 8 Hours		Workday > 8 Hours				
#	Weekly Schedule	MH per Week	MH Cost per Week	Added MH per Week	Added MH $ per Week	MH per Week	MH Cost per Week	Added MH per Week	Added MH $ per Week	MH per Week	MH Cost per Week	Added MH per Week	Added MH $ per Week	TOTAL MH per Week	TOTAL MH Cost per Week	Composite MH Cost per Hour
1	(4)-10 hr days Mon-Fri (w/o OT)	40	$2,091	0	$0	0	$0	0	$0	0	$0	0	$0	**40**	$2,091	**$52.28**
2	(5)-8 hr days Mon-Fri	40	$2,091											**40**	$2,091	**$52.28**
3	(5)-8 hr days Mon-Fri + Incidental OT	40	$2,091	0	$0	0	$0	0	$0	0	$0	0	$0	**40**	$2,091	**$52.28**
4	(4)-10 hr days Mon-Fri (with OT)	32	$1,673	8	$557									**40**	$2,229	**$55.74**
5	(6)-8 hr days Mon-Sat	40	$2,091	0	$0	8	$557	0	$0	0	$0	0	$0	**48**	$2,648	**$55.16**
6	(4)-12 hr days Mon-Fri	32	$1,673	16	$1,113									**48**	$2,786	**$58.04**
7	(5)-10 hr days Mon-Fri	40	$2,091	10	$696	0	$0	0	$0	0	$0	0	$0	**50**	$2,787	**$55.74**
8	(7)-8 hr days Mon-Sun	40	$2,091			8	$557			8	$695			**56**	$3,343	**$59.69**
9	(5)-10 hr days Mon-Fri + 8 hrs Sat	40	$2,091	10	$696	8	$557	0	$0	0	$0	0	$0	**58**	$3,344	**$57.65**
10	(5)-12 hr days Mon-Fri	40	$2,091	20	$1,392									**60**	$3,483	**$58.04**
11	(6)-10 hr days Mon-Sat	40	$2,091	10	$696	8	$557	2	$174	0	$0	0	$0	**60**	$3,517	**$58.62**
12	(5)-12 hr days Mon-Fri + 8 hrs Sat	40	$2,091	20	$1,392	8	$557							**68**	$4,039	**$59.40**
13	(6)-10 hr days Mon-Sat + 8 hrs Sun	40	$2,091	10	$696	8	$557	2	$174	8	$695	0	$0	**68**	$4,212	**$61.95**
14	(7)-10 hr days Mon-Sun	40	$2,091	10	$696	8	$557	2	$174	8	$695	2	$243	**70**	$4,455	**$63.65**
15	(6)-12 hr days Mon-Sat	40	$2,091	20	$1,392	8	$557	4	$348	0	$0	0	$0	**72**	$4,387	**$60.93**
16	(6)-12 hr days Mon-Sat + 8 hrs Sun	40	$2,091	20	$1,392	8	$557	4	$348	8	$695			**80**	$5,082	**$63.53**
17	(7)-12 hr days Mon-Sun	40	$2,091	20	$1,392	8	$557	4	$348	8	$695	4	$486	**84**	$5,568	**$66.29**

MWH
CONSTRUCTORS

OPCC SUMMARY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	**Wilsonville, OR**	**30-Nov-17**	**Jim Ward**	**002**	**30503765**

Assumptions

Project Delivery & Bid Scope	BID/BUILD with PRE-CONSTRUCTION	*EQ Inspections & Start-Up Assistance*	2.00%
Prime Contractor	GENERAL CONTRACTOR as CM	*EQ Spare Parts & Special Tools/Supplies*	1.87% for both Start-Up & 1-Year Supply
Construction Execution	PRIME with 63% of Direct Cost by SUBS	*Packing & Freight Categories*	EQ (excluding permanent materials)
Payroll Deductions & Workers Compensation	32.00%	*Packing & Freight*	3.50%
Small Tools & Personal Safety Gear	3.50%	*Labor Escalation - BY OTHERS*	
Tax Type & Categories Applied	TAX EXCLUDED and/or EXEMPT	*Materials Escalation - BY OTHERS*	
Tax Rate Applied (Wilsonville, OR)		*Equipment Escalation - BY OTHERS*	
Builders Risk Insurance - Carried by PRIME	0.70%	*Years of Escalation - NOT APPLICABLE*	
Liability Insurances - SUBS	0.55%	*Estimate Contingency*	15.00%
Umbrella & Vehicle Insurances - SUBS	0.25%	*Scope Contingency*	15.00%
Bonds (payment-performance-supply) - SUBS	1.30%	*Local Market Issues - EXCLUDED*	
Overhead & General Conditions - SUBS	5.00%	*Anticipated Construction Duration*	TBD
Profit - SUBS	10.00%	*Special Project Consideration*	PHASED Demo & Rehab Project

Build-Up to Cost-of-Work

	Work Self-Performed by Prime Contractor				*Work Performed by Subcontractors*				
Description	Install MH	MH $	M&CE $	EQ $	Install MH	MH $	M&CE $	EQ $	TOTAL
Direct Cost (i.e. DIVS 1-17 less DIV 1 Staff cost)	43,121	$2,261,111	$1,980,874	$5,442,024	24,018	$1,424,220	$2,743,720	$3,845,335	***$17,697,284***
Payroll Deductions & Workers Compensation		$479,176				$301,821			*$780,997*
Small Tools & Personal Safety Gear		$52,410				$33,012			*$85,422*
EQ Inspections & Start-Up Assistance - VENDORS				$108,840				$76,907	*$185,747*
EQ Spare Parts & Special Tool/Materials - VENDORS				$205,346				$145,098	*$350,444*
EQ Packing & Freight - VENDORS				$190,471				$134,587	*$325,058*
SALES TAX - NOT APPLICABLE									
Subtotal A	43,121	$2,792,697	$1,980,874	$5,946,681	24,018	$1,759,053	$2,743,720	$4,201,927	***$19,424,951***
Overhead & General Conditions - SUBS						$87,953	$137,186	$210,096	*$435,235*
Profit - SUBS						$184,701	$288,091	$441,202	*$913,993*
Subtotal B	43,121	$2,792,697	$1,980,874	$5,946,681	24,018	$2,031,706	$3,168,996	$4,853,225	***$20,774,179***
Builders Risk Insurance (re: PRIME CONTRACTOR below)									
Liability Insurance - SUBS						$11,174			*$11,174*
Umbrella & Vehicle Insurances - SUBS						$5,079	$7,922		*$13,002*
Bonds (payment, performance, & supply) - SUBS						$26,623	$41,300	$63,092	*$131,015*
Subtotal C	43,121	$2,792,697	$1,980,874	$5,946,681	24,018	$2,074,583	$3,218,218	$4,916,317	***$20,929,371***
Escalation - BY OTHERS									
Estimate Contingency	6,468	$418,905	$297,131	$892,002	3,603	$311,188	$482,733	$737,448	*$3,139,406*
Scope Contingency	6,468	$418,905	$297,131	$892,002	3,603	$311,188	$482,733	$737,448	*$3,139,406*
Local Market Issues - EXCLUDED									
Subtotal D	56,057	$3,630,507	$2,575,136	$7,730,685	31,224	$2,696,958	$4,183,684	$6,391,212	***$27,208,182***
GROSS RECEIPTS TAX - NOT APPLICABLE									
Subtotal - Cost-of-Work	56,057	$3,630,507	$2,575,136	$7,730,685	31,224	$2,696,958	$4,183,684	$6,391,212	***$27,208,182***

MWH CONSTRUCTORS

OPCC SUMMARY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Prime Contractor Cost, Burdens, & Mark-Ups

Description	Basis	TOTAL
Project Staff Labor	DIV 1 PRIME CONTRACTOR STAFF sheet	*$2,823,055*
Project Staff Travel, Living, & Other	DIV 1 PRIME CONTRACTOR STAFF sheet	*$171,722*
Project Staff Camp Allowance - NOT APPLICABLE		
Tradesmen & Supervision Camp Allowance - NOT APPLICABLE		
(TBD)		
Subtotal E		***$2,994,777***
Escalation - BY OTHERS		
Insurances (i.e. builders risk, liability, umbrella, & vehicle)	1.51% of Subtotal B above	*$312,885*
Subtotal F		***$3,307,662***
General & Administrative	5% of Cost-of-Work Subtotal & Subtotal F above	*$1,525,792*
Profit	10% of Cost-of-Work Subtotal & Subtotal F above	*$3,051,584*
Project Engineering including Geotechnical, Design, Permitting, & Support during Construction	15% of Cost-of-Work Subtotal	*$4,081,227*
(TBD)		
Subtotal G		***$11,966,266***
Bonds (payment, performance, & supply)	0.89% of Cost-of-Work Subtotal & Subtotal G above	*$349,639*
Subtotal H		***$12,315,905***
GROSS RECEIPTS TAX - NOT APPLICABLE		
	Subtotal - Prime Contractor Burdens & Mark-Ups	***$12,315,905***

Pass-Through Scope

Description	Basis	TOTAL
(EQ TBD)		
EQ Inspections & Start-Up Assistance - NOT APPLICABLE		
EQ Extra Materials & Spare Parts - NOT APPLICABLE		
Packing & Freight - NOT APPLICABLE		
SALES TAX - NOT APPLICABLE		
Subtotal I		
Escalation - NOT APPLICABLE		
Estimate Contingency - NOT APPLICABLE		
Scope Contingency - NOT APPLICABLE		
Subtotal J		
Bonds (payment, performance, & supply)		
Subtotal K		
GROSS RECEIPTS TAX - NOT APPLICABLE		
	Subtotal - Pass-Through Scope	

OPCC Summary Total

OPCC GRAND TOTAL	***$39,524,088***

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OPCC SUMMARY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Glossary of OPCC Summary Terms

PROJECT DELIVERY & BID SCOPE: Identifies the bid & installation work scope approach (i.e. Bid/Build or Design/Build), which subsequently establishes the baseline burdens and add-on rates.

PRIME CONTRACTOR: Identifies the entity having the overall construction oversight and/or construction management responsibilities, which adjusts a portion of the assigned burden & add-ons.

CONSTRUCTION EXECUTION: Identifies the entity actually performing the supply/install work scope, which finalizes the balance of the assigned burden and add-on rates.

PAYROLL DEDUCTIONS & WORKERS COMP: Percent applied to the supply/install Contractor(s) base MH rate (i.e. excluding fringes) to cover the payroll taxes (FICA, FUTA, & SUTA), payroll insurances, pension contributions, union assessments, bonus programs (excluding profit sharing), training funds, industry/administrative funds, and state workers compensation insurance.

SMALL TOOLS & PERSONAL SAFETY GEAR: Percent applied to the supply/install Contractor(s) base MH rate (i.e. excluding fringes) to cover the supply and/or replacement of the small "expendable" items (i.e. hand tools, hand-held power tools, etc.), and personal protection equipment, with any single item value anticipated to be no greater than $250.

TAX TYPE & CATEGORIES APPLIED: Identifies the type of tax and the MH, M&CE, and/or EQ cost categories to which the tax percentage assigned below shall apply.

TAX RATE: Percent applied to the categories identified above which calculates the supply/install or Prime Contractor(s) tax burden.

BUILDERS RISK INSURANCE: Percent applied to the direct MH, M&CE, & EQ costs to cover the capital and installation risk insurance carried either by the Owner or Prime Contractor (carried under the Prime section).

LIABILITY INSURANCES: Percent applied to the supply/install Subcontractor(s) direct MH cost for the general liability insurances.

UMBRELLA & VEHICLE INSURANCES: Percent applied to the supply/install Subcontractor(s) direct MH & M&CE costs for the umbrella & vehicle insurances.

PAYMENT, PERFORMANCE, & SUPPLY BONDS: Percent applied to the supply/install Subcontractor(s) applicable direct MH, M&CE, & EQ costs for the bonds to ensure satisfactory completion and payment to the suppliers, Vendors, & Subcontractors.

OVERHEAD & GENERAL CONDITIONS: Percent applied to the supply/install Subcontractor(s) direct MH, M&CE, & EQ costs for direct & indirect field overhead expenses, the indirect home office expenses, and all general conditions incurred during execution of the installation.

PROFIT: Percent applied to the supply/install Subcontractor(s) direct MH, M&CE, & EQ costs for the profit.

EQ INSPECTIONS & START-UP ASSISTANCE: Percent applied to the direct EQ costs for the tax-exempt services provided by the Manufacturer/Vendor, such as installation inspections and start-up assistance, including all related T&L costs.

EQ EXTRA MATERIALS & SPARE PARTS: Identifies the additional buy-out EQ supplies to be provided by either the Manufacturer or Vendor, such as special tools, lubricants, & spare parts.

PACKING & FREIGHT CATEGORIES: Identifies the EQ and/or M&CE cost categories to which the freight percentage assigned below is applied.

PACKING & FREIGHT: Percent applied to the categories identified above for the supply/install Contractor(s) freight costs for packing, shrink-wrapping, crating, containerization and/or shipping expenses.

LABOR ESCALATION APR: Annual percentage rate applied to all direct labor and Prime Contractor staff travel and living costs, which is then pro-rated to the projected duration from the date of this OPCC to mid-point of construction.

MATERIALS ESCALATION APR: Annual percentage rate applied to all direct costs for construction materials, consumbables, and construction equipment (M&CE), which is then pro-rated to the projected duration from the date of this OPCC to mid-point of construction.

EQUIPMENT ESCALATION APR: Annual percentage rate applied to all direct costs for process and buy-out equipment (EQ), which is then pro-rated to the projected duration from the date of this OPCC to mid-point of construction.

YEARS OF ESCALATION: Identifies the "life" of this OPCC (starting from the completion date of the OPCC), over which the APR escalation rates identified above will be applied, and reflecting the overall time anticipated to pass for executing pre-con issues that could include sampling, surveys/testing, bench tests, design development, Contractor solicitations/negotiations, Prime and/or Subcontractor site staffing, site set-up, submittals/approvals, early/long-lead equipment procurement, and planning/coordination for any special demolition, phasing, and/or shut-downs.

ESTIMATE CONTINGENCY: Percent applied to the direct MH, M&CE, & EQ costs for the purpose of covering the potential Estimator errors/omissions, variability with the take-off and quantification efforts, and misinterpretation of the design documents.

SCOPE CONTINGENCY: Percent applied to the direct MH, M&CE, & EQ costs for covering the potential growth due to design changes/revisions, Owner preferences, and unknown regulatory requirements.

LOCAL MARKET ISSUES: Percent applied to the supply/install Contractor(s) direct MH & M&CE costs for the local construction/bid climate issues such as bidder quantity, bidder quality, contractor risk appetite, project size/complexity, bonding capacity, availability of labor, materials, and/or equipment, local governmental/bureaucratic mandates, and perceived project execution issues.

ANTICIPATED CONSTRUCTION DURATION: Identifies the total construction duration (from physical notice-to-proceed mobilization through to substantial completion) either in weeks, months, or years for the project with the labor headcount and production efficiency assigned in this OPCC, and excluding time for testing & final completion/sign-off.

SPECIAL PROJECT CONSIDERATION: Identifies the anticipated special project considerations for demolition, rehabilitation, phasing, personal protective equipment (PPE), or combination of these.

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OPCC SUMMARY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

PROJECT STAFF LABOR: The costs attributable to the labor hours generated by all the Prime Contractor's on-site and home-office based personnel directly billable to the project.

PROJECT STAFF TRAVEL, LIVING, & OTHER: The costs attributable to the travel, living, & miscellaneous related costs generated by all the Prime Contractor's on-site and home-office based personnel directly billable to the project.

PROJECT STAFF CAMP ALLOWANCE: The anticipated total cost for providing all Tradesmen and Supervision with travel to/from a remote work site, as well as the establishment & maintenance of a remote camp

TRADESMEN & SUPERVISION CAMP ALLOWANCE: The anticipated total cost for providing all Tradesmen and Supervision with travel to/from a remote work site, as well as the establishment & maintenance of a remote camp.

ESCALATION: The anticipated increase in the Prime Contractor's Pre-Construction & Construction Staff labor, travel/living, and camp costs due to the project duration (i.e. years of escalation) and escalation APR's indicated above.

INSURANCES: An allowance for the overall project builders risk insurance, as well as the miscellaneous umbrella, vehicle, and liability insurances carried by the Prime Contractor.

GENERAL & ADMINISTRATIVE: The costs attributable to the Prime Contractor's indirect costs that are attributable to labor, supplies, materials, equipment, tools, facilities and/or overheads, both field and home office, during execution of the project.

PROJECT & CONSTRUCTION MANAGEMENT FEE: The anticipated profit for the Prime Contractor in executing and/or managing the project.

PROJECT ENGINEERING: The forecasted cost of the project engineering effort, which may include geotechnical testing and design, detailed project design, and/or support and oversight during construction.

BONDS: Percent applied to the applicable overall project MH, M&CE, & EQ costs for the bonds to ensure satisfactory completion (to the Owner) and payment to the suppliers, Vendors, & Subcontractors.

WBS COST BUILD-UP SUMMARY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Introduction

This MAP presents another view of how the OPCC goes from DIRECT COSTS to COST-OF-WORK, and identifies the development of the overall project cost build-up. ***NOTE: The dollar amounts reflect the OPCC while the percentages are provided for general informational purposes only and do not represent how the individual costs were established.***

CATEGORY	WBS	DESCRIPTION	INSTALLATION COSTS		TOTAL COST	%	OPCC SOURCE
			Prime Contractor	Subcontractors			
INSTALLING CONTRACTOR(S) DIRECT COSTS	1	General Conditions	$1,408,927	$0	$1,408,927	8.0%	INSTALLATION OVERVIEW & DIVS 1-17
	2	General Allowances	$55,459	$49,683	$105,142	0.6%	
	3	Process Control EQ	$0	$328,569	$328,569	1.9%	
	4	***20 MGD CAPACITY UPGRADES***					
	5	Extend Chem Lines & Utilidor-CHEM	$135,554	$83,671	$219,225	1.2%	
	6	Procure Shelf-Spare Solids/Sand Pump (1)-ACT	$18,500		$18,500	0.1%	
	7	Install 2nd Flash Mix Pump (1)-ACT	$27,744	$40,979	$68,723	0.4%	
	8	Install Shelf-Spare Mix Pump (1)-SOL		$40,227	$40,227	0.2%	
	9	Replace 4 MGD Pump with 7.5 MGD (1)-FWPS	$331,800	$172,039	$503,839	2.8%	
	10	Replace Switchgear-ELEC		$1,539,287	$1,539,287	8.7%	
	11	Rewire to Support BU Power Supply-ELEC	$0	$106,273	$106,273	0.6%	
	12	Replace 1 MW Genset with 2 MW (1)-ELEC	$108,671	$1,402,889	$1,511,560	8.5%	
	13	***20 MGD REPAIR & REPLACE***	$0	$0	$0	0.0%	
	14	Replace Polymer Unit PLC (1)-CHEM	$7,500	$1,662	$9,162	0.1%	
	15	DELETED: Replace Meter Pumps (17)-CHEM	$0	$0	$0	0.0%	
	16	Replace Actiflo System PLC (1)-ACT	$20,000	$5,541	$25,541	0.1%	
	17	Replace Sample Pumps (2)-ACT	$3,000	$14,523	$17,523	0.1%	
	18	Replace Tube Modules in Settle Tanks (2)-ACT	$90,250	$13,721	$103,971	0.6%	
	19	DELETED: Replace GAC Media (3X)-FILT	$0	$0	$0	0.0%	
	20	Upgrade/Replace Existing Wiring-FILT		$88,560	$88,560	0.5%	
	21	Chem Line Support Mods-WWEQ	$0	$16,076	$16,076	0.1%	
	22	Replace VFD Units (3)-FWPS		$334,948	$334,948	1.9%	
	23	***20 MGD LIFE SAFETY***	$0	$0	$0	0.0%	
	24	Replace Faded NFPA Signage-CHEM		$3,265	$3,265	0.0%	
	25	Add Exit Door Panic Hardware (3)-CHEM	$4,449	$0	$4,449	0.0%	
	26	Change Door Swing Direction (1)-O3	$2,157		$2,157	0.0%	
	27	Add Exit Area Containment Pans (2)-CHEM	$1,795	$2,744	$4,539	0.0%	
	28	Add Exit Emergency Shut-Off (2)-O3		$4,297	$4,297	0.0%	
	29	Replace Guardrail (20 LF)-ACT	$2,626	$0	$2,626	0.0%	
	30	Seal & Waterstop Corner Leaks (2)-ACT	$14,753		$14,753	0.1%	
	31	Add Exit Door Panic Hardware (2)-ACT	$2,966	$0	$2,966	0.0%	
	32	Add West Guardrail Kickplate (20 LF)-ACT	$950		$950	0.0%	
	33	Upgrade Outlets to GFI's (8)-ACT	$0	$874	$874	0.0%	
	34	Replace Guardrail (20 LF)-OZ	$2,626		$2,626	0.0%	
	35	Upgrade Outlets to GFI's (8)-CHEM	*$0*	*$874*	$874	0.0%	
	36	Replace Guardrail (20 LF)-FILT	*$2,626*		$2,626	0.0%	
	37	Seal & Waterstop Corner Leaks (2)-FILT	*$14,156*	*$0*	$14,156	0.1%	
	38	Add Ladder Pit Kickplate (20 LF)-FILT	*$950*		$950	0.0%	
	39	Upgrade Outlets to GFI's (16)-FILT	*$0*	*$1,748*	$1,748	0.0%	
	40	Add Exit Door Panic Hardware (2)-FWPS	*$2,966*		$2,966	0.0%	
	41	Install Scupper & Downspout (1)-DEW	*$3,771*	*$0*	$3,771	0.0%	
	42	Seal & Waterstop Corner Leaks (2)-OZ	*$18,213*		$18,213	0.1%	
	43	***20 MGD SEISMIC RETROFITS***	*$0*	*$0*	$0	0.0%	
	44	Add Pipe Bracing-CHEM/O3/LOX		*$13,291*	$13,291	0.1%	
	45	Add Destruct Pipe Bracing: OZ	*$0*	*$4,344*	$4,344	0.0%	
	46	Add N & S Wall Beams & Columns (3)-WWEQ	*$88,141*		$88,141	0.5%	
	47	Add Basin Width Beams & Columns (3)-WWEQ	*$79,036*	*$0*	$79,036	0.4%	
	48	Add W & E Wall Roof Anchors (23)-FWPS	*$60,200*		$60,200	0.3%	
	49	Replace Deficient Deck Sections (1,966 SF)-FW	*$56,084*	*$0*	$56,084	0.3%	
	50	Strengthen Chord Connections (44)-FWPS	*$4,965*		$4,965	0.0%	
	51	Add Shear Wall Plates & Anchors (46)-FWPS	*$36,400*	*$0*	$36,400	0.2%	
	52	Add Cable Tray Bracing-FWPS		*$5,245*	$5,245	0.0%	
	53	Install E Side Frame Braces for 2nd Floor (1)-DE	*$20,761*	*$0*	$20,761	0.1%	

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WBS COST BUILD-UP SUMMARY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	**Wilsonville, OR**	**30-Nov-17**	**Jim Ward**	**002**	**30503765**

Introduction

This MAP presents another view of how the OPCC goes from DIRECT COSTS to COST-OF-WORK, and identifies the development of the overall project cost build-up. ***NOTE: The dollar amounts reflect the OPCC while the percentages are provided for general informational purposes only and do not represent how the individual costs were established.***

			INSTALLATION COSTS				
CATEGORY	WBS	DESCRIPTION	Prime Contractor	Subcontractors	TOTAL COST	%	OPCC SOURCE
	54	Add E & W Wall Roof Anchors (6)-DEW	*$26,751*		$26,751	0.2%	
	55	Tie Floor Slab to Walls (2)-DEW	*$11,056*	*$0*	$11,056	0.1%	
	56	Install Space Heater Braces (8)-SITE		*$4,116*	$4,116	0.0%	
	57	***30 MGD CAPACITY UPGRADES***	*$0*	*$0*	$0	0.0%	
	58	Install New Ozone Generator (1)-O3	*$400,773*	*$107,638*	$508,411	2.9%	
	59	Install New Flow Channel & Gallery (1)-ACT	*$1,510,141*	*$502,560*	$2,012,702	11.4%	
	60	Install New Flow Channel & Gallery (1)-OZ	*$900,213*	*$467,702*	$1,367,916	7.7%	
	61	Install New Thickener (1)-SOL	*$230,402*	*$127,610*	$358,012	2.0%	
	62	Install New Cells (2) & Gallery-FILT	*$1,182,064*	*$525,142*	$1,707,206	9.6%	
	63	Replace 7.5 MGD Pumps with 12 MGD (3)-FWF	*$1,301,400*	*$727,231*	$2,028,631	11.5%	
	64	Install 5th 7.5 MGD Pump (1)-FWPS	*$331,800*	*$162,369*	$494,169	2.8%	
	65	Replace 7.5 MGD Pumps with 15 MGD (2)-RWF	*$354,300*	*$365,472*	$719,772	4.1%	
	66	Install 3rd Centrifuge & Solids Pump (1)-DEW	*$474,744*	*$222,699*	$697,444	3.9%	
	67	***30 MGD REPAIR & REPLACE***	*$0*	*$0*	$0	0.0%	
	68	DELETED: Replace Meter Pumps (17)-CHEM					
	69	Replace Flash Mix Pumps (2)-ACT	*$55,000*	*$96,196*	$151,196	0.9%	
	70	Replace Thickener Drive (1)-SOL	*$20,000*	*$25,598*	$45,598	0.3%	
	71	DELETED: Replace GAC Media (1X)-FILT	*$0*	*$0*	$0	0.0%	
	72	Replace Solids Transfer Pumps (2)-DEW	*$30,000*	*$93,906*	$123,906	0.7%	
	73	0	*$0*	*$0*	$0	0.0%	
	74	**ADDERS per 17NOV17 Email**					
	75	***20 MGD CAPACITY UPGRADES***	*$0*	*$0*	$0	0.0%	
	76	Add Hypochlorite Vent Return Line-CHEM		*$2,501*	$2,501	0.0%	
	77	Add Meter Pump Strainers (17)-CHEM	*$2,465*	*$1,804*	$4,269	0.0%	
	78	Upgrade Sitewide Lighting to LED-SITE		*$58,947*	$58,947	0.3%	
	79	Replace Rental LOX Tank with Larger (1)-O3	*$0*	*$32,491*	$32,491	0.2%	
	80	***20 MGD LIFE SAFETY***					
	81	Improve Bldg/Gallery Ventilation-ACT	*$0*	*$12,511*	$12,511	0.1%	
	82	Replace Stairwell Door with Fire Door-FILT	*$1,484*	*$25*	$1,509	0.0%	
	83	Improve Blower Room Ventilation-FILT	*$0*	*$16,404*	$16,404	0.1%	
	84	Improve SWGR Room Ventilation-FWPS		*$30,920*	$30,920	0.2%	
	85	Add SWGR Door Panic Hardware (2)-FWPS	*$2,966*	*$0*	$2,966	0.0%	
	86	Improve South Stairwell Ventilation-OZ		*$3,960*	$3,960	0.0%	
	87	Add Fall Protection to Plate Hatches (10)-SITE	*$18,326*	*$0*	$18,326	0.1%	
	88	Add Ladder Fall Restraint to Basin-WWEQ	*$3,209*		$3,209	0.0%	
	89	Improve Room/Bldg Ventilation-WWEQ	*$0*	*$13,264*	$13,264	0.1%	
	90	***20 MGD REPAIR & REPLACE***					
	91	Replace Security Camera & Computer (1)-MISC	*$0*	*$8,922*	$8,922	0.1%	
	92	***30 MGD CAPACITY UPGRADES***					
	93	Convert Wet NaOCl System to Dry-CHEM	*$157,365*	*$105,768*	$263,133	1.5%	
	94	Storage Room Mods for Added Space-CHEM	*$41,550*	*$22,185*	$63,735	0.4%	
	95	0	*$0*	*$0*	$0	0.0%	
	96						
	97	0	*$0*	*$0*	$0	0.0%	
	98						
	99	0	*$0*	*$0*	$0	0.0%	
		Direct Costs Subtotal	$9,684,009	$8,013,275	**$17,697,284**		
	Payroll Deducts & Workers Comp		$479,176	$301,821	$780,997	4.4%	
	Small Tools & Personal Safety Gear		$52,410	$33,012	$85,422	0.5%	
	Vendor Inspections & Start-Up Assistance		$108,840	$76,907	$185,747	1.0%	
	Vendor Spare Parts & Special Tools		$205,346	$145,098	$350,444	2.0%	
	Vendor Packing & Freight		$190,471	$134,587	$325,058	1.8%	
	Sales Tax						

MWH
CONSTRUCTORS

WBS COST BUILD-UP SUMMARY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	**Wilsonville, OR**	**30-Nov-17**	**Jim Ward**	**002**	**30503765**

Introduction

This MAP presents another view of how the OPCC goes from DIRECT COSTS to COST-OF-WORK, and identifies the development of the overall project cost build-up. ***NOTE: The dollar amounts reflect the OPCC while the percentages are provided for general informational purposes only and do not represent how the individual costs were established.***

CATEGORY	WBS	DESCRIPTION	INSTALLATION COSTS Prime Contractor	Subcontractors	TOTAL COST	%	OPCC SOURCE
INSTALLING CONTRACTOR(S) BURDENS & MARK-UPS		Overhead & General Conditions		$435,235	$435,235	2.5%	**OPCC SUMMARY**
		Profit		$913,993	$913,993	5.2%	
		Builders Risk Insurance		$0	$0	0.0%	
		Liability Insurance		$11,174	$11,174	0.1%	
		Umbrellla & Vehicle Insurances		$13,002	$13,002	0.1%	
		Bonds		$131,015	$131,015	0.7%	
		Burdens & Mark-Ups Subtotal	$1,036,243	$2,195,844	**$3,232,087**	18.3%	
		Running Total	***$10,720,252***	***$10,209,119***	***$20,929,371***		
ESTIMATOR GROSS ADJUSTMENTS		Escalation	$0	$0	$0	0.0%	**OPCC SUMMARY**
		Estimate Contingency	$1,608,038	$1,531,368	$3,139,406	15.0%	
		Scope Contingency	$1,608,038	$1,531,368	$3,139,406	15.0%	
		Local Market Issues					
		Gross Recipts Tax	$0	$0	$0	0.0%	
		Gross Adjustments Subtotal	$3,216,076	$3,062,736	**$6,278,811**	30.0%	
		Running Total	***$13,936,327***	***$13,271,855***	***$27,208,182***		
PRIME CONTRACTOR COSTS		Field Staff Labor	$2,823,055		$2,823,055	10.4%	**OPCC SUMMARY (Prime Contractor Section) & DIV 1 PRIME CONTRACTOR STAFF**
		Field Staff Travel & Living	$171,722		$171,722	0.6%	
		Remote Camp (Field Staff & Tradesmen)	$0		$0	0.0%	
		Escalation	$0		$0	0.0%	
		Insurances	$312,885		$312,885	1.1%	
		General & Administration	$1,525,792		$1,525,792	5.6%	
		Profit	$3,051,584		$3,051,584	11.2%	
		Project Engineering	$4,081,227		$4,081,227	15.0%	
		Bonds	$349,639		$349,639	1.3%	
		Gross Receipts Tax					
		Prime Contractor Subtotal	$12,315,905	$0	**$12,315,905**	45.3%	
		GRAND TOTAL	***$26,252,233***	***$13,271,855***	***$39,524,088***		

MWH CONSTRUCTORS

WORK BREAKDOWN STRUCTURE

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

WBS Items

						Direct Costs Costs are compilations of WBS coded items in DIVS 1-17 sheets					*Cost-of-Work* Build-up methodology of Direct Costs to these costs is demonstrated in OPCC SUMMARY sheet						
WBS	Description	ALLOCATED to OTHER WBS	CIP SCOPE ASSIGNMENT	EXCLUDE from ALLOCATIONS	ALLOCATED to CIP SCOPES	MH	MH $	M&CE $	EQ $	DIRECT COST TOTAL	MH	MH $	M&CE $	EQ $	COST-OF-WORK (C-O-W) TOTAL	C-O-W TOTAL after PROPORTIONAL ALLOCATION of CHECKED WBS ITEMS (at left)	CIP SCOPE C-O-W TOTAL with ALLOCATION of CHECKED CIP SCOPE ITEMS (at left)
0	*Prime Contractor*	✓				40,964	$2,823,055	$171,722		**$2,994,777**					**$12,315,905**		
1	*General Conditions*	✓				5,820	$281,427	$1,127,500		**$1,408,927**	7,566	$451,868	$1,465,750		**$1,917,618**		
2	*General Allowances*	✓				974	$51,010	$36,526	$17,607	**$105,142**	1,266	$86,658	$51,145	$29,090	**$166,893**		
3	*Process Control EQ*	✓				1,375	$81,477	$84,194	$162,898	**$328,569**	1,787	$154,288	$128,381	$270,748	**$553,417**		
4	***20 MGD CAPACITY UPGRADES***		1			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$10,542,965**
5	*Extend Chem Lines & Utilidor-CHEM*		1			2,423	$130,421	$49,413	$39,391	**$219,225**	3,151	$227,230	$69,136	$55,957	**$352,323**	**$566,752**	
6	*Procure Shelf-Spare Solids/Sand Pump (1)-ACT*		1						$18,500	**$18,500**				$26,280	**$26,280**	**$42,275**	
7	*Install 2nd Flash Mix Pump (1)-ACT*		1			160	$9,607	$30,517	$28,600	**$68,723**	208	$18,140	$46,518	$40,893	**$105,551**	**$169,791**	
8	*Install Shelf-Spare Mix Pump (1)-SOL*		1			154	$9,223	$29,904	$1,100	**$40,227**	200	$17,465	$45,598	$1,828	**$64,891**	**$104,385**	
9	*Replace 4 MGD Pump with 7.5 MGD (1)-FWPS*		1			455	$27,296	$73,642	$402,900	**$503,839**	591	$51,689	$112,292	$589,513	**$753,493**	**$1,212,081**	
10	*Replace Switchgear-ELEC*		1			2,661	$157,738	$120,649	$1,260,900	**$1,539,287**	3,460	$298,699	$183,968	$2,095,703	**$2,578,370**	**$4,147,606**	
11	*Rewire to Support BU Power Supply-ELEC*		1			720	$42,673	$63,600		**$106,273**	936	$80,806	$96,979		**$177,785**	**$285,988**	
12	*Replace 1 MW Genset with 2 MW (1)-ELEC*		1			1,641	$93,778	$82,981	$1,334,800	**$1,511,560**	2,133	$168,807	$121,315	$2,205,246	**$2,495,368**	**$4,014,088**	
13	***20 MGD REPAIR & REPLACE***		2			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$1,551,738**
14	*Replace Polymer Unit PLC (1)-CHEM*		2			24	$1,422	$240	$7,500	**$9,162**	31	$2,694	$366	$10,654	**$13,714**	**$22,060**	
	***DELETED:** Replace Meter Pumps (17)-CHEM*		2														
16	*Replace Actiflo System PLC (1)-ACT*		2			80	$4,741	$800	$20,000	**$25,541**	104	$8,978	$1,220	$28,411	**$38,609**	**$62,108**	
17	*Replace Sample Pumps (2)-ACT*		2			100	$6,022	$8,501	$3,000	**$17,523**	131	$11,404	$12,962	$4,262	**$28,628**	**$46,051**	
18	*Replace Tube Modules in Settle Tanks (2)-ACT*		2			160	$9,721	$4,000	$90,250	**$103,971**	208	$18,408	$6,099	$128,205	**$152,713**	**$245,656**	
	***DELETED:** Replace GAC Media (3X)-FILT*		2														
20	*Upgrade/Replace Existing Wiring-FILT*		2			600	$35,560	$53,000		**$88,560**	780	$67,339	$80,816		**$148,154**	**$238,323**	
21	*Chem Line Support Mods-WWEQ*		2			100	$6,076	$10,000		**$16,076**	130	$11,505	$15,248		**$26,753**	**$43,036**	
22	*Replace VFD Units (3)-FWPS*		2			206	$12,210	$25,238	$297,500	**$334,948**	268	$23,122	$38,484	$494,465	**$556,071**	**$894,504**	
23	***20 MGD LIFE SAFETY***		3			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$220,366**
24	*Replace Faded NFPA Signage-CHEM*		3			50	$2,015	$1,250		**$3,265**	65	$3,816	$1,906		**$5,722**	**$9,205**	
25	*Add Exit Door Panic Hardware (3)-CHEM*		3			24	$1,314	$210	$2,925	**$4,449**	31	$2,110	$273	$4,155	**$6,538**	**$10,517**	
26	*Change Door Swing Direction (1)-O3*		3			12	$657	$300	$1,200	**$2,157**	16	$1,055	$390	$1,705	**$3,150**	**$5,067**	
27	*Add Exit Area Containment Pans (2)-CHEM*		3			32	$1,944	$800	$1,795	**$4,539**	42	$3,682	$1,220	$2,549	**$7,451**	**$11,985**	
28	*Add Exit Emergency Shut-Off (2)-O3*		3			32	$1,897	$2,400		**$4,297**	42	$3,591	$3,660		**$7,251**	**$11,664**	
29	*Replace Guardrail (20 LF)-ACT*		3			27	$1,510	$124	$992	**$2,626**	35	$2,425	$161	$1,410	**$3,995**	**$6,427**	
30	*Seal & Waterstop Corner Leaks (2)-ACT*		3			212	$10,746	$4,007		**$14,753**	276	$17,255	$5,209		**$22,464**	**$36,136**	
31	*Add Exit Door Panic Hardware (2)-ACT*		3			16	$876	$140	$1,950	**$2,966**	21	$1,407	$182	$2,770	**$4,359**	**$7,011**	
32	*Add West Guardrail Kickplate (20 LF)-ACT*		3			10	$529	$124	$298	**$950**	12	$849	$161	$423	**$1,433**	**$2,305**	
33	*Upgrade Outlets to GFI's (8)-ACT*		3			8	$474	$400		**$874**	10	$898	$610		**$1,508**	**$2,425**	
34	*Replace Guardrail (20 LF)-OZ*		3			27	$1,510	$124	$992	**$2,626**	35	$2,425	$161	$1,410	**$3,995**	**$6,427**	

WORK BREAKDOWN STRUCTURE

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

WBS Items

						Direct Costs Costs are compilations of WBS coded items in DIVS 1-17 sheets					*Cost-of-Work* Build-up methodology of Direct Costs to these costs is demonstrated in OPCC SUMMARY sheet						
WBS	Description	ALLOCATED to OTHER WBS	CIP SCOPE ASSIGNMENT	EXCLUDE from ALLOCATIONS	ALLOCATED to CIP SCOPES	MH	MH $	M&CE $	EQ $	DIRECT COST TOTAL	MH	MH $	M&CE $	EQ $	COST-OF-WORK (C-O-W) TOTAL	C-O-W TOTAL after PROPORTIONAL ALLOCATION of CHECKED WBS ITEMS (at left)	CIP SCOPE C-O-W TOTAL with ALLOCATION of CHECKED CIP SCOPE ITEMS (at left)
35	*Upgrade Outlets to GFI's (8)-CHEM*		3			8	$474	$400		**$874**	10	$898	$610		**$1,508**	**$2,425**	
36	*Replace Guardrail (20 LF)-FILT*		3			27	$1,510	$124	$992	**$2,626**	35	$2,425	$161	$1,410	**$3,995**	**$6,427**	
37	*Seal & Waterstop Corner Leaks (2)-FILT*		3			210	$10,680	$3,476		**$14,156**	273	$17,148	$4,519		**$21,667**	**$34,854**	
38	*Add Ladder Pit Kickplate (20 LF)-FILT*		3			10	$529	$124	$298	**$950**	12	$849	$161	$423	**$1,433**	**$2,305**	
39	*Upgrade Outlets to GFI's (16)-FILT*		3			16	$948	$800		**$1,748**	21	$1,796	$1,220		**$3,016**	**$4,851**	
40	*Add Exit Door Panic Hardware (2)-FWPS*		3			16	$876	$140	$1,950	**$2,966**	21	$1,407	$182	$2,770	**$4,359**	**$7,011**	
41	*Install Scupper & Downspout (1)-DEW*		3			36	$1,971	$1,800		**$3,771**	47	$3,165	$2,340		**$5,505**	**$8,855**	
42	*Seal & Waterstop Corner Leaks (2)-OZ*		3			256	$12,977	$5,237		**$18,213**	333	$20,836	$6,808		**$27,644**	**$44,468**	
43	***20 MGD SEISMIC RETROFITS***		4			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$996,607**
44	*Add Pipe Bracing-CHEM/O3/LOX*		4			120	$7,291	$6,000		**$13,291**	156	$13,806	$9,149		**$22,955**	**$36,926**	
45	*Add Destruct Pipe Bracing: OZ*		4			32	$1,944	$2,400		**$4,344**	42	$3,682	$3,660		**$7,341**	**$11,809**	
46	*Add N & S Wall Beams & Columns (3)-WWEO*		4			1,330	$71,323	$16,818		**$88,141**	1,730	$114,519	$21,863		**$136,382**	**$219,386**	
47	*Add Basin Width Beams & Columns (3)-WWEO*		4			1,210	$64,850	$14,186		**$79,036**	1,573	$104,126	$18,442		**$122,568**	**$197,164**	
48	*Add W & E Wall Roof Anchors (23)-FWPS*		4			686	$37,573	$22,627		**$60,200**	892	$60,329	$29,415		**$89,744**	**$144,364**	
49	*Replace Deficient Deck Sections (1,966 SF)-FWPS*		4			310	$16,955	$39,129		**$56,084**	403	$27,223	$50,868		**$78,091**	**$125,618**	
50	*Strengthen Chord Connections (44)-FWPS*		4			66	$3,614	$1,351		**$4,965**	86	$5,802	$1,756		**$7,559**	**$12,159**	
51	*Add Shear Wall Plates & Anchors (46)-FWPS*		4			428	$23,446	$12,954		**$36,400**	557	$37,646	$16,840		**$54,486**	**$87,647**	
52	*Add Cable Tray Bracing-FWPS*		4			48	$2,845	$2,400		**$5,245**	62	$5,387	$3,660		**$9,047**	**$14,553**	
53	*Install E Side Frame Braces for 2nd Floor (1)-DEW*		4			160	$8,761	$12,000		**$20,761**	208	$14,066	$15,600		**$29,666**	**$47,722**	
54	*Add E & W Wall Roof Anchors (6)-DEW*		4			253	$13,870	$12,881		**$26,751**	329	$22,270	$16,745		**$39,016**	**$62,761**	
55	*Tie Floor Slab to Walls (2)-DEW*		4			58	$3,157	$7,898		**$11,056**	75	$5,069	$10,268		**$15,337**	**$24,672**	
56	*Install Space Heater Braces (8)-SITE*		4			48	$2,916	$1,200		**$4,116**	62	$5,523	$1,830		**$7,352**	**$11,827**	
57	***30 MGD CAPACITY UPGRADES***		5			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$24,054,666**
58	*Install New Ozone Generator (1)-O3*		5			401	$24,083	$84,328	$400,000	**$508,411**	521	$45,443	$128,538	$568,221	**$742,202**	**$1,193,917**	
59	*Install New Flow Channel & Gallery (1)-ACT*		5			10,598	$576,038	$523,899	$912,765	**$2,012,702**	13,777	$961,821	$757,784	$1,304,637	**$3,024,243**	**$4,864,843**	
60	*Install New Flow Channel & Gallery (1)-OZ*		5			13,142	$708,624	$508,604	$150,687	**$1,367,916**	17,084	$1,172,362	$727,521	$226,763	**$2,126,646**	**$3,420,955**	
61	*Install New Thickener (1)-SOL*		5			1,620	$88,233	$120,321	$149,459	**$358,012**	2,106	$150,983	$177,836	$212,314	**$541,133**	**$870,475**	
62	*Install New Cells (2) & Gallery-FILT*		5			10,834	$593,709	$514,901	$598,596	**$1,707,206**	14,084	$999,469	$743,912	$858,355	**$2,601,737**	**$4,185,194**	
63	*Replace 7.5 MGD Pumps with 12 MGD (3)-FWPS*		5			1,543	$92,582	$256,349	$1,679,700	**$2,028,631**	2,006	$175,317	$390,886	$2,477,469	**$3,043,672**	**$4,896,098**	
64	*Install 5th 7.5 MGD Pump (1)-FWPS*		5			361	$21,666	$69,603	$402,900	**$494,169**	469	$41,027	$106,133	$589,513	**$736,672**	**$1,185,023**	
65	*Replace 7.5 MGD Pumps with 15 MGD (2)-RWPS*		5			990	$59,639	$163,634	$496,500	**$719,772**	1,287	$112,934	$249,512	$739,648	**$1,102,095**	**$1,772,847**	
66	*Install 3rd Centrifuge & Solids Pump (1)-DEW*		5			795	$47,701	$148,142	$501,600	**$697,444**	1,033	$90,277	$225,876	$719,095	**$1,035,248**	**$1,665,316**	
67	***30 MGD REPAIR & REPLACE***		6			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$808,553**
	DELETED: *Replace Meter Pumps (17)-CHEM*		6														
69	*Replace Flash Mix Pumps (2)-ACT*		6			452	$27,148	$66,848	$57,200	**$151,196**	588	$51,409	$101,931	$81,787	**$235,127**	**$378,229**	

WORK BREAKDOWN STRUCTURE

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

WBS Items

Direct Costs

Costs are compilations of WBS coded items in DIVS 1-17 sheets

Cost-of-Work

Build-up methodology of Direct Costs to these costs is demonstrated in OPCC SUMMARY sheet

WBS	Description	ALLOCATED to OTHER WBS	CIP SCOPE ASSIGNMENT	EXCLUDE from ALLOCATIONS	ALLOCATED to CIP SCOPES	MH	MH $	M&CE $	EQ $	DIRECT COST TOTAL	MH	MH $	M&CE $	EQ $	COST-OF-WORK (C-O-W) TOTAL	C-O-W TOTAL after PROPORTIONAL ALLOCATION of CHECKED WBS ITEMS (at left)	CIP SCOPE C-O-W TOTAL with ALLOCATION of CHECKED CIP SCOPE ITEMS (at left)
70	*Replace Thickener Drive (1)-SOL*		6			163	$9,733	$15,864	$20,000	**$45,598**	212	$18,431	$24,190	$28,411	**$71,033**	**$114,264**	
	DELETED: *Replace GAC Media (1X)-FILT*		6														
72	*Replace Solids Transfer Pumps (2)-DEW*		6			395	$23,651	$56,055	$44,200	**$123,906**	514	$44,787	$85,474	$66,218	**$196,479**	**$316,059**	
	ADDERS per 17NOV17 Email																
75	***20 MGD CAPACITY UPGRADES***		7			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$263,571**
76	*Add Hypochlorite Vent Return Line-CHEM*		7			28	$1,701	$800		**$2,501**	36	$3,221	$1,220		**$4,441**	**$7,144**	
77	*Add Meter Pump Strainers (17)-CHEM*		7			26	$1,549	$255	$2,465	**$4,269**	33	$2,934	$389	$3,502	**$6,824**	**$10,978**	
78	*Upgrade Sitewide Lighting to LED-SITE*		7			340	$20,132	$38,815		**$58,947**	442	$38,122	$59,186		**$97,308**	**$156,532**	
79	*Replace Rental LOX Tank with Larger (1)-O3*		7			258	$15,541	$16,950		**$32,491**	335	$29,430	$25,846		**$55,275**	**$88,917**	
80	***20 MGD LIFE SAFETY***		8			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$264,660**
81	*Improve Bldg/Gallery Ventilation-ACT*		8			69	$4,186	$8,324		**$12,511**	90	$7,928	$12,693		**$20,621**	**$33,171**	
82	*Replace Stairwell Door with Fire Door-FILT*		8			6	$294	$215	$1,000	**$1,509**	7	$478	$281	$1,421	**$2,179**	**$3,505**	
83	*Improve Blower Room Ventilation-FILT*		8			91	$5,489	$10,915		**$16,404**	118	$10,395	$16,643		**$27,038**	**$43,493**	
84	*Improve SWGR Room Ventilation-FWPS*		8			171	$10,347	$20,574		**$30,920**	223	$19,593	$31,371		**$50,964**	**$81,982**	
85	*Add SWGR Door Panic Hardware (2)-FWPS*		8			16	$876	$140	$1,950	**$2,966**	21	$1,407	$182	$2,770	**$4,359**	**$7,011**	
86	*Improve South Stairwell Ventilation-OZ*		8			22	$1,325	$2,635		**$3,960**	29	$2,509	$4,018		**$6,527**	**$10,499**	
87	*Add Fall Protection to Plate Hatches (10)-SITE*		8			60	$3,326	$3,000	$12,000	**$18,326**	78	$5,340	$3,900	$17,047	**$26,286**	**$42,284**	
88	*Add Ladder Fall Restraint to Basin-WWEQ*		8			20	$1,109	$600	$1,500	**$3,209**	26	$1,780	$780	$2,131	**$4,691**	**$7,546**	
89	*Improve Room/Bldg Ventilation-WWEQ*		8			74	$4,439	$8,825		**$13,264**	96	$8,405	$13,457		**$21,862**	**$35,168**	
90	***20 MGD REPAIR & REPLACE***		9			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$22,729**
91	*Replace Security Camera & Computer (1)-MISC*		9			24	$1,422	$7,500		**$8,922**	31	$2,694	$11,436		**$14,130**	**$22,729**	
92	***30 MGD CAPACITY UPGRADES***		10			0	$0	$0	$0	$0	0	$0	$0	$0	$0	$0	**$798,233**
93	*Convert Wet NaOCl System to Dry-CHEM*		10			537	$32,165	$74,467	$156,500	**$263,133**	698	$60,728	$113,496	$222,317	**$396,541**	**$637,883**	
94	*Storage Room Mods for Added Space-CHEM*		10			672	$36,235	$27,500		**$63,735**	874	$61,661	$38,021		**$99,682**	**$160,350**	
WBS TOTAL						108,103	$6,508,386	$4,896,315	$9,287,359	**$20,692,061**	87,281	$6,327,465	$6,758,820	$14,121,897	**$39,524,088**	**$39,524,088**	**$39,524,088**

MWH CONSTRUCTORS

INSTALLATION OVERVIEW

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

Project and Owner Market	Municipal/Governmental	*Project Site Condition*	Rehabiltate/Replace & Expand Existin
Installation Labor Classification	Prevailing Wage/Davis Bacon	*Site Condition Assessment*	Above & Below Grade Issues
Installation Labor Work Schedule	(5)-8 hr days Mon-Fri	*Work Area Congestion*	80% of Work Congested
Installation Labor Work Shifts	1 Shift (daylight)	*Work Area Spread*	20% of Work Spread Out
Installation Shift Differential Pay		*Pipe & Raceway Layouts*	Typical Manifolds & Branches
Installation Labor Productivity	90% (7.2 hrs production/8 hrs)	*Pipe & Raceway Supports*	304 SS Strut & Structural Shapes
Bldg & Structure Risk Category	Category IV - Essential facility	*High Work*	
Site Seismic Consideration	0.40-0.80 (x G) Peak acceleration	*Clean Room Work*	
Site Frost Depth Consideration	5"-10"	*Hazardous Work*	
Site Wind Speed Consideration	Zone II - 160 MPH	*Hot Weather Work*	5% performed over 95°
Site Location Accessibility	Slightly Difficult	*Cold Weather Work*	5% performed under 30°
Owner's Project Representative	None (i.e. direct contract with GC)	*Rain or Snow Work*	15% of work in Rain/Snow
Maximum Pipe Size & Flow Rates	72"Ø: 25,370(g)-91,510(p) GPM	*Night Work*	
(un-assigned)		*DBE & MBE Work*	5% of work by DBE/MBE

Work Self-Performed by Prime Contractor

- ☑ DIV 1 Site Mgmt & Oversight Staff
- ☑ DIV 1 General Conditions
- ☑ DIV 2 Common Site Work
- ☐ DIV 2 Specialty Site Work
- ☐ DIV 2 Well Work
- ☑ DIV 3 Concrete
- ☑ DIV 4 Masonry
- ☑ DIV 5 SUPPLY EQ: Miscellaneous Metals
- ☑ DIV 5 INSTALL EQ: Miscellaneous Metals
- ☑ DIVS 5-8 Buildings & Components
- ☐ DIVS 9-10 Finishes
- ☑ DIVS 11-15 SUPPLY EQ: Process & Mechanical
- ☐ DIVS 11-15 INSTALL EQ: Process and Mechanical
- ☐ DIV 13 Field-Erected Tanks
- ☐ DIV 13 Shop-Fabricated Tanks
- ☐ DIVS 16-17 INSTALL EQ: Process & Mechanical
- ☐ DIVS 16-17 SUPPLY EQ: Electrical and I&C
- ☐ DIVS 16-17 INSTALL EQ: Electrical and I&C

Direct Cost Roll-Up of DIVS 1-17 Sheets

CSI 1995	CSI 2004	Description *(NIS = not in scope)*	SF	CY	TON	MH	MH $	M&CE $	EQ $	TOTAL
DIV 1	01	*General Conditions*				5,820	$281,427	$1,127,500		*$1,408,927*
DIV 2	02 & 31-35	*Common Site Work*				4,445	$214,947	$166,305		*$381,252*
DIV 2	02 & 31-35	*Specialty Site Work - NIS*								
DIV 2	33	*Well Work - NIS*								
DIV 3	03	*Concrete*		1,718		29,146	$1,562,423	$528,269		*$2,090,692*
DIV 4	04	*Masonry*	680			265	$13,141	$9,977		*$23,118*
DIV 5	05	*EQ: Miscellaneous Metals*			9.0				$144,539	*$144,539*
DIV 5	05	*Miscellaneous Metals Installation*				1,008	$55,880	$18,066		*$73,946*
DIVS 5-8	05-08	*Buildings & Components*	1,882			2,437	$133,294	$130,756		*$264,050*
DIVS 9-10	09-10	*Finishes*	3,120			698	$28,136	$15,629		*$43,765*
DIV 13	33	*Tanks: Field Erected - NIS*								
DIV 13	33	*Tanks: Shop Fabricated - NIS*								
DIVS 11-15	40-45	*EQ: Process & Mechanical*							$5,297,485	*$5,297,485*
DIVS 11-15	21-23	*Process & Mechanical Installation*				9,368	$569,182	$1,343,963		*$1,913,145*
DIVS 16-17	25-28 & 33	*EQ: Electrical and I&C*							$3,845,335	*$3,845,335*
DIVS 16-17	25-28 & 33	*Electrical and I&C Installation*				13,952	$826,902	$1,384,128		*$2,211,029*
		DIVS 1-17 DIRECT COST TOTAL				67,139	$3,685,331	$4,724,593	$9,287,359	***$17,697,284***

MWH
CONSTRUCTORS

DIV 1 (01) PRIME CONTRACTOR STAFF

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	**Wilsonville, OR**	**30-Nov-17**	**Jim Ward**	**002**	**30503765**

Assumptions

"Trips" Destination	Local Only	*Lodging (short vs. long)*	
Per-Diem Option		*Vehicle (short vs. long)*	$50 vs. $17 per Day
Meetings Coverage	Managers & Start-Up	*Fuel-Oil-Maintenance*	$15 per Day
Baggage Fees		*Ride Sharing*	
Airport Parking		*Meals (exludes meetings)*	$45 per Day
Personal Mileage		*Incidentals*	$10 per Day

Prime Contractor Staff

Site Management & Oversight Labor Allowances

Anticipated Project Construction Duration

TBD

Labor During both Pre-Construction & Construction

Labor Category Allowance	Project Director	Project Manager	Construction Manager	Construction Superintendents	Construction & Safety Engineers	Scheduling & Estimating	Contracts & Procurement	Start-Up, Test & Commission	Clerical & Administrative
Head Count		1.0	1.0	2.0	6.0			1.5	1.5
Multiple Shift Coverage		NA	NA	NA	NA			NA	NA
Travel & Living Classification		VEHICLE +	VEHICLE	VEHICLE	VEHICLE			VEHICLE	EXEMPT
Work Hours per Week		40	40	40	40			40	40
Base Rate + Benefits at 38%		$114	$99	$83	$61			$76	$30
Meals/Meetings Coverage		Included	Excluded	Excluded	Excluded			Excluded	Excluded
Travel & Living Cycle in Days		1	1	1	1			1	
Travel & Living Frequency		100%	100%	100%	100%			100%	
Construction Coverage		115.0%	115.0%	112.5%	112.5%			30.0%	115.0%

Labor Summary

Labor Metric	Project Director	Project Manager	Construction Manager	Construction Superintendents	Construction & Safety Engineers	Scheduling & Estimating	Contracts & Procurement	Start-Up, Test & Commission	Clerical & Administrative
LABOR Hours		3,496	3,496	6,840	20,520			1,368	5,244
LABOR Cost		$398,020	$344,950	$571,072	$1,245,974			$103,831	$159,208

Labor Total

Labor Hours	Labor Cost
40,964	**$2,823,055**

Labor Assignment by WBS

WBS	%	WBS Hours	WBS Cost

DAY-BASED Travel & Living Allowances

Expenses During both Pre-Construction & Construction

DAILY Expense Allowance	Project Director	Project Manager	Construction Manager	Construction Superintendents	Construction & Safety Engineers	Scheduling & Estimating	Contracts & Procurement	Start-Up, Test & Commission	Clerical & Administrative
Per-Diem Option									
Meals/Meetings		$56							
Vehicle		$17	$17	$17	$17			$17	
Fuel-Oil-Maintenance (FOM)		$15	$15	$15	$15			$15	
Incidentals		$10							

Travel & Living Summary

Travel & Living Metric	Project Director	Project Manager	Construction Manager	Construction Superintendents	Construction & Safety Engineers	Scheduling & Estimating	Contracts & Procurement	Start-Up, Test & Commission	Clerical & Administrative
DAY Cost		$98	$32	$32	$32			$32	
DAY Count		437	437	855	2,565			171	
DAYS Cost		$42,826	$13,984	$27,360	$82,080			$5,472	

Day Travel & Living Total

Day Count	Day Cost
4,465	**$171,722**

Day Travel & Living Assignment by WBS

WBS	%	WBS Cost

MWH CONSTRUCTORS

DIV 1 (01) PRIME CONTRACTOR STAFF

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

TRIP-BASED Travel & Living Allowances

Expenses During both Pre-Construction & Construction

TRIP Expense Allowance	Project Director	Project Manager	Construction Manager	Construction Superintendents	Construction & Safety Engineers	Scheduling & Estimating	Contracts & Procurement	Start-Up, Test & Commission	Clerical & Administrative
Surface Travel									
Baggage Fees									
Airport Parking									
Personal Mileage									
Lodging									
Meals/Meetings									
Vehicle									
Fuel-Oil-Maintenance (FOM)									
Incidentals									

Travel & Living Summary

Travel & Living Metric	Project Director	Project Manager	Construction Manager	Construction Superintendents	Construction & Safety Engineers	Scheduling & Estimating	Contracts & Procurement	Start-Up, Test & Commission	Clerical & Administrative
TRIP Cost									
TRIP Count									
TRIPS Cost									

Trip Travel & Living Total

Trip Count	Trip Cost

Trip Travel & Living Assignment by WBS

WBS	%	WBS Cost

Camp Allowances for Prime Contractor Staff

Considerations During both Pre-Construction & Construction

	Travel Metric		Roundtrip Cost		Daily Cost		Daily Cost
Work Days per Week		*Air Transportation*		*Meals*		*Housekeep*	
Rotation Cycle - Weeks		*Ground Transportation*		*Mobility & FOM*		*Laundry*	
1-Way Travel Time- Hours		*Tips, Meals, & Miscellany*		*Lodging*		*Incidentals*	

Camp Summary

☐ Report in OPCC SUMMARY

Camp Cost per Manhour	Eligible Manhours	TOTAL Camp Cost

Camp Assignment by WBS

WBS	%	WBS Cost

Miscellaneous Allowances

WBS	Description	Quantity	Trades MH	MH @ $0	M&CE $	EQ $	TOTAL
				$			
				$			
				$			
				$			
				$			
				$			
				$			
				$			
				$			
				$			
Subtotal - Miscellaneous Allowances							

Prime Contractor Staff Total

	MH	MH @ $69 (avg)	T&L $	Camp $	M&CE $	EQ $	TOTAL
DIV 1(s) TOTAL	40,964	$2,823,055	$171,722				***$2,994,777***

MWH
CONSTRUCTORS

DIV 1 (01) PRIME CONTRACTOR STAFF

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	**Wilsonville, OR**	**30-Nov-17**	**Jim Ward**	**002**	**30503765**

Glossary of Travel & Living Terms

CONSTRUCTION DURATION COVERAGE: Any durations in excess of 100% indicates Pre-Construction time

SHORT VS. LONG: Identifies the anticipated short-term higher cost "rental" usuallly applying for (1) month or less, versus a longer term and less expensive "lease" option

EXEMPT: Personnel originating *LOCAL* to the project site who do not have a need or expectation of generating travel & living expenses.

HO *:* Home office personnel (i.e. Denver, CO based) originating either *LOCAL* or *REMOTE* to the project site who typically would not generate any travel & living expenses.

VEHICLE: Personnel originating *LOCAL* to the project site who are reimbursed 100% for the eligible daily expenses of a vehicle and related fuel-oil-maintenance thoughout the individual's project time (re: "Construction Coverage").

VEHICLE +: Personnel originating *LOCAL* to the project site who are reimbursed 100% for the eligible daily expenses of meals, potential meetings coverage, and incidentals, all in addition to the vehicle and related fuel-oil-maintenance thoughout the individual's project time (re: "Construction Coverage").

MIXED: Personnel originating *LOCAL* to the project site who are reimbursed 100% for the eligible daily expenses of a vehicle and related fuel-oil-maintenance, miscellaneous & incidental costs, and meals and potential meetings coverage (depending on staff position) at the indicated duration (re: "Travel & Living Cycle in Days"), as well as the eligible travel expenses to & from the home office location (i.e. Denver, CO based) at the indicated frequency (re: "Travel & Living Frequency") and project time (re: "Construction Coverage").

TRIPS: Personnel originating *REMOTE* to the project site who are reimbursed 100% for the eligible travel expenses to & from their remote home/home office location (i.e. Denver, CO based) at the indicated frequency (re: "Travel & Living Frequency") and durations (re: "Travel & Living Cycle in Days") thoughout the individual's project time (re: "Construction Coverage").

PER-DIEM: Personnel originating *REMOTE* to the project site who receive a negotiated lump-sump daily stipend intended to cover 100% of the living costs for a full-time project area residence, as well as the travel expenses to & from their home/home office location (i.e. Denver, CO based) at the indicated/negotiated frequency thoughout the individual's project time (re: "Construction Coverage").

REMOTE: Personnel originating *REMOTE* to the project site who are reimbursed 100% for the eligible living expenses related to a full-time project area residence, as well as the eligible travel expenses to & from their home/home office location (i.e. Denver, CO based) at the indicated frequency (re: "Travel & Living Cycle in Days") thoughout the individual's project time (re: "Construction Coverage").

MWH CONSTRUCTORS

DIV 1 (01) GENERAL REQUIREMENTS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

General Conditions Level Standard

(un-assigned)

General Requirements

General Conditions Allowances

Anticipated Project Construction Duration

TBD

Temporary Construction Facilities

Prime Staff Trailers	Subcontractor Trailers	Owner/Rep Trailers	Meeting/Kitchen Trailers	Decon/Change Trailers	Material/Storage Containers	Equipment/Tool Containers	Portable Toilets	First-Aid & Sanitize Stations
2	2				2	2	3	3

Temporary Site & Project Conditions

WBS	Category	Potential Sub-Categories	Trades MH	MH @ $48	M&CE $	TOTAL
	Mobilization	Site occupancy and delivery/layout/staging coordination of facilities, utilities, equipment, & materials	360	$17,408	$11,600	*$29,008*
	Field Office: Facilities	Lease, deliver, and set-up trailers, containers, toilets, & first-aid/sanitize stations	120	$5,803	$89,600	*$95,403*
	Field Office: Carpentry	Supply/install facility decks, porches, canopies, ramps, stairways, landings, & misc accessways	60	$2,901	$9,500	*$12,401*
	Field Office: Utilities	Install & connect electric, water (potable, utility, and/or fire), gas/propane, telecommunications, & internet	70	$3,385	$20,400	*$23,785*
	Field Office: Equipment	Desks, chairs, tables, file cabinets, drawing racks, shelving, water coolers, refrigerators, & microwaves	30	$1,451	$14,100	*$15,551*
	Field Office: Tools	Landline phones, computers, software, faxes, printers, copiers, & coffee makers	80	$3,868	$70,400	*$74,268*
	Field Office: Supplies	Copy & printer paper, ink cartridges, pens/markers, coffee, tea, hot chocolate, bottled water, & cups	20	$967	$23,500	*$24,467*
	Field Office: Incidentals	Petty cash, lockboxes, postage, Fedex, reproduction, meetings, meals, workshops, & janitorial services	510	$24,661	$17,000	*$41,661*
	Field Staff: Safety	Training, certifications, personal protection equipment (>$250), celebrations, events, & awards			$12,800	*$12,800*
	Field Staff: Communications	Cell phones, I-Pads, portable radios, LAN, pagers, docking/charging stations, & batteries			$24,400	*$24,400*
	Field Staff: Public Relations	Advertising, solicitations, public notices, MBE programs, community service/outreach, & progress meetings			$29,700	*$29,700*
	Construction: Accessibility	Bridges, cross-overs, scaffolds, decking, ramps, platforms, landings, docks, & stairways	160	$7,737	$16,200	*$23,937*
	Construction: Aids	Large/Specialty hoists, cranes, forklifts, front-end loaders, trucks, conveyors, & elevators	900	$43,520	$231,100	*$274,620*
	Construction: Aids Support	Mats, dunnage, spreaders, slings, rollers, dollies, maintenance, & FOG (fuel-oil-grease)	110	$5,319	$115,600	*$120,919*
	Construction: Permitting	Applications, inspections, notifications, approvals, fees, & support documentation			$46,200	*$46,200*
	Construction: QA & QC	Samples, tests, inspections, & certifications, & miscellaneous consultants/subcontractors	640	$30,947	$169,700	*$200,647*
	Construction: Utilities	Gensets, lights, heaters, fans, compressors, pumps, welders, & miscellaneous appliances	320	$15,474	$21,200	*$36,674*
	Work Area: Accessibility	Road re-routes, turn-arounds, overpasses, haul routes, scaffolds, sidewalks, & parking/staging areas	100	$4,836	$6,400	*$11,236*
	Work Area: Protection	Lighting, visual barriers, fencing, barricades, & protection for existing trees, plants, and/or structures	150	$7,253	$9,800	*$17,053*
	Work Area: Safety & Health	Signage, fall/debris nets, ventilation blowers, fire extinquishers, first-aid supplies, water, ice, & cups	90	$4,352	$5,800	*$10,152*
	Work Area: Passive Security	Guard shacks, work-time entry/exit guards, & video surveillance & recording system				
	Work Area: Active Security	24-hour watchman & monitoring of video surveillance system				
	Work Area: Transportation	Golf carts, remote parking facilities, & daily transportation to/from remote parking				
	Work Area: Housekeeping	Handling of waste dunnage & crating, general trash collection, waste containers, & tipping/disposal fees	240	$11,605	$14,900	*$26,505*
	Controls: Site	Surveys, layouts, benchmarks, monuments, aerial & progress photos/videos, & GPS			$27,000	*$27,000*
	Controls: Environmental	Stormwater, erosion, dirt, mud, dust, noise, ice, snow, excessive cold/heat, pollution, & pest	130	$6,286	$4,300	*$10,586*
	Controls: EQ & Materials	Handling, transport, storage, staging, maintenance, & damage/loss management	160	$7,737	$8,500	*$16,237*
	Controls: Passive Traffic	Barriers, cones, steel cover plates, traffic control signage/flashers, & long-term detours	150	$7,253	$7,400	*$14,653*
	Controls: Active Traffic	Day flagmen & nightly changes in barriers, traffic control signage/flashers, & short-term detours				
	Startup: Initial	Installation punchlisting, alignments, gross adjustments, 1st fill of oils & lubricants, and functional testing	160	$7,737	$3,800	*$11,537*
	Startup: Clean & Disinfect	Pipe, tank, and equipment flushing, cleaning, disinfecting, & fluids/waste handling & disposal	220	$10,638	$6,900	*$17,538*
	Startup: Final	Calibrations, fine adjustments, 1st fill of fuels & chemicals/reagents, & operational training/testing,	130	$6,286	$14,200	*$20,486*
	Startup: Test & Commission	Functional & operational punchlisting, O&M manuals, on-line interfacing/coordination, & performance testing	160	$7,737	$21,700	*$29,437*
	Close-Out: Project	Punchlist sign-offs, record/as-built documents, warranty initiation, & bond closure/sign-offs	360	$17,408	$57,800	*$75,208*
	Close-Out: Site	Disconnect utilities and remove facilities, carpentry, construction equipment/tools, & surplus materials	100	$4,836	$11,400	*$16,236*
	Demobilization	Remove utilities and vacate site, along with final housekeeping, & area restoration	290	$14,023	$4,600	*$18,623*
1	**Subtotal - General Conditions Allowances**		5,820	$281,427	$1,127,500	***$1,408,927***

MWH CONSTRUCTORS

DIV 1 (01) GENERAL REQUIREMENTS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Camp Allowances for Tradesmen & Supervision

Considerations During both Pre-Construction & Construction

	Travel Metric		Roundtrip Cost		Daily Cost		Daily Cost
Work Days per Week	0	*Air Transportation*	$0	*Meals*	$0	*Housekeep*	$0
Rotation Cycle - Weeks		*Ground Transportation*	$0	*Mobility & FOM*	$0	*Laundry*	$0
1-Way Travel Time- Hours		*Tips, Meals, & Miscellany*	$0	*Lodging*	$0	*Incidentals*	$0

Camp Summary

☐ Report in OPCC SUMMARY

Camp Cost per Manhour	Eligible Manhours	TOTAL Camp Cost

Camp WBS Assignment

WBS	%	WBS Cost

Miscellaneous Allowances

WBS	Description	Quantity	Trades MH	MH @ $0	M&CE $	EQ $	TOTAL
				$			
				$			
				$			
				$			
				$			
				$			
				$			
				$			
				$			
				$			
Subtotal - Miscellaneous Allowances							

General Requirements Total

	MH	MH @ $48 (avg)	M&CE $	Camp $	EQ $	TOTAL
DIV 1(g) TOTAL	5,820	$281,427	$1,127,500			***$1,408,927***

DIV 2 (02 & 31-35) COMMON SITE WORK

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

Clearing & Grubbing		*Stormwater Control*	
Primary Excavation Issue	Dust Control	*Temporary Shoring*	Shoring (walers & tiebacks)
Secondary Excavation Issue	Unstable Soil	*Temporary Dewatering*	Full-time Low Point Pumping
Hauling & Disposal Distance	5.1 - 10.0 miles roundtrip	*Temporary Erosion Control*	(re: General Allowances)
Base, Bed, & Fill Supply	100% Import	*Temporary Traffic Control*	(re: General Allowances)
General Excavations		*Saw-Cutting*	(re: General Allowances)
General Excavation Base & Fill		*Core-Drilling*	(re: General Allowances)
Structural Excavations	Excavate & Fill w/ Partial Haul	*Pot-Holing*	(re: General Allowances)
Structural Excavation Base	Crushed Stone ¾"-1½"	*Liners & Geo-Materials*	
Trench Excavations		*Random Base & Fill*	Crushed Stone ¾"-1½"
Trench Excavation Bed & Fill		*General Allowances*	Low

Common Site Work Scope

Structural Excavations

WBS	Description	Qty	Type	Lng-Iss	Wd-Bse	Deep	Cut °	CY	TON	MH	MH @ $48	M&CE $	TOTAL
12	*New GEN slab*	1	1.30	45.0	22.5	2.0	45	85	109	27	$1,311	$422	*$1,733*
12	*Compacted Base*	25%	1.2	1.6	3.0			21	29	4	$195	$439	*$634*
12	*New GEN diesel storage tank slab*	1	1.30	49.0	27.0	2.0	45	110	141	35	$1,677	$542	*$2,218*
12	*Compacted Base*	25%	1.2	1.6	3.0			27	37	5	$250	$563	*$813*
61	*New SOL thickener*	1	1.30	0.0	45.0	11.0	90	648	831	186	$8,977	$3,111	*$12,087*
61	*Compacted Base*	5%	1.2	1.6	3.0			29	40	5	$250	$606	*$855*
62	*New FILT cells*	1	1.30	85.0	40.0	13.0	90	1,637	2,100	379	$18,314	$7,433	*$25,747*
62	*Compacted Base*	4%	1.2	1.6	3.0			63	85	9	$459	$1,295	*$1,754*
60	*New OZ channel & gallery*	1	1.30	74.0	25.5	14.0	90	978	1,255	262	$12,683	$4,612	*$17,296*
60	*Compacted Base*	4%	1.2	1.6	3.0			35	47	6	$282	$719	*$1,001*
59	*New ACT channel & gallery*	1	1.30	85.0	35.0	14.0	90	1,543	1,978	365	$17,650	$7,043	*$24,693*
59	*Compacted Base*	4%	1.2	1.6	3.0			55	74	8	$408	$1,133	*$1,541*
5	*Utilidor*	1	1.30	300.0	6.0	3.5	45	373	478	113	$5,445	$1,818	*$7,263*
5	*Compacted Base*	14%	1.2	1.6	3.0			53	72	10	$469	$1,096	*$1,566*
30	*ACT corner leak area*	2	1.30	6.0	6.0	20.0	90	53	68	17	$828	$265	*$1,093*
30	*Compacted Base*	3%	1.2	1.6	3.0			1	2		$12	$27	*$40*
37	*FILT corner leak area*	2	1.30	6.0	6.0	18.0	90	48	62	15	$746	$238	*$984*
37	*Compacted Base*	3%	1.2	1.6	3.0			1	2		$12	$27	*$40*
42	*OZ corner leak area*	2	1.30	6.0	6.0	24.0	90	64	82	21	$993	$318	*$1,311*
42	*Compacted Base*	2%	1.2	1.6	3.0			1	2		$12	$27	*$40*
		0	0.00	0.0	0.0	0.0	0						
0		0%	0.0	0.0	0.0								
Subtotal - Structural Excavations								5,539	7,104	1,468	$70,974	$31,734	***$102,708***

Temporary Shoring

WBS	Description	Qty	Type	Long	Wide/Ø	Deep	Comm	SF	LF	MH	MH @ $48	M&CE $	TOTAL
61	*New SOL thickener area*	1	16.0		50.0	11.0	1.00	1,728	157	181	$8,746	$4,041	*$12,787*
		0	0.0	0.0	0.0	0.0	0.00						
62	*New FILT cells area*	1	16.0	85.0	40.0	13.0	2.00	3,250	250	340	$16,450	$8,325	*$24,775*
		0	0.0	0.0	0.0	0.0	0.00						
60	*New OZ channel & gallery area*	1	16.0	90.0	40.0	14.0	2.00	3,640	260	381	$18,424	$9,729	*$28,153*
		0	0.0	0.0	0.0	0.0	0.00						
59	*New ACT channel & gallery area*	1	16.0	85.0	35.0	14.0	2.00	3,360	240	352	$17,007	$8,981	*$25,988*
		0	0.0	0.0	0.0	0.0	0.00						
30	*ACT corner leak area*	2	16.0	6.0	6.0	20.0	2.00	960	48	100	$4,859	$3,207	*$8,067*
			0.0	0.0	0.0		0.00						
37	*FILT corner leak area*	2	16.0	6.0	6.0	18.0	2.00	864	48	90	$4,373	$2,694	*$7,067*
			0.0	0.0	0.0		0.00						
42	*OZ corner leak area*	2	16.0	6.0	6.0	24.0	2.00	1,152	48	121	$5,831	$4,362	*$10,193*
		0	0.0	0.0	0.0	0.0	0.00						
		0	0.0	0.0	0.0	0.0	0.00						
Subtotal - Temporary Shoring								14,954	1,051	1,565	$75,692	$41,339	***$117,030***

MWH CONSTRUCTORS

DIV 2 (02 & 31-35) COMMON SITE WORK

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Temporary Dewatering

WBS	Description	Qty	Type	Long	Wide/Ø	SF	MH	MH @ $48	M&CE $	TOTAL
61	*New SOL thickener area*	1	2.0		50.0	1,963	125	$6,058	$10,768	*$16,826*
		0	0.0	0	0					
62	*New FILT cells area*	1	2.0	85.0	40.0	3,400	217	$10,490	$18,647	*$29,136*
		0	0.0	0	0					
60	*New OZ channel & gallery area*	1	2.0	90.0	40.0	3,600	230	$11,107	$19,744	*$30,850*
		0	0.0	0	0					
59	*New ACT channel & gallery area*	1	2.0	85.0	35.0	2,975	190	$9,179	$16,316	*$25,494*
		0	0.0	0.0	0.0					
5	*Utilidor area*	1	2.0	300.0	6.0	1,800	115	$5,553	$9,872	*$15,425*
		0	0.0	0	0					
30	*ACT corner leak area*	2	2.0	6.0	6.0	72	5	$222	$395	*$617*
			0.0	0.0	0.0					
37	*FILT corner leak area*	2	2.0	6.0	6.0	72	5	$222	$395	*$617*
			0.0	0.0	0.0					
42	*OZ corner leak area*	2	2.0	6.0	6.0	72	5	$222	$395	*$617*
		0	0.0	0	0					
		0	0.0	0	0					
	Subtotal - Temporary Dewatering					13,954	890	$43,053	$76,531	***$119,584***

General Allowances

This summary category is intended to provide coverage of the minor DIV 2 sitework and/or related items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the identified scope items above when these DIV costs are exported to other worksheets.***

WBS		MH	MH @ $48	M&CE $	TOTAL
2	**Subtotal - General Allowances**	522	$25,229	$16,701	***$41,930***

Common Site Work Total

	MH	MH @ $48	M&CE $	TOTAL
DIV 2(c) TOTAL	4,445	$214,947	$166,305	**$381,252**

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

Cement Type	Type II (lo heat & sulfate resist)	*Footer Width*	2x Foundation Width
Mix Additives	1 Admixture (generic)	*Slope of Haunch Foundation*	45° from horizontal
Mix Strength	4,500 PSI (7-8 sacks/CY)	*Base Slab Cantilever for Walls*	1' Past Wall (all sides)
ACI Install Code	ACI 350R (environmental)	*Elevated Channels & Troughs*	
Reinforcement	A615-Plain Steel (qty in tons)	*Embedments*	Typical Types & Densities
Foundation Style	Monolithic Perimeter Haunch	*Rebar Density Above Grade*	Normal
Foundation Width	18" (excludes haunch slope)	*Rebar Density Below Grade*	Normal
Foundation Depth	2' with top-mount (TS) slab	*General Allowances*	Low

CIP Concrete Scope

Column Structures

WBS	Description	Qty	Type	Long	Wd-Ø	PC		TON	CY	Component	Hi-Thk	MH	MH @ $54	M&CE $	TOTAL
46	*WWEQ N/S wall beam supports*	3	5.0	1.0	1.0				1.9	*Rect Column*	17.00	297	$15,925	$1,598	*$17,523*
			Total $	$19,056		Tot CY	2		0.4	*Spread Footer*	1.00	25	$1,352	$181	*$1,533*
47	*WWEQ W wall beam supports*	3	5.0	1.0	1.0				2.0	*Rect Column*	18.00	313	$16,754	$1,687	*$18,440*
			Total $	$19,974		Tot CY	2		0.4	*Spread Footer*	1.00	25	$1,352	$181	*$1,533*
		0	0.0	0.0	0.0						0.00				
											0.00				
Subtotal - Columns								0.7	4.8			660	$35,383	$3,647	***$39,030***

Beam & Bulkhead Structures

WBS	Description	Qty	Type	Struct	Long	Wd-Ø	PC	TON	CY	Component	Hi/Thk	MH	MH @ $54	M&CE $	TOTAL
46	*WWEQ N/S wall brace beams*	3	5.0	6	41.5	1.0		0.63	6.9	*Beam*	1.50	558	$29,923	$3,788	*$33,712*
		0	0.0	0	0.0	0.0					0.00				
47	*WWEQ W wall brace beams*	3	5.0	6	35.0	1.0		0.53	5.8	*Beam*	1.50	512	$27,446	$3,318	*$30,764*
		0	0.0	0	0.0	0.0					0.00				
		0	0.0	0	0.0	0.0					0.00				
		0	0.0	0	0.0	0.0					0.00				
Subtotal - Beams & Bulkheads								1.2	12.8			1,070	$57,369	$7,107	***$64,476***

Lean Fill & Mudmats

WBS	Description	Qty	Type	Long	Wd-Ø	CY	Component	Thick	MH	MH @ $54	M&CE $	TOTAL
59	*New ACT structure settler*	1	5.0	19.0	19.0	33.4	*Conc w/o Rebar*	2.50	48	$2,581	$3,560	*$6,140*
		0	0.0	0.0	0.0			0.00				
		0	0.0	0.0	0.0			0.00				
		0	0.0	0.0	0.0			0.00				
Subtotal - Lean Fill & Mudmats						33.4			48	$2,581	$3,560	***$6,140***

Housekeeping Pad & Sidewalk Structures

WBS	Description	Qty	Type	Long	Wd-Ø	Sides	Clear	TON	CY	Component	Thick	MH	MH @ $54	M&CE $	TOTAL
62	*FILT control console*	1	5.0	4.0	3.0	4.0	0.00	0.01	0.2	*Rectangular Pad*	0.5	4	$238	$86	*$324*
		0	0.0	0.0	0.0	0.0	0.00				0.0				
59	*ACT sand/sludge pumps*	2	5.0	4.0	1.5	4.0	0.00	0.01	0.2	*Rectangular Pad*	0.5	4	$229	$84	*$312*
		0	0.0	0.0	0.0	0.0	0.00				0.0				
58	*O3 generator skid*	1	5.0	6.0	5.0	4.0	0.00	0.02	0.6	*Rectangular Pad*	0.5	11	$564	$209	*$773*
		0	0.0	0.0	0.0	0.0	0.00				0.0				
7	*ACT flash mix pump*	1	5.0	4.5	2.0	4.0	0.00	0.01	0.2	*Rectangular Pad*	0.5	3	$180	$65	*$244*
		0	0.0	0.0	0.0	0.0	0.00				0.0				
66	*DEW solids transfer pump*	1	5.0	6.0	1.5	4.0	0.00	0.01	0.2	*Rectangular Pad*	0.5	3	$180	$65	*$244*
		0	0.0	0.0	0.0	0.0	0.00				0.0				
93	*CHEM dry NaOCl equip legs*	4	5.0	1.5	1.5	4.0	0.00	0.01	0.2	*Rectangular Pad*	0.5	3	$153	$60	*$212*
93	*CHEM dry NaOCl mix skid*	1	5.0	5.0	5.0	4.0	0.00	0.02	0.5	*Rectangular Pad*	0.5	9	$477	$176	*$653*
		0	0.0	0.0	0.0	0.0	0.00				0.0				
		0	0.0	0.0	0.0	0.0	0.00				0.0				
		0	0.0	0.0	0.0	0.0	0.00				0.0				
		0	0.0	0.0	0.0	0.0	0.00				0.0				
Subtotal - Housekeeping Pads & Sidewalks								0.1	2.0			38	$2,020	$743	***$2,764***

MWH
CONSTRUCTORS

DIV 3 (03) CONCRETE

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Rectangular Slab Structures

WBS	Description	Qty	Type	Long	Wide	Fndtn	Factor		CY	Component	Thk/Dp	MH	MH @ $54	M&CE $	TOTAL
12	New GEN slab	1	5.0	40.0	17.5	2	2.00		26	Slab	1.00	156	$8,361	$6,485	$14,846
			Total $	$20,811		TON	2.1		13	Haunch	1.50	61	$3,290	$2,675	$5,965
			Tot CY	39							0.00				
12	New GEN diesel tank slab	1	5.0	44.0	22.0	2	2.00		36	Slab	1.00	216	$11,562	$8,967	$20,530
			Total $	$27,461		TON	2.9		15	Haunch	1.50	71	$3,823	$3,108	$6,931
			Tot CY	51							0.00				
			0.0	0.0	0.0	0	0.00				0.00				
											0.00				
											0.00				
	Subtotal - Rectangular Slabs							5.0	90			504	$27,036	$21,236	$48,272

Rectangular Wall & Tank Structures

WBS	Description	Qty	Type	Long	Wide	SW	To/Bo	Fndtn	CY	Component	Thk/Dp	MH	MH @ $54	M&CE $	TOTAL
62	New FILT cells	2	5.0	25.0	23.0	18.2	1.0	3	80	Slab	1.34	400	$21,453	$20,484	$41,937
			Total $	$190,503			Cntlvr	2.00			0.00				
			Tot CY	197			Wall Factor	1.48			0.00				
			TON	15.7			F&F Sides	2.00			0.00				
									117	Wall	1.17	2,128	$114,087	$34,479	$148,566
62	New FILT influent & gallery	1	5.0	25.0	16.0	21.2	2.0	3	29	Slab	1.34	149	$7,981	$7,513	$15,494
			Total $	$133,788			Cntlvr	2.00	18	Elevated Slab	1.00	241	$12,906	$5,253	$18,159
			Tot CY	114			Wall Factor	2.00			0.00				
			TON	9.7			F&F Sides	2.00			0.00				
									67	Wall	1.00	1,462	$78,398	$21,737	$100,135
62	New FILT influent channel floor	2	5.0	25.0	16.0		0.0	3							
			Total $	$29,892			Cntlvr	0.00	30	Elevated Slab	1.00	396	$21,245	$8,647	$29,892
			Tot CY	30			Wall Factor	0.00			0.00				
							F&F Sides	0.00			0.00				
											0.00				
62	New FILT influent weir walls	2	5.0	20.0	0.0	4.8	0.0	0							
			Total $	$17,454			Cntlvr	0.00			0.00				
			Tot CY	7			Wall Factor	0.00			0.00				
			TON	0.4			F&F Sides	2.00			0.00				
									7	Wall	1.00	282	$15,110	$2,344	$17,454
62	New FILT WW gullet	2	5.0	23.0	4.0	14.5	2.0	3							
			Total $	$44,832			Cntlvr	2.00	11	Elevated Slab	1.00	149	$7,967	$3,243	$11,210
			Tot CY	38			Wall Factor	0.85			0.00				
			TON	2.9			F&F Sides	2.00			0.00				
									26	Wall	1.00	482	$25,819	$7,803	$33,622
60	New OZ channel & gallery	1	5.0	74.0	25.5	24.0	2.0	3	99	Slab	1.17	514	$27,574	$25,958	$53,532
			Total $	$569,805			Cntlvr	2.00	77	Elevated Slab	1.00	1,035	$55,503	$22,590	$78,093
			Tot CY	472			Wall Factor	3.27			0.00				
			TON	41.8			F&F Sides	2.00			0.00				
									295	Wall	1.00	6,400	$343,063	$95,117	$438,180
60	New OZ basin baffle walls	2	5.0	10.0	3.0	20.5	2.0	3			0.00				
			Total $	$76,129			Cntlvr	2.00	4	Elevated Slab	1.00	158	$8,487	$1,657	$10,145
			Tot CY	50			Wall Factor	2.00			0.00				
			TON	4.2			F&F Sides	2.00			0.00				
									46	Wall	1.00	961	$51,501	$14,483	$65,985
60	New OZ basin baffle walls	3	5.0	10.0	0.0	21.0	0.0	0			0.00				
			Total $	$32,939			Cntlvr	0.00			0.00				
			Tot CY	23			Wall Factor	0.00			0.00				
			TON	2.0			F&F Sides	2.00			0.00				
									23	Wall	1.00	478	$25,625	$7,314	$32,939
60	New OZ basin baffle walls	4	5.0	10.0	0.0	18.0	0.0	0			0.00				
			Total $	$32,157			Cntlvr	0.00			0.00				
			Tot CY	27			Wall Factor	0.00			0.00				
			TON	2.1			F&F Sides	2.00			0.00				
									27	Wall	1.00	457	$24,519	$7,638	$32,157

DIV 3 (03) CONCRETE

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

59	*New ACT channel*	1	5.0	70.3	19.0	20.7	2.0	3	99	*Slab*	1.50	510	$27,342	$25,740	*$53,082*
			Total $	$391,281			Cntlvr	2.00	59	*Elevated Slab*	1.00	784	$42,007	$17,097	*$59,104*
			Tot CY	345			Wall Factor	2.00			0.00				
			TON	29.3			F&F Sides	2.00			0.00				
									188	*Wall*	1.33	4,076	$218,511	$60,584	*$279,095*
59	*New ACT internal walls*	1	5.0	83.5	0.0	20.7	0.0	0			0.00				
			Total $	$94,959			Cntlvr	0.00			0.00				
			Tot CY	64			Wall Factor	0.00			0.00				
			TON	5.4			F&F Sides	2.00			0.00				
									64	*Wall*	1.00	1,387	$74,346	$20,613	*$94,959*
59	*New ACT effluent area*	1	5.0	19.0	12.0	5.5	2.0	3			0.00				
			Total $	$19,433			Cntlvr	2.00	11	*Elevated Slab*	1.00	146	$7,808	$3,178	*$10,985*
			Tot CY	15			Wall Factor	0.62			0.00				
			TON	1.2			F&F Sides	2.00			0.00				
									4	*Wall*	1.00	133	$7,152	$1,295	*$8,448*
		0	0.0	0.0	0.0	0.0	0.0	0			0.00				
								0.00			0.00				
								0.00			0.00				
								0.00			0.00				
											0.00				
	Subtotal - Rectangular Walls & Tanks							114.8	1,381			22,728	$1,218,407	$414,765	***$1,633,172***

Circular Clarifier/Thickener Structures

WBS	Description	Qty	Type	Ø	SW	Cntlvr	Launder		CY	Component	Thk/Dp	MH	MH @ $54	M&CE $	TOTAL
62	*New SOL thickener*	1	5.0	35.0	13.7	2.0	Inside		52	*Slab & Center Well*	1.17	267	$14,315	$13,476	*$27,792*
			Total $	$112,365					57	*Wall*	1.00	1,071	$57,436	$17,114	*$74,550*
			Tot CY	125					9	*Launder*	0.66	115	$6,155	$2,505	*$8,660*
			TON	8.8					7	*Rake Grouting*	0.21	11	$573	$791	*$1,364*
		0	0.0	0.0	0.0	0.0	0.0				0.00				
											0.00				
											0.00				
											0.00				
	Subtotal - Circular Clarifiers/Thickeners							8.8	125			1,464	$78,480	$33,886	***$112,365***

Trench Structures

WBS	Description	Qty	Type	Style	Long	Wide	SW		CY	Component	Thick	MH	MH @ $54	M&CE $	TOTAL
5	*Utilidor structure*	1	5.0	1.25	300	2.5	2.0		22.3	*Slab*	0.50	134	$7,203	$5,586	*$12,789*
			Total $	$61,059		TON	2.41		22.5	*Walls*	0.50	774	$41,485	$6,786	*$48,271*
		0	0.0	0.00	0	0.0	0.0				0.00				
											0.00				
	Subtotal - Trenches							2.4	45			908	$48,688	$12,372	***$61,059***

Elevated Personnel Access Structures

WBS	Description	Qty	Type	Style	Lng/Hi	Wide	Slope°	TON	CY	Component	Thick	MH	MH @ $54	M&CE $	TOTAL
61	*New FILT cell walkways*	2	5.0	1	24.0	5.0	0	0.8	8.9	*Walkway*	1.00	154	$8,258	$2,700	*$10,958*
61	*New FILT cell walkways*	2	5.0	1	22.0	4.0	0	0.6	6.5	*Walkway*	1.00	173	$9,281	$2,202	*$11,483*
		0	0.0	0	0.0	0.0	0				0.00				
		0	0.0	0	0.0	0.0	0				0.00				
		0	0.0	0	0.0	0.0	0				0.00				
	Subtotal - Elevated Personnel Accesses							1.4	15.4			327	$17,539	$4,903	***$22,441***

Miscellaneous Work Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $54	M&CE $	TOTAL
46	*WWEQ N&S wall braces-LS/EA*	1	3	150	$3,750	3	450	$24,123	$11,250	*$35,373*
47	*WWEQ width braces-LS/EA*	1	3	120	$3,000	3	360	$19,299	$9,000	*$28,299*
30	*Seal ACT corner leaks-VLF/EA*	20	2	2.3	$2.81	40	90	$4,825	$113	*$4,937*
37	*Seal FILT corner leaks-VLF/EA*	18	2	2.8	$3.37	36	99	$5,326	$121	*$5,448*

DIV 3 (03) CONCRETE

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $54	M&CE $	TOTAL
42	*Seal OZ corner leaks-VLF/EA*	24	2	2.3	$2.81	48	110	$5,918	$135	*$6,053*
94	*CHEM area contain mods-LS*	1	1	100	$2,000	1	100	$5,361	$2,000	*$7,361*
Subtotal - Miscellaneous Work Allowances							1,210	$64,852	$22,619	***$87,471***

Demolition & Disposal Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $54	M&CE $	TOTAL
94	*CHEM area contain mods-LS*	1	1	40	$800	1	40	$2,144	$800	*$2,944*
Subtotal - Demolition & Disposal Allowances							40	$2,144	$800	***$2,944***

General Allowances

This summary category is intended to provide coverage of the minor DIV 3 concrete work and/or related items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the identified scope items above when these DIV costs are exported to other worksheets.***

WBS		Rebar	CY		MH	MH @ $54	M&CE $	TOTAL
2	**Subtotal - General Allowances**	0.7	9		148	$7,925	$2,632	***$10,557***

CIP Concrete Total

	Rebar	CY		MH	MH @ $54	M&CE $	TOTAL
DIV 3 TOTAL	135	1,718		29,146	$1,562,423	$528,269	***$2,090,692***

MWH CONSTRUCTORS

DIV 4 (04) MASONRY

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date		Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17		Jim Ward	002	30503765

Assumptions

Exterior Type & Finish	8" CMU with Paint/Seal Face (2)	*Interior Type & Finish*	
Exterior CMU Type/Quality	3-Cell Units	*Interior CMU Type/Quality*	
Exterior Cell Fill	Rebar & Concrete-Fill (total)	*Interior Cell Fill*	
Exterior Wall Openings	Low density (20%)	*Interior Wall Openings*	
Exterior Cavity Treat		*Interior Cavity Treat*	
Exterior Architecture Treat	Minimum Enhancement	*Interior Architecture Treat*	Minimum Enhancement
Insulation & Liner		*General Allowances*	Low

Masonry Scope

Exterior Masonry Structures

WBS	Description	Qty	Type	Long	Wide	High	Cell	Open	Cavity	Corner	Gable	SF	MH	MH @ $50	M&CE $	TOTAL
59	*New ACT building (50%)*	1	7	18.7	9.7	12.0	9	5	1	4	0.00	680	261	$12,947	$9,830	*$22,776*
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
	Subtotal - Exterior Masonry Structures											680	261	$12,947	$9,830	***$22,776***

Interior Masonry Structures

WBS	Description	Qty	Type	Long	Wide	High	Cell	Open	Cavity	Corner	Gable	SF	MH	MH @ $0	M&CE $	TOTAL
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
			0				0	0	0	0	0.00					
	Subtotal - Interior Masonry Structures															

Miscellaneous Work Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $0	M&CE $	TOTAL
	Subtotal - Miscellaneous Work Allowances									

Demolition & Disposal Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $0	M&CE $	TOTAL
	Subtotal - Demolition & Disposal Allowances									

General Allowances

This summary category is intended to provide coverage of the minor DIV 4 masonry and/or related work items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the identified scope items above when these DIV costs are exported to other worksheets.***

WBS		MH	MH @ $50	M&CE $	TOTAL
2	**Subtotal - General Allowances**	4	$194	$147	***$342***

Masonry Total

	SF	MH	MH @ $50	M&CE $	TOTAL
DIV 4 TOTAL	680	265	$13,141	$9,977	***$23,118***

MWH CONSTRUCTORS

DIV 5 (05) MISCELLANEOUS METALS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

Supply Responsibility	Prime or Subcontractor	*Guardposts & Bollards*	
Access Assemblies	Aluminum Structure & Grate	*Racks & Bents*	
Gratings & Coverplates	Aluminum Structure & Grate	*Elevated Decks*	
Hatches & Covers	Aluminum	*Fabrications Level*	Standard
Hoist & Crane Rails		*General Allowances*	Low

Miscellaneous Metals Scope

Access Stairway & Landing Assemblies

WBS	Description	Qty	Type	Wide	High	Style	Risers	Erect MH	MH @ $55	M&CE $	TON	Assembly $	TOTAL
61	*New SOL thickener*	1	2.51	3.5	7.0	1.0	11	17	$961	$406	0.18	$3,252	*$4,619*
		0	0.00	0.0	0.0	0.0							
62	*New FILT cells*	1	2.51	3.5	10.0	1.5	15	29	$1,591	$741	0.33	$5,925	*$8,257*
62	*New FILT cells*	1	2.51	3.5	22.0	1.5	33	42	$2,332	$1,434	0.73	$11,471	*$15,236*
		0	0.00	0.0	0.0	0.0							
60	*New OZ structure*	1	2.51	3.5	12.0	1.5	18	32	$1,782	$889	0.40	$7,110	*$9,781*
60	*New OZ structure*	1	2.51	3.5	24.0	1.5	36	46	$2,544	$1,564	0.80	$12,513	*$16,621*
		0	0.00	0.0	0.0	0.0							
59	*New ACT structure*	1	2.51	3.5	7.0	1.5	11	22	$1,225	$518	0.23	$4,147	*$5,891*
59	*New ACT structure*	1	2.51	3.5	22.0	1.5	33	42	$2,332	$1,434	0.73	$11,471	*$15,236*
		0	0.00	0.0	0.0	0.0							
		0	0.00	0.0	0.0	0.0							
		0	0.00	0.0	0.0	0.0							
Subtotal - Access Stairway & Landing Assemblies							157	230	$12,768	$6,986	3.40	$55,889	***$75,642***

Access Handrail & Toeplate Assemblies

WBS	Description	Qty	Type	Long	Wide/Ø	Style	LF	Erect MH	MH @ $55	M&CE $	TON	Assembly $	TOTAL
61	*New FILT cell walkways*	2	2.51	24.0	5.0	2.0	116	125	$6,909	$633	0.15	$5,067	*$12,609*
61	*New FILT cell walkways*	2	2.51	22.0	4.0	2.0	104	116	$6,456	$580	0.14	$4,640	*$11,676*
0		0	0.00	0.0	0.0	0.0							
60	*New OZ \structure*	1	2.51	74.0	25.5	2.0	199	38	$2,086	$886	0.26	$7,091	*$10,063*
		0	0.00	0.0	0.0	0.0							
59	*New ACT structure*	1	2.51	201.0	0.0	2.0	201	38	$2,107	$895	0.26	$7,162	*$10,164*
		0	0.00	0.0	0.0	0.0							
29	*Replace ACT guardrail*	1	2.51	20.0	0.0	2.0	20	27	$1,510	$124	0.03	$992	*$2,626*
		0	0.00	0.0	0.0	0.0							
32	*Add ACT west guardrail kickplate*	1	2.51	20.0	0.0	2.0	20	10	$529	$124	0.03	$298	*$950*
		0	0.00	0.0	0.0	0.0							
34	*Replace OZ guardrail*	1	2.51	20.0	0.0	2.0	20	27	$1,510	$124	0.03	$992	*$2,626*
		0	0.00	0.0	0.0	0.0							
36	*Replace FILT guardrail*	1	2.51	20.0	0.0	2.0	20	27	$1,510	$124	0.03	$992	*$2,626*
		0	0.00	0.0	0.0	0.0							
38	*Add FILT ladder pit kickplate*	1	2.51	20.0	0.0	2.0	20	10	$529	$124	0.03	$298	*$950*
		0	0.00	0.0	0.0	0.0							
		0	0.00	0.0	0.0	0.0							
		0	0.00	0.0	0.0	0.0							
Subtotal - Access Handrail & Toeplate Assemblies							720	418	$23,145	$3,615	0.95	$27,532	***$54,292***

Grating & Coverplate Assemblies

WBS	Description *(NIS = not in scope)*	Qty	Type	Long	Wide/Ø	Style	SF	Erect MH	MH @ $55	M&CE $	TON	Assembly $	TOTAL
5	*Utilidor structure trench*	1	2.51	300.0	2.5	5.0	750	151	$8,388	$2,462	3.94	$39,391	*$50,241*
0		0	0.00	0.0	0.0	0.0							
0		0	0.00	0.0	0.0	0.0							
0		0	0.00	0.0	0.0	0.0							
Subtotal - Grating & Coverplate Assemblies							750	151	$8,388	$2,462	3.94	$39,391	***$50,241***

Hatch & Cover Assemblies

WBS	Description	Qty	Type	Long	Wide/Ø	Style	SF	Erect MH	MH @ $55	M&CE $	TON	Assembly $	TOTAL
60	*New OZ channel & gallery*	7	2.51	3.0	3.0	2.0	63	52	$2,871	$548	0.28	$8,767	*$12,186*
60	*New OZ channel & gallery*	1	2.51	4.0	3.0	2.0	12	9	$524	$100	0.05	$1,606	*$2,231*
		0	0.00	0.0	0.0	0.0							

DIV 5 (05) MISCELLANEOUS METALS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

59	*New ACT structure*	2	2.51	2.0	2.0	2.0	8	8	$423	$80	0.04	$1,284	*$1,787*
59	*New ACT structure*	4	2.51	3.0	3.0	2.0	36	30	$1,640	$313	0.16	$5,010	*$6,964*
59	*New ACT structure*	1	2.51	4.0	4.0	2.0	16	12	$669	$129	0.06	$2,058	*$2,855*
59	*New ACT structure*	1	2.51	4.0	4.5	2.0	18	13	$740	$143	0.07	$2,283	*$3,166*
		0	0.00	0.0	0.0	0.0							
		0	0.00	0.0	0.0	0.0							
		0	0.00	0.0	0.0	0.0							
	Subtotal - Hatch & Cover Assemblies						153	124	$6,867	$1,313	0.66	$21,008	***$29,188***

Miscellaneous Work Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	MH	MH @ $55	M&CE $		TOTAL
87	*Install SITE plate hatch guardrails-LS/E*	1	10	6.0	$300	60	$3,326	$3,000		*$6,326*
88	*Install WWEQ ladder fall restraint-LS*	1	1	20	$600	20	$1,109	$600		*$1,709*
	Subtotal - Miscellaneous Work Allowances					80	$4,434	$3,600		***$8,034***

General Allowances

This summary category is intended to provide coverage of the minor DIV 5 miscellaneous metals and/or related work items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the identified scope items above when these DIV costs are exported to other worksheets.***

WBS		Erect MH	MH @ $55	M&CE $	TON	Assembly $	TOTAL
2	**Subtotal - General Allowances**	5	$278	$90	0.04	$719	***$1,087***

Miscellaneous Metals Total

	Erect MH	MH @ $55	M&CE $	TON	Assembly $	TOTAL
DIV 5 TOTAL	1,008	$55,880	$18,066	8.99	$144,539	***$218,485***

MWH
CONSTRUCTORS

DIVS 5-8 (05-08) BUILDINGS & COMPONENTS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

PE Steel Building (SB)		Arched Fabric (AF)	
SB Add-On's		AF Services (re: DIVS 15-17)	
SB Services (re: DIVS 15-17)		Precast & Tilt-Up System	
PE Steel Roof (SR)		Interior Architectural Level	
SR Add-On's		Exterior Architectural Level	Minimum Enhancement
SR Services (re: DIVS 15-17)		Climate Type for Services	Northwest US (or similar)
Flat Roof (FR)	Varies by Structure	(un-assigned)	
FR Services (re: DIVS 15-17)	HV-Light-Plumb	General Allowances	Low

Buildings & Components Scope

Flat Roof Structures

WBS	Description	Qty	Type	Lng-Wall	Wd-Flrs	Hi-OC	SF-Lev	Watt	MH	MH @ $50	M&CE $	TOTAL
62	New FILT gallery area (services only)	1	2	25.0	16.0	13.0	400					
62	HV-Light-Plumb	1	6	2.00	1	4	1.15	8				
60	New OZ gallery area (services only)	1	2	74.0	14.5	24.0	1,073					
60	HV-Light-Plumb	1	6	2.00	1	4	1.15	8				
59	New ACT gallery area (services only)	1	2	19.0	12.0	13.0	228					
59	HV-Light-Plumb	1	6	2.00	1	4	1.15	8				
59	New ACT building (50% of full size)	1	16	18.7	9.7	10.0	181		31	$1,556	$3,704	$5,260
59	HV-Light-Plumb	1	6	2.00	1	4	1.15	8				
		0	0	0.0	0.0	0.0						
0		0	0	0.00	0	0	0.00	0				
	Subtotal - Flat Roof Structures						1,882		31	$1,556	$3,704	$5,260

Miscellaneous Work Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $55	M&CE $	TOTAL
25	Install CHEM door panic hardware-LS/EA	1	3	6.0	$60	3	18	$986	$180	$1,166
26	Reverse CHEM door open direction-LS	1	1	12.0	$300	1	12	$657	$300	$957
31	Install ACT door panic hardware-LS/EA	1	2	6.0	$60	2	12	$657	$120	$777
40	Install FWPS door panic hardware-LS/EA	1	2	6.0	$60	2	12	$657	$120	$777
41	Install DEW scupper & downspout-LS	1	1	36	$1,800	1	36	$1,971	$1,800	$3,771
48	4" coated tees-LB/LF	6.5	650	0.010	$2.25	4,227	42	$2,315	$9,511	$11,826
48	Install & weld to decking & ledger-LS/EA	1	23	18.0	$200	23	414	$22,668	$4,600	$27,268
48	Drill & install epoxy anchor rods-QTY/EA	2	23	1.50	$75	46	69	$3,778	$3,450	$7,228
49	New 3" dp-16 guage decking-SF	1	1,966	0.0180	$4.58	1,966	35	$1,938	$8,995	$10,932
49	New polyiso 3½: board insulation-QTY/SF	2	1,966	0.012	$2.93	3,932	47	$2,584	$11,502	$14,085
49	New 90 mil EPDM adhered membrane-SF	1	1,966	0.046	$2.98	1,966	91	$4,967	$5,859	$10,826
49	Insulation for balance of roof-SF	1	1,859	0.012	$2.93	1,859	22	$1,221	$5,436	$6,657
49	Membrane for balance of roof-SF	1	1,859	0.046	$2.98	1,859	86	$4,695	$5,539	$10,234
50	Install 16" x 4" x ½" chord splice bars-LS/EA	2	22	1.50	$30.71	44	66	$3,614	$1,351	$4,965
51	Install 16" x 8" x ½" shear plates-QTY/EA	2	23	3.0	$51.33	46	138	$7,556	$2,361	$9,917
51	Drill & install epoxy anchor rods-QTY/EA	2	23	1.50	$75	46	69	$3,778	$3,450	$7,228
51	Existing wall bush down at plates-QTY/EA	2	23	3.50	$88	46	161	$8,815	$4,025	$12,840
51	Reinstall roof decking-SF	1	1,859	0.0180	$0.76	1,859	33	$1,832	$1,417	$3,249
53	Install DEW E Wall Frame Braces-LS	1	1	160	$12,000	1	160	$8,761	$12,000	$20,761
54	4" coated tees-LB/LF	6.5	132	0.010	$2.25	858	9	$470	$1,931	$2,400
54	Install & weld to decking & ledger-LS/EA	1	6	18.0	$200	6	108	$5,913	$1,200	$7,113
54	Drill & install epoxy anchor rods-QTY/EA	2	6	1.50	$75	12	18	$986	$900	$1,886

DIVS 5-8 (05-08) BUILDINGS & COMPONENTS

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

54	*Reinstall roof decking-SF*	1	748	0.0180	$0.76	748	13	$737	$570	*$1,308*
54	*New polyiso 3½: board insulation-QTY/SF*	2	748	0.012	$2.93	1,496	18	$983	$4,376	*$5,359*
54	*New 90 mil EPDM adhered membrane-SF*	1	748	0.046	$2.98	748	35	$1,890	$2,229	*$4,119*
55	*DEW wall/slab anchor 4" angle-SS-LB/LF*	9.8	68	0.010	$6.75	666	7	$365	$4,498	*$4,863*
55	*Drill & install epoxy anchor rods-QTY/EA*	2	34	0.750	$50	68	51	$2,792	$3,400	*$6,192*
85	*Install FWPS door panic hardware-LS/EA*	1	2	6.0	$60	2	12	$657	$120	*$777*
82	*Install FILT stairwell 1-leaf door-LS*	1	1	1.50	$75	1	2	$82	$75	*$157*
82	*Install magnetic door closer/holder-LS*	1	1	2.50	$125	1	3	$137	$125	*$262*
94	*Install CHEM area roll-up door/frame-LS*	1	1	16	$2,300	1	16	$876	$2,300	*$3,176*
94	*Install CHEM area roll-up motor op-LS*	1	1	4	$1,200	1	4	$219	$1,200	*$1,419*
94	*CHEM bldg mods for space-LS*	1	1	160	$8,000	1	160	$8,761	$8,000	*$16,761*
	Subtotal - Miscellaneous Work Allowances						1,978	$108,316	$112,940	***$221,256***

Demolition & Disposal Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $55	M&CE $	TOTAL
25	*Remove CHEM door open hardware-LS/EA*	1	3	2.00	$10	3	6	$329	$30	*$359*
31	*Remove ACT door open hardware-LS/EA1*	1	2	2.00	$10	2	4	$219	$20	*$239*
40	*Remove FWPS door open hardware-LS/EA*	1	2	2.00	$10	2	4	$219	$20	*$239*
48	*Remove FWPS roof membrane & insulation*	1	3,825	0.042	$1.32	3,825	161	$8,813	$5,066	*$13,879*
49	*Remove FWPS roof decking-SF*	1	1,966	0.014	$0.92	1,966	28	$1,550	$1,799	*$3,349*
51	*Remove FWPS balance of roof decking-SF*	1	1,859	0.014	$0.92	1,859	27	$1,465	$1,701	*$3,166*
54	*Remove DEW roof membrane & insulation-*	1	748	0.053	$1.32	748	39	$2,154	$991	*$3,145*
54	*Remove FWPS roof decking-SF*	1	748	0.018	$0.92	748	13	$737	$684	*$1,422*
85	*Remove FWPS door open hardware-LS/EA*	1	2	2.0	$10	2	4	$219	$20	*$239*
82	*Remove FILT stairwell 1-leaf door-LS*	1	1	1.0	$10	1	1	$55	$10	*$65*
94	*Remove CHEM area wall for door-LS*	1	1	60	$1,500	1	60	$3,285	$1,500	*$4,785*
94	*CHEM bldg mods for space-LS*	1	1	64	$1,600	1	64	$3,504	$1,600	*$5,104*
	Subtotal - Demolition & Disposal Allowances						412	$22,550	$13,440	***$35,990***

General Allowances

This summary category is intended to provide coverage of the minor DIVS 5-8 buildings, components, and/or related work items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the identified scope items above when these DIV costs are exported to other worksheets.***

WBS		MH	MH @ $55	M&CE $	TOTAL
2	**Subtotal - General Allowances**	16	$872	$672	***$1,544***

Buildings & Components Total

	SF	MH	MH @ $55	M&CE $	TOTAL
DIVS 5-8 TOTAL	1,882	2,437	$133,294	$130,756	***$264,050***

MWH CONSTRUCTORS

DIVS 9-10 (09-10) FINISHES

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

CIP Concrete	Blast, Prime, & Epoxy	*Buildings - Exterior*	
Tanks - Exterior		*EIFS Structural System*	
Tanks - Interior		*EIFS Finish System*	
Pipes & Ducts		*Finishes Level*	Standard
Buildings - Spaces	Varies by Structure	*Contain & Clean-Up (C&C)*	Minimum
Buildings - Interior	Varies by Space	*General Allowances*	Low

Finishes Scope

CIP Concrete Finishes

WBS	Description	Qty	Type	Long	Wide/Ø	Hi/Dp	To/Bo	C&C	SF	MH	MH @ $40	M&CE $	TOTAL
60	*OZ basin diffuser chamber*	1	11.0	10.0	10.0	24.0	2.00	1.2	1,160	234	$9,449	$5,117	*$14,567*
		0	0.0	0.0	0.0	0.0	0.00	0.0					
5	*Utilidor structure trench*	1	11.0	300.0	2.5	2.0	1.00	1.2	1,960	322	$12,969	$7,023	*$19,992*
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
0		0	0.0	0.0	0.0	0.0	0.00	0.0					
Subtotal - CIP Concrete Finishes									3,120	556	$22,418	$12,140	***$34,558***

Miscellaneous Work Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $40	M&CE $	TOTAL
24	*Replace faded CHEM NFPA signs-LS*	1	1	50	$1,250	1	50	$2,015	$1,250	*$3,265*
82	*Install FILT stairwell door sign-LS*	1	1	0.50	$5.00	1		$20	$5	*$25*
94	*CHEM area mods coating allowance-SF*	400	1	0	$5.00	400	80	$3,224	$2,000	*$5,224*
Subtotal - Miscellaneous Work Allowances							131	$5,260	$3,255	***$8,515***

General Allowances

This summary category is intended to provide coverage of the minor DIVS 9-10 finishes and/or related work items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the identified scope items above when these DIV costs are exported to other worksheets.***

WBS		MH	MH @ $40	M&CE $	TOTAL
2	**Subtotal - General Allowances**	11	$458	$234	***$692***

Finishes Total

	SF	MH	MH @ $40	M&CE $	TOTAL
DIVS 9-10 TOTAL	3,120	698	$28,136	$15,629	***$43,765***

MWH CONSTRUCTORS

DIV 15 (21-23) MECHANICAL INSTALLATION

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	**Wilsonville, OR**	**30-Nov-17**	**Jim Ward**	**002**	**30503765**

Assumptions

Piping System Material 1	Class 50 DIP-MJ-Cement Lined	40%	*Area & Structure Ductwork*	
Piping System Material 2	Sch 40 CS-Butt Weld	20%	*Air & Liquid Distributors*	Shallow Bed/Tower Filter Manifold
Piping System Material 3	Sch 40 Galv CS-Thread	20%	*Face Pipe Assemblies*	
Piping System Material 4	Sch 10 316 SS-Butt Weld	10%	*Media*	Granular: Mono-Media
Piping System Material 5	Sch 80 CPVC-Socket Weld	10%	*Media Supports*	Shallow Bed Filter/Tower
Pipe Installation Code	ASME B31.3 - Process Piping		*Tank Insulation*	
Pipe Insulation & Jacketing			*Tank Insulation Jacketing*	
Pipe Protection & Coating	Enamel or Acrylic Paint		*Tank Heat-Tracing*	
Equipment & Tank Ductwork			*(un-assigned)*	
Tagging & Labeling	Standard (plastic & 316SS)		*General Allowances*	Low

Mechanical Installation Scope

Process Equipment Installation Summary

Breakdown of this section's subtotal by all the major equipment scope items is provided in the DIVS 11-17 PROCESS EQUIPMENT sheets

WBS	Description *(NIS = not in scope)*	Qty	Type	%	MH	MH @ $61	M&CE $	TOTAL
	Rigging & Setting Allowance	1	1.00		1,625	$98,730	$85,220	*$183,950*
0	*Piping & Valving Allowance*	1	1.00		3,272	$198,785	$1,038,553	*$1,237,338*
0	*Piping Insulation NIS*	0	0.00	0%				
0	*Pipe & EQ Coating Allowance*	1	1.20	50%	667	$40,552	$61,946	*$102,498*
0	*Dynamic Ventilation NIS*	0	0.00					
0	*Static Ventilation NIS*	0	0.00					
0	*Tagging & Labeling Allowance*	1			72	$4,355	$2,960	*$7,315*
	Subtotal - Process Equipment Installation Summary				5,636	$342,423	$1,188,679	***$1,531,102***

DIVS 5-8 Flat Roof Structure Mechanical, HVAC, Fire Protection, & Plumbing

WBS	Description	Qty	Type	Floors	A-Level	Scope	SF	MH	MH @ $61	M&CE $	TOTAL
62	*New FILT gallery area (services only)*	1	6	1	1.00	1.01	400	53	$3,205	$4,082	*$7,287*
60	*New OZ gallery area (services only)*	1	6	1	1.00	1.01	1,073	154	$9,360	$12,975	*$22,335*
59	*New ACT gallery area (services only)*	1	6	1	1.00	1.01	228	30	$1,827	$2,327	*$4,154*
59	*New ACT building (50% of full size)*	1	6	1	1.00	1.01	181	24	$1,429	$1,796	*$3,226*
0	0	0	0	0	0.00	0.00					
0	0	0	0	0	0.00	0.00					
0	0	0	0	0	0.00	0.00					
	Subtotal - DIVS 5-8 Flat Roof Mechanical						1,882	260	$15,820	$21,181	***$37,001***

Miscellaneous Work Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $61	M&CE $	TOTAL
44	*Install CHEM pipe seismic bracing-LS*	1	1	120.0	$6,000	1	120	$7,291	$6,000	*$13,291*
45	*Install OZ destruct pipe seismic bracing-LS*	1	1	32.0	$2,400	1	32	$1,944	$2,400	*$4,344*
21	*Install WWEQ chem line supports-LS*	1	1	100.0	$10,000	1	100	$6,076	$10,000	*$16,076*
27	*Install CHEM exit door contain tray & drain-L*	1	2	16.0	$400	2	32	$1,944	$800	*$2,744*
18	*Install ACT settling tank tubes-LS/EA*	1	2	48.0	$1,200	2	96	$5,833	$2,400	*$8,233*
56	*Install SITE space heater bracing-LS/EA*	1	8	6.0	$150	8	48	$2,916	$1,200	*$4,116*
5	*Utilidor 1" PVC chem pipe & ftgs-LF/EA*	410	7	0.20	$3.00	2,870	574	$34,875	$8,610	*$43,485*
5	*3" PVC contain pipe for open/bldg runs-LF/E*	110	7	0.30	$8.00	770	231	$14,035	$6,160	*$20,195*
81	*Upgrade ACT bldg/gallery HVAC-SF*	577	1	0.063	$8.75	577	36	$2,189	$5,045	*$7,234*
83	*Upgrade FILT bldg/gallery HVAC-SF*	756	1	0.063	$8.75	756	47	$2,871	$6,615	*$9,486*
84	*Upgrade FWPS SWGR room HVAC-SF*	1,425	1	0.063	$8.75	1,425	89	$5,411	$12,469	*$17,880*

DIV 15 (21-23) MECHANICAL INSTALLATION

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

86	*Upgrade OZ bldg stairwell HVAC-SF*	183	1	0.063	$8.75	183	11	$693	$1,597	*$2,290*
89	*Upgrade WWEQ bldg/room HVAC-SF*	611	1	0.063	$8.75	611	38	$2,321	$5,349	*$7,670*
76	*Install CHEM NaOCl vent return line-LS/EA*	1	2	14.0	$400	2	28	$1,701	$800	*$2,501*
77	*Install CHEM meter pump strainers-LS/EA*	1	17	1.50	$15	17	26	$1,549	$255	*$1,804*
79	*Install larger LOX rental tank-LS*	1	1	120	$12,000	1	120	$7,291	$12,000	*$19,291*
	Subtotal - Miscellaneous Work Allowances						1,628	$98,941	$81,699	***$180,640***

Demolition & Disposal Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $61	M&CE $	TOTAL
70	*Remove SOL thicken drive unit-LS*	1	1	16.4	$169	1	16	$996	$169	*$1,165*
17	*Remove ACT sample pumps/valves-LS/EA*	1	2	7.6	$77	2	15	$924	$154	*$1,077*
69	*Remove ACT flash mix pumps/valves-LS/E*	1	2	38.8	$1,732	2	78	$4,715	$3,463	*$8,178*
72	*Remove DEW xfer pumps/valves-LS/EA*	1	2	23.6	$1,056	2	47	$2,868	$2,112	*$4,979*
18	*Remove ACT settling tank tubes-LS/EA*	1	2	32.0	$800	2	64	$3,888	$1,600	*$5,488*
9	*Remove FWPS 4 MGD pump/valves-LS/EA*	1	1	53.5	$2,386	1	54	$3,253	$2,386	*$5,640*
63	*Remove FWPS 7.5 MGD pumps/valves-LS/*	1	3	56.2	$2,835	3	169	$10,238	$8,505	*$18,743*
65	*Remove RWPS 7.5 MGD pumps/valves-LS*	1	2	84.3	$4,253	2	169	$10,238	$8,505	*$18,743*
15	*Remove 2 gph CHEM pumps/valves-LS/EA*		5	2.9	$38					
15	*Remove 6 gph CHEM pumps/valves-LS/EA*		3	5.1	$66					
15	*Remove 39 gph CHEM pumps/valves-LS/EA*		6	8.7	$113					
15	*Remove 77 gph CHEM pumps/valves-LS/EA*		3	10.3	$132					
15	*Remove 1" CHEM flush valve-LS/EA*		17	1.5	$19					
68	*Remove 2 gph CHEM pumps/valves-LS/EA*		5	2.9	$38					
68	*Remove 6 gph CHEM pumps/valves-LS/EA*		3	5.1	$66					
68	*Remove 39 gph CHEM pumps/valves-LS/EA*		6	8.7	$113					
68	*Remove 77 gph CHEM pumps/valves-LS/EA*		3	10.3	$132					
68	*Remove 1" CHEM flush valve-LS/EA*		17	1.5	$19					
81	*Remove ACT bldg/gallery HVAC items-SF*	577	1	0.025	$1.75	577	14	$876	$1,009	*$1,885*
83	*Remove FILT blower room HVAC items-SF*	756	1	0.025	$1.75	756	19	$1,148	$1,323	*$2,471*
84	*Remove FWPS SWGR room HVAC items-S*	1,425	1	0.025	$1.75	1,425	36	$2,164	$2,494	*$4,658*
86	*Remove OZ bldg stairwell HVAC items-SF*	183	1	0.025	$1.75	183	5	$277	$319	*$597*
89	*Remove WWEQ bldg/room HVAC items-SF*	611	1	0.025	$1.75	611	15	$929	$1,070	*$1,998*
79	*Remove smaller LOX rental tank-LS*	1	1	48	$1,200	1	48	$2,916	$1,200	*$4,116*
93	*Remove un-used CHEM NaOCl pipe-LS*	1	1	24	$600	1	24	$1,458	$600	*$2,058*
94	*Remove CHEM NH3 equip & pipe-LS*	1	1	60	$1,500	1	60	$3,645	$1,500	*$5,145*
	Subtotal - Demolition & Disposal Allowances						832	$50,534	$36,409	***$86,943***

MWH CONSTRUCTORS

DIV 15 (21-23) MECHANICAL INSTALLATION

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Air & Liquid Distributors (installation only)

WBS	Description	Qty	Type	Long	Wide/Ø	SF	MH	MH @ $61	M&CE $	TOTAL
19	*Filter GAC media replacement # 1*		0.00	23.0	20.0					
19	*Filter GAC media replacement # 2*		0.00	23.0	20.0					
19	*Filter GAC media replacement # 3*		0.00	23.0	20.0					
			0.00							
71	*Filter GAC media replacement # 4*		0.00	23.0	20.0					
		0	0.00	0.0	0.0					
62	*New GAC filter cells*	2	0.75	23.0	20.0	920	177	$10,764	$1,275	*$12,039*
		0	0.00	0.0	0.0					
		0	0.00	0.0	0.0					
	Subtotal - Air & Liquid Distributors					920	177	$10,764	$1,275	***$12,039***

Media (installation only)

WBS	Description	Qty	Type	Long	Wide/Ø	Deep	CF	MH	MH @ $61	M&CE $	TOTAL
19	*Filter GAC media replacement # 1*	0	0.00	23.0	20.0	7.0					
19	*Filter GAC media replacement # 2*	0	0.00	23.0	20.0	7.0					
19	*Filter GAC media replacement # 3*	0	0.00	23.0	20.0	7.0					
0	*0*	0	0.00	0.0	0.0	0.0					
71	*Filter GAC media replacement # 4*	0	0.00	23.0	20.0	7.0					
0	*0*	0	0.00	0.0	0.0	0.0					
62	*New GAC filter cells*	2	2.50	23.0	20.0	7.0	6,440	516	$31,322	$7,090	*$38,411*
0	*0*	0	0.00	0.0	0.0	0.0					
0	*0*	0	0.00	0.0	0.0	0.0					
	Subtotal - Media						6,440	516	$31,322	$7,090	***$38,411***

Media Supports (installation only)

WBS	Description	Qty	Type	Long	Wide/Ø	GAL/Minute	MH	MH @ $61	M&CE $	TOTAL
19	*Filter GAC media replacement # 1*	0	0.00	23.0	20.0					
19	*Filter GAC media replacement # 2*	0	0.00	23.0	20.0					
19	*Filter GAC media replacement # 3*	0	0.00	23.0	20.0					
0	*0*	0	0.00	0.0	0.0					
71	*Filter GAC media replacement # 4*	0	0.00	23.0	20.0					
0	*0*	0	0.00	0.0	0.0					
62	*New GAC filter cells*	2	0.75	23.0	20.0	920	219	$13,336	$2,504	*$15,839*
0	*0*	0	0.00	0.0	0.0					
0	*0*	0	0.00	0.0	0.0					
	Subtotal - Media Supports					920	219	$13,336	$2,504	***$15,839***

General Allowances

This summary category is intended to provide coverage of the minor DIV 15 mechanical, piping, and/or related work items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the scope items in the "Process & Mechanical EQ Installation" section above.***

WBS		MH	MH @ $61	M&CE $	TOTAL
2	**Subtotal - General Allowances**	99	$6,043	$5,127	***$11,170***

Mechanical Installation Total

	MH	MH @ $61	M&CE $	TOTAL
DIV 15 TOTAL	9,368	$569,182	$1,343,963	***$1,913,145***

MWH CONSTRUCTORS

DIVS 16-17 (25-28 & 33) ELECTRICAL INSTALLATION

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

Raceway System Material 1	Rigid Galv Steel (RGS)	50%	*Tagging & Labeling*	Standard (plastic & 316SS)
Raceway System Material 2	Sch 80 PVC	25%	*Site Lighting Units*	30' FRP Pole w/ Base-400W-LED
Raceway System Material 3	PVC Coated RGS	15%	*Typical Motor Efficiency*	90% (average)
Raceway System Material 4	Electric Metallic Tubing	10%	*Local Power Factor*	0.80 (anticipated)
Raceway System Material 5			*1Ø Controls Voltage*	120V
Local/Field Switches	HOA (motor & CV) & Disconnects		*3Ø Low Voltage*	480V
Equipment Installed	All Electrical Gear & Equipment		*3Ø Medium Voltage*	4.16KV
Grounding & Lightning	EQ & Structures		*3Ø High Voltage*	15KV
Pipe & EQ Heat-Tracing			*General Allowances*	Low

Electrical Installation Scope

Process Equipment Installation Summary

Breakdown of this section's subtotal by all the major equipment scope items is provided in the DIVS 11-17 PROCESS EQUIPMENT sheets

WBS	Description *(NIS = not in scope)*	Qty	Type	%	MH	MH @ $59	M&CE $	TOTAL
	Rigging & Setting Allowance	1	1.00		537	$31,842	$7,337	*$39,179*
0	*Wiring & Switching Allowance*	1	1.00		3,204	$189,899	$765,779	*$955,677*
0	*Grounding & Lightning Allowance*	1	6.00		1,359	$80,546	$48,952	*$129,498*
0	*Piping Heat-Trace NIS*	0	0.00	0%				
0	*Tagging & Labeling Allowance*	1			66	$3,933	$2,067	*$6,000*
	Subtotal - Process Equipment Installation Summary				5,167	$306,221	$824,134	***$1,130,354***

DIVS 5-8 Flat Roof Structure Electrical, Lighting, HVAC, & Fire Protection

WBS	Description	Qty	Type	Floors	A-Level	Scope	SF	MH	MH @ $59	M&CE $	TOTAL
62	*New FILT gallery area (services only)*	1	6	1	1.00	1.00	400	88	$5,212	$4,674	*$9,886*
60	*New OZ gallery area (services only)*	1	6	1	1.00	1.00	1,073	257	$15,223	$14,855	*$30,078*
59	*New ACT gallery area (services only)*	1	6	1	1.00	1.00	228	50	$2,971	$2,664	*$5,635*
59	*New ACT building (50% of full size)*	1	6	1	1.00	1.00	181	39	$2,324	$2,057	*$4,381*
0	*0*	0	0	0	0.00	0.00					
0	*0*	0	0	0	0.00	0.00					
	Subtotal - DIVS 5-8 Flat Roof Electrical						1,882	434	$25,730	$24,250	***$49,980***

Miscellaneous Work Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $59	M&CE $	TOTAL
14	*Replace & test CHEM polymer PLC-LS*	1	1	24.0	$240	1	24	$1,422	$240	*$1,662*
16	*Replace & test ACT master PLC-LS*	1	1	80.0	$800	1	80	$4,741	$800	*$5,541*
28	*Install O3 gen exit emergency stops-LS/EA*	1	2	16.0	$1,200	2	32	$1,897	$2,400	*$4,297*
33	*Replace ACT outlets with GFI's-LS/EA*	1	8	1.0	$50	8	8	$474	$400	*$874*
35	*Replace CHEM outlets with GFI's-LS/EA*	1	8	1.0	$50	8	8	$474	$400	*$874*
39	*Replace FILT outlets with GFI's-LS/EA*	1	16	1.0	$50	16	16	$948	$800	*$1,748*
52	*Install FWPS cable tray bracing-LS*	1	1	48.0	$2,400	1	48	$2,845	$2,400	*$5,245*
11	*Install new system BU power wiring-LS*	1	1	480	$60,000	1	480	$28,448	$60,000	*$88,448*
20	*Install new wiring at existing FILT-LS*	1	1	400	$50,000	1	400	$23,707	$50,000	*$73,707*
81	*Upgrade ACT bldg/gallery HVAC-SF*	577	1	0.023	$3.28	577	14	$801	$1,892	*$2,693*
83	*Upgrade FILT bldg/gallery HVAC-SF*	756	1	0.023	$3.28	756	18	$1,050	$2,481	*$3,531*
84	*Upgrade FWPS SWGR room HVAC-SF*	1,425	1	0.023	$3.28	1,425	33	$1,979	$4,676	*$6,655*
86	*Upgrade OZ bldg stairwell HVAC-SF*	183	1	0.023	$3.28	183	4	$254	$599	*$852*

DIVS 16-17 (25-28 & 33) ELECTRICAL INSTALLATION

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

89	*Upgrade WWEQ bldg/room HVAC-SF*	611	1	0.023	$3.28	611	14	$849	$2,006	*$2,855*
91	*Replace MISC security camera/comp-LS*	1	1	24	$7,500	1	24	$1,422	$7,500	*$8,922*
79	*Install larger LOX rental tank-LS*	1	1	60	$3,000	1	60	$3,556	$3,000	*$6,556*
94	*Install CHEM area roll-up motor op-LS*	1	1	8	$600	1	8	$474	$600	*$1,074*
94	*CHEM bldg elect mods for space-LS*	1	1	40	$5,000	1	40	$2,371	$5,000	*$7,371*

	MH	MH @ $59	M&CE $	TOTAL
Subtotal - Miscellaneous Work Allowances	1,311	$77,713	$145,193	***$222,906***

Demolition & Disposal Allowances

WBS	Description	Qty	Each	Unit MH	Unit M&CE $	Total Units	MH	MH @ $59	M&CE $	TOTAL
70	*Remove SOL thicken drive power/control-L*	1	1	33.2	$1,320	1	33	$1,968	$1,320	*$3,288*
17	*Remove ACT sample pump elect-LS/EA*	1	2	8.0	$317	2	16	$948	$634	*$1,582*
22	*Remove FWPS VFD & elect-300 hp-LS*	1	1	17.6	$670	1	18	$1,043	$670	*$1,713*
22	*Remove FWPS VFD & elect-500 hp-LS/EA*	1	2	22.6	$862	2	45	$2,679	$1,724	*$4,403*
69	*Remove ACT flash mix pump elect/I&C-LS/*	1	2	30.2	$1,240	2	60	$3,580	$2,481	*$6,060*
72	*Remove DEW xfer pump elect/I&C-LS/EA*	1	2	35.0	$1,438	2	70	$4,149	$2,876	*$7,025*
9	*Remove FWPS 4 MGD pump elect/I&C-LS/*	1	1	40.1	$1,653	1	40	$2,377	$1,653	*$4,030*
63	*Remove FWPS 7.5 MGD pump elect/I&C-L*	1	3	52.8	$2,304	3	159	$9,394	$6,912	*$16,306*
65	*Remove RWPS 7.5 MGD pump elect/I&C-L*	1	2	29.0	$1,382	2	58	$3,438	$2,764	*$6,202*
15	*Remove 2 gph CHEM pump elect-LS/EA*		5	4.2	$207					
15	*Remove 6 gph CHEM pump elect-LS/EA*		3	4.3	$207					
15	*Remove 39 gph CHEM pump elect-LS/EA*		6	4.6	$224					
15	*Remove 77 gph CHEM pump elect-LS/EA*		3	4.9	$241					
15	*Remove 1" CHEM flush valve-LS/EA*		17	1.1	$52					
68	*Remove 2 gph CHEM pump elect-LS/EA*		5	4.2	$207					
68	*Remove 6 gph CHEM pump elect-LS/EA*		3	4.3	$207					
68	*Remove 39 gph CHEM pump elect-LS/EA*		6	4.6	$224					
68	*Remove 77 gph CHEM pump elect-LS/EA*		3	4.9	$241					
68	*Remove 1" CHEM flush valve elect-LS/EA*		17	1.1	$52					
10	*Remove existing SWGR & wiring-LS*	1	1	614	$14,974	1	614	$36,414	$14,974	*$51,388*
11	*Remove existing system BU power wiring-L*	1	1	240	$3,600	1	240	$14,224	$3,600	*$17,824*
12	*Remove existing 1mW genset system-LS*	1	1	273	$3,911	1	273	$16,168	$3,911	*$20,079*
20	*Remove existing FILT wiring-LS*	1	1	200	$3,000	1	200	$11,853	$3,000	*$14,853*
81	*Remove ACT bldg/gallery HVAC items-SF*	577	1	0.009	$0.66	577	5	$320	$378	*$699*
83	*Remove FILT blower room HVAC items-SF*	756	1	0.009	$0.66	756	7	$420	$496	*$916*
84	*Remove FWPS SWGR room HVAC items-S*	1,425	1	0.009	$0.66	1,425	13	$792	$935	*$1,727*
86	*Remove OZ bldg stairwell HVAC items-SF*	183	1	0.009	$0.66	183	2	$101	$120	*$221*

DIVS 16-17 (25-28 & 33) ELECTRICAL INSTALLATION

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

89	*Remove WWEQ bldg/room HVAC items-SF*	611	1	0.009	$0.66	611	6	$340	$401	*$741*
79	*Remove smaller LOX rental tank-LS*	1	1	30	$750	1	30	$1,778	$750	*$2,528*
93	*Remove un-used CHEM NaOCl elect-LS*	1	1	16	$400	1	16	$948	$400	*$1,348*
78	*Remove SITE light-20' pole (G)-LS/EA*	1	10	4	$88	10	35	$2,087	$880	*$2,968*
78	*Remove SITE light-10' pole (F)-LS/EA*	1	9	2	$59	9	21	$1,252	$528	*$1,781*
78	*Remove SITE light-Wall (E)-LS/EA*	1	13	3	$78	13	41	$2,412	$1,017	*$3,430*
94	*Remove CHEM NH3 equip elect.I&C-LS*	1	1	24	$600	1	24	$1,422	$600	*$2,022*
94	*CHEM bldg elect mods for space-LS*	1	1	16	$400	1	16	$948	$400	*$1,348*
	Subtotal - Demolition & Disposal Allowances						2,043	$121,057	$53,426	***$174,483***

Site Lighting Units

WBS	Description	Qty	Type	Watts	MH	MH @ $59	M&CE $	TOTAL
59	*New ACT flow channel & gallery topside*	6	12.0	360	141	$8,350	$20,059	*$28,408*
			0.0					
60	*New OZ flow channel & gallery topside*	8	12.0	480	188	$11,133	$26,745	*$37,878*
		0	0.0					
61	*New SOL thickener*	2	12.0	120	47	$2,783	$6,686	*$9,469*
		0	0.0					
62	*New FILT cells & gallery topside*	5	12.0	300	117	$6,958	$16,716	*$23,674*
		0	0.0					
78	*Light pole head LED upgrade-20'-175W (G)*	10	20.0	600	88	$5,218	$12,138	*$17,356*
78	*Lightpole head LED upgrade-10'-70W (F)*	9	12.0	540	53	$3,131	$7,522	*$10,653*
78	*Wallpak replacement to LED-70W (E)*	13	4.0	975	102	$6,030	$16,729	*$22,759*
		0	0.0					
		0	0.0					
	Subtotal - Site Lighting Units			3,375	736	$43,603	$106,594	***$150,198***

General Allowances

This summary category is intended to provide coverage of the minor DIVS 16-17 electrical, wiring, and/or related work items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the scope items in the "Divs 11-17 Process Equipment" installation section above.***

WBS		MH	MH @ $59	M&CE $	TOTAL
2	**Subtotal - General Allowances**	143	$8,494	$9,552	***$18,046***

Electrical Installation Total

	MH	MH @ $59	M&CE $	TOTAL
DIVS 16-17(i) TOTAL	9,834	$582,818	$1,163,149	***$1,745,966***

MWH CONSTRUCTORS

DIVS 16-17 (25-28 & 33) ELECTRICAL EQUIPMENT

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Assumptions

480V EQ Rating	NEMA 1 Gasketed (Std)	*120V EQ Rating*	NEMA 12 (Std)
4.16KV EQ Rating	NEMA 1 Gasketed (Std)	*Process Controls EQ*	Utilization of Existing SCADA
15KV EQ Rating	NEMA 1 Gasketed (Std)	*Site Controls EQ*	
SWBRD Main Breakers	All Voltages - (1) Main Only	*Process & Site Controls*	Local Monitor & Control Only
MCC Main Breakers	All Voltages - (1) Main Only	*Power/Controls Siting*	Centralized
Walk-IN SWBRD & MCC		*General Allowances*	Add-On to Existing System

Electrical Equipment Scope

120V Power Equipment

WBS	Description *(NIS = not in scope)*	Qty	AMP	MH	MH @ $59	M&CE $	EQ $	TOTAL
0	*PNLBRD (panelboard) Package with Main Breaker - NIS*	0	0					
0	*ON-OFF Local Control Switches - NIS*	0						
3	*HAND-OFF-AUTO Local Control Switches*	65		481	$28,483	$43,025	$4,993	*$76,501*
0	*LCP (local control panel) Components - NIS*	0						
0	*Fabrication, Assembly, Testing, & Enclosure(s) - NIS*	0						
0	*Engineering & Testing - NIS*	0						
0	*Lightning & Surge Protection Devices - NIS*	0						
	Subtotal - 120V Power Equipment			481	$28,483	$43,025	$4,993	***$76,501***

480V Power Equipment

WBS	Description *(NIS = not in scope)*	Qty	AMP	KW	MH	MH @ $59	M&CE $	EQ $	TOTAL
10	*PNLBRD (panelboard) Package with Main Breaker - NIS*								
0	*GENSET Package with ATS, Integral Fuel System, & Noise Enclosure - NIS*	0						$0	
0	*GENSET Paralleling Gear Package - NIS*	0							
10	*SWBRD (switchboard) Package & Main Breaker(s) Allowance*	1			275	$16,301	$15,237	$148,800	*$180,338*
10	*MCC (motor control center) Package & Main Breaker(s) Allowance - 22 section(s)*	1			487	$28,860	$21,581	$329,300	*$379,741*
10	*XFRMR (transformer) Package & Main Breaker Allowance - 90 KVA*	1			81	$4,820	$3,605	$5,300	*$13,725*
10	*Metering, Monitoring, & Communication Device Allowance*	1						$13,600	*$13,600*
10	*Lightning & Surge Protection Device Allowance*	1						$6,800	*$6,800*
10	*Integration Allowance (i.e. this power & control equipment to existing)*	1			63	$3,749	$3,032	$18,100	*$24,880*
	Subtotal - 480V Power Equipment				907	$53,729	$43,455	$521,900	***$619,084***

4.16KV Power Equipment

WBS	Description *(NIS = not in scope)*	Qty	KW	MH	MH @ $59	M&CE $	EQ $	TOTAL
0	*GENSET Package with ATS, Integral Fuel System, & Noise Enclosure - NIS*	0					$0	
0	*GENSET Paralleling Gear Package - NIS*	0						
10	*SWBRD (switchboard) Package & Main Breaker(s) Allowance*	1		187	$11,098	$11,412	$92,100	*$114,610*
10	*MCC (motor control center) Package & Main Breaker(s) Allowance - 2 section(s)*	1		190	$11,260	$9,262	$116,800	*$137,322*
10	*XFRMR (transformer) Package & Main Breaker Allowance - 5000 KVA*	1		407	$24,101	$19,825	$277,500	*$321,426*
10	*Metering, Monitoring, & Communication Device Allowance*	1					$13,700	*$13,700*
10	*Lightning & Surge Protection Device Allowance*	1					$6,800	*$6,800*
10	*Integration Allowance (i.e. this power & control equipment to existing)*	1		59	$3,484	$3,037	$18,200	*$24,722*
	Subtotal - 4.16KV Power Equipment			843	$49,944	$43,536	$525,100	***$618,580***

15KV Power Equipment

WBS	Description *(NIS = not in scope)*	Qty	KW	MH	MH @ $59	M&CE $	EQ $	TOTAL
12	*GENSET Package with ATS, Integral Fuel System, & Noise Enclosure*	1	2,000	671	$39,766	$29,737	$1,278,200	*$1,347,704*
0	*GENSET Paralleling Gear Package - NIS*	0						
10	*SWBRD (switchboard) Package & Main Breaker(s) Allowance*	1		230	$13,645	$15,306	$103,800	*$132,752*
0	*MCC (motor control center) Package & Main Breaker(s) - NIS*	0						
	XFRMR (transformer) Package & Main Breaker - NIS							
10	*Metering, Monitoring, & Communication Device Allowance*	1					$38,900	*$38,900*
10	*Lightning & Surge Protection Device Allowance*	1					$19,400	*$19,400*
10	*Integration Allowance (i.e. this power & control equipment to existing)*	1		68	$4,006	$3,378	$51,800	*$59,184*
	Subtotal - 15KV Power Equipment			969	$57,418	$48,422	$1,492,100	***$1,597,939***

DIVS 16-17 (25-28 & 33) ELECTRICAL EQUIPMENT

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Date	Estimator	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	30-Nov-17	Jim Ward	002	30503765

Process Controls Equipment

WBS	Description *(NIS = not in scope)*	Qty	MH	MH @ $59	M&CE $	EQ $	TOTAL
3	*Process Control System, HMI, RTU, & Software Package Allowance*	1	832	$49,297	$38,297	$41,655	*$129,249*
3	*Fabrication, Assembly, Testing, & Indoor (coated steel) Enclosure(s)*	1				$67,325	*$67,325*
3	*Engineering, Programming, Testing, & Training Allowance*	1				$33,325	*$33,325*
3	*UPS, RTU, Antenna, Lightning, & Surge Protection Device Allowance*	1				$12,500	*$12,500*
3	*Integration Allowance (i.e. this process control system to existing)*	1	62	$3,697	$2,872	$3,100	*$9,670*
	Subtotal - Process Controls Equipment		894	$52,994	$41,169	$157,905	***$252,069***

Site Controls Equipment

WBS	Description *(NIS = not in scope)*	Qty	MH	MH @ $0	M&CE $	EQ $	TOTAL
0	*Health & Safety System Components Package - NIS*	0					
0	*Security System Components Package - NIS*	0					
0	*Surveillance System Components Package - NIS*	0					
0	*Remote Transmittance Components Package - NIS*	0					
0	*Fabrication, Assembly, Testing, & Indoor (coated steel) Enclosure(s)*	0					
0	*Engineering, Programming, Testing, & Training - NIS*	0					
0	*UPS, RTU, Antenna, Lightning, & Surge Protection Devices - NIS*	0					
0	*Integration - NIS*	0					
	Subtotal - Site Controls Equipment						

General Allowances

This summary category is intended to provide coverage of the minor DIVS 16-17 electrical equipment and/or related work items that could be needed but are currently either too small to consider or cannot yet be quantified. ***NOTE: The absence of an assigned WBS code below indicates this allowance cost is being allocated across the identified scope items above when these DIV costs are exported to other worksheets.***

WBS		MH	MH @ $59	M&CE $	EQ $	TOTAL
2	**Subtotal - General Allowances**	26	$1,516	$1,373	$16,887	***$19,776***

Electrical Equipment Total

	MH	MH @ $59	M&CE $	EQ $	TOTAL
DIVS 16-17(e) TOTAL	4,118	$244,084	$220,979	$2,718,885	***$3,183,949***

DIVS 11-17 (40-45) PROCESS EQUIPMENT

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Date	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	30-Nov-17	002	30503765

Equipment Scope

DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item (NIS-not in scope)	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
	New GEN 2MW Genset											
12	*2X wall diesel tank package-40K gallon*	1	$55,000	92	$5,603	$22,516	$28,119					
12	*Ultrasonic level LIT*	1		10	$607	$482	$1,089	$1,600				
12	*120 VAC power & signal*	1							20	$1,164	$3,134	$4,298
	New SOL Thickener											
61	*Thickener structure-35' Ø (divs 2,3,5)*	1		172	$10,460	$50,222	$60,681					
61	*Power & control connectivity*	1							71	$4,221	$11,360	$15,581
61	*Thickener mechanism & weirs*	1	$130,000	125	$7,591	$6,021	$13,612					
61	*LCP*	1							49	$2,911	$7,834	$10,745
61	*480 VAC power (1 hp)*	1							31	$1,834	$4,936	$6,770
61	*10" PV-motorized-sludge blowdown*	1	$6,500	23	$1,374	$5,080	$6,454					
61	*120 VAC power & signal*	1							20	$1,164	$3,134	$4,298
	Replace SOL Thickener Drive											
70	*Thickener drive assembly*	1	$20,000	33	$2,024	$1,606	$3,630					
70	*LCP*	1							49	$2,911	$7,834	$10,745
70	*480 VAC power (1 hp)*	1							31	$1,834	$4,936	$6,770
	New FILT Cells (2)											
62	*Structure-68' x 25' (divs 2,3,5)*	1		229	$13,886	$66,674	$80,560					
62	*Power & control connectivity*	1							95	$5,604	$15,081	$20,685
62	*Control console/panel (1 per 2 cells)*	1	$70,100									
62	*Underdrain & air pipe-23' x 20'-460 SF (div 15*	2	$138,000									
62	*Sand media-460 SF-12" deep (div 15)*	2	$9,200									
62	*GAC media-460 SF-72" deep (div 15)*	2	$193,200									
62	*FRP trough assemblies-3 @ 20 LF*	2	$30,000	58	$3,542	$2,810	$6,352					
62	*Ultrasonic level LIT*	2		20	$1,214	$963	$2,178	$3,200				
62	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
62	*Diff pressure DPIT (pipe mount w/ valves)*	2		23	$1,374	$5,080	$6,454	$7,000				
62	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
62	*Turbidity AIT (pipe mount w/ valves)*	2		23	$1,374	$5,080	$6,454	$10,000				
62	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
62	*Particle counter AIT (pipe mount w/ valves)*	2		23	$1,374	$5,080	$6,454	$13,000				
62	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
62	*HC C/C sample pump-3 gpm @ 15' (1+0)*	1	$1,500	20	$1,237	$4,572	$5,809					
62	*120 VAC power*	1							20	$1,164	$3,134	$4,298
62	*30" BFV-motorized-WW*	2	$31,000	122	$7,422	$27,430	$34,851					
62	*480 VAC power (1 hp)*	2							55	$3,260	$8,774	$12,035
62	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
	EQ SHEET TOTAL		**$684,500**	972	$59,084	$203,613	**$262,697**	**$34,800**	622	$36,838	$99,143	**$135,982**
	TOTAL: ALL DIVS 11-17 EQ SHEETS		**$5,297,485**	5,636	$342,423	$1,188,679	**$1,531,102**	**$1,126,450**	5,167	$306,221	$824,134	**$1,130,354**

DIVS 11-17 (40-45) PROCESS EQUIPMENT

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Date	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	30-Nov-17	002	30503765

Equipment Scope

	DIVS 11-17 EQ & Related Components		*DIVS 11-15 EQ Buyout*	*DIV 15 EQ & Piping Installation*				*DIVS 16-17 EQ Buyout*	*DIVS 16-17 Power and I&C Installation*			
WBS	Item *(NIS-not in scope)*	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
62	*24" BFV-motorized-BW*	2	$22,000	109	$6,597	$24,382	$30,979					
62	*480 VAC power (0.5 hp)*	2							55	$3,260	$8,774	$12,035
62	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
62	*20" BFV-motorized-FI*	2	$20,000	95	$5,773	$21,334	$27,107					
62	*480 VAC power (0.5 hp)*	2							55	$3,260	$8,774	$12,035
62	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
62	*20" BFV-motorized-FE*	2	$20,000	95	$5,773	$21,334	$27,107					
62	*480 VAC power (0.5 hp)*	2							55	$3,260	$8,774	$12,035
62	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
62	*10" BFV-motorized-AW*	2	$13,000	45	$2,749	$10,159	$12,908					
62	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
	New FILT Media # 1											
19	*Sand media-460 SF-12" deep (div 15)*											
19	*GAC media-460 SF-72" deep (div 15)*											
	New FILT Media # 2											
19	*Sand media-460 SF-12" deep (div 15)*											
19	*GAC media-460 SF-72" deep (div 15)*											
	New FILT Media # 3											
19	*Sand media-460 SF-12" deep (div 15)*											
19	*GAC media-460 SF-72" deep (div 15)*											
	New FILT Media # 4											
71	*Sand media-460 SF-12" deep (div 15)*											
71	*GAC media-460 SF-72" deep (div 15)*											
	New OZ Channel & Gallery Structure											
60	*Structure-74' x 25½' (divs 2,3,5)*	1		243	$14,788	$71,003	$85,791					
60	*Power & control connectivity*	1							101	$5,968	$16,060	$22,028
60	*Ozone diffusers-SS*	4	$8,000	74	$4,483	$18,013	$22,495					
60	*Pressure PIT (pipe mount w/ valve)*	2		11	$687	$2,540	$3,227	$2,800				
60	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
60	*Diff pressure DPIT (pipe mount w/ valves)*	2		23	$1,374	$5,080	$6,454	$7,000				
60	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
60	*Demister unit*	2	$3,000	11	$687	$2,540	$3,227					
60	*Ozone concentration meter*	8		53	$3,239	$2,569	$5,808	$20,000				
60	*120 VAC power & signal*	8							157	$9,315	$25,070	$34,385
60	*Ozone concentration meter*	8		53	$3,239	$2,569	$5,808	$20,000				
60	*120 VAC power & signal*	8							157	$9,315	$25,070	$34,385
	EQ SHEET TOTAL		**$86,000**	813	$49,388	$181,522	**$230,910**	**$49,800**	772	$45,731	$123,077	**$168,809**

MWH CONSTRUCTORS

DIVS 11-17 (40-45) PROCESS EQUIPMENT

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Date	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	30-Nov-17	002	30503765

Equipment Scope

DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item *(NIS-not in scope)*	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
60	*Pressure PIT (pipe mount w/ valve)*	2		11	$687	$2,540	$3,227	$2,800				
60	*120 VAC power & signal*	2							39	$2,329	$6,267	$8,596
60	*Ozone destruct skid unit*	2	$50,000	90	$5,498	$20,318	$25,816					
60	*LCP*	2							49	$2,911	$7,834	$10,745
60	*480 VAC power*	2							96	$5,706	$15,355	$21,061
	New ACT Channel & Gallery											
59	*Structure-70.34' x 19' (divs 2,3,5)*	1		220	$13,345	$64,076	$77,421					
59	*Power & control connectivity*	1							91	$5,385	$14,494	$19,879
59	*Ultrasonic level LIT*	1		10	$607	$482	$1,089	$1,600				
59	*120 VAC power & signal*	1							20	$1,164	$3,134	$4,298
59	*High/Low safety float switch assembly*	1						$350	25	$1,455	$3,917	$5,373
59	*Vendor Actiflo package-1x10 MGD unit*	1	$800,000									
59	*Injection chamber vertical mixer*	1		17	$1,012	$803	$1,815					
59	*480 VAC power*	1							38	$2,241	$6,032	$8,274
59	*120 VAC signal*	1							12	$728	$1,959	$2,686
59	*VFD (7.5 hp)*	1						$6,000	17	$1,019	$2,741	$3,760
59	*Anti-vortex baffle assemblies*	1		17	$1,012	$803	$1,815					
59	*Coag chamber vertical mixer*	1		17	$1,012	$803	$1,815					
59	*480 VAC power*	1							38	$2,241	$6,032	$8,274
59	*120 VAC signal*	1							12	$728	$1,959	$2,686
59	*VFD (7.5 hp)*	1						$6,000	17	$1,019	$2,741	$3,760
59	*Anti-vortex baffle assemblies*	1		17	$1,012	$803	$1,815					
59	*Maturation chamber vertical mixer*	1		23	$1,417	$1,124	$2,541					
59	*480 VAC power*	1							41	$2,445	$6,581	$9,026
59	*120 VAC signal*	1							12	$728	$1,959	$2,686
59	*VFD (10 hp)*	1						$7,000	17	$1,019	$2,741	$3,760
59	*Anti-vortex baffle assemblies*	1		25	$1,518	$1,204	$2,722					
59	*19' Ø scraper assemblies*	1		78	$4,757	$3,773	$8,530					
59	*480 VAC power*	1							34	$2,038	$5,484	$7,522
59	*120 VAC signal*	1							12	$728	$1,959	$2,686
59	*VFD (3 hp)*	1						$5,000	11	$679	$1,828	$2,507
59	*Lamella tube module & support sets*	1		37	$2,227	$1,766	$3,993					
59	*Overflow trough & support sets*	1		50	$3,036	$2,409	$5,445					
59	*Hydrocyclone assemblies-3" (2+1)*	3		54	$3,299	$12,191	$15,490					
59	*½" flush water solenoid & FS assembly*	3		28	$1,681	$6,755	$8,436					
59	*120 VAC power & signal*	3							59	$3,493	$9,401	$12,894
59	*LCP*	1							123	$7,277	$19,586	$26,863
59	*3' x 3' gates-motorized-SS-influent & effluent*	2	$28,000	65	$3,947	$3,131	$7,078					
59	*480 VAC power (0.5 hp)*	2							48	$2,853	$7,678	$10,530
59	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
	EQ SHEET TOTAL		**$878,000**	758	$46,067	$122,980	**$169,047**	**$28,750**	838	$49,641	$133,599	**$183,240**

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DIVS 11-17 (40-45) PROCESS EQUIPMENT

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Equipment Scope

DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item (NIS-not in scope)	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
59	*30" BFV-motorized-effluent*	1	$15,500	61	$3,711	$13,715	$17,426					
59	*480 VAC power (1 hp)*	1							28	$1,630	$4,387	$6,017
59	*120 VAC signal*	1							12	$728	$1,959	$2,686
59	*HC sand/sludge xfer pump-155 gpm @ 70' (1*	2		162	$9,862	$39,628	$49,489					
59	*480 VAC power (10 hp)*	2							76	$4,483	$12,065	$16,548
59	*120 VAC signal*	4							40	$2,364	$6,363	$8,728
59	*PS & PI assembly (pipe mount w/ valve)*	2		7	$412	$1,524	$1,936	$1,500				
59	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
59	*½" seal water solenoid assembly*	2		15	$897	$3,603	$4,499	$500				
59	*120 VAC power*	2							15	$873	$2,350	$3,224
59	*½" seal water FS*	2		5	$275	$1,016	$1,291	$200				
59	*120 VAC FS signal*	2							5	$291	$783	$1,075
59	*HC C/C sample pump-3 gpm @ 15' (1+0)*	1	$1,500	20	$1,237	$4,572	$5,809					
59	*120 VAC power*	1							20	$1,164	$3,134	$4,298
59	*pH & temperature AIT*	1	$1,200	5	$304	$241	$544					
59	*120 VAC power & signal*	1							20	$1,164	$3,134	$4,298
59	*Turbidity AIT (pipe mount w/ valves)*	1		11	$687	$2,540	$3,227	$5,000				
59	*120 VAC power & signal*	1							20	$1,164	$3,134	$4,298
	Upgrade CHEM Polymer PLC											
14	*Vendor programmed PLC replacement*	1	$7,500									
	Upgrade ACT System PLC											
16	*Vendor programmed PLC replacement*	1	$20,000									
	Replace ACT Sample Pumps											
17	*HC C/C sample pump-3 gpm @ 15' (1+0)*	2	$3,000	30	$1,822	$1,445	$3,267					
17	*120 VAC power*	2							39	$2,329	$6,267	$8,596
	Replace FWPS VFD Units											
22	*VFD (300 hp)-free standing-NEMA 4X*	1						$92,500	40	$2,377	$6,396	$8,773
22	*VFD (500 hp)-free standing-NEMA 4X*	2						$205,000	103	$6,111	$16,448	$22,559
	Add CHEM Door Panic Hardware (3)											
25	*Panic hardware package*	3	$2,925									
	Reverse Opening Direction to (1) Door											
26	*Replacement door hardware*	1	$1,200									
	Add ACT Door Panic Hardware (1)											
31	*Panic hardware package*	2	$1,950									
	Add FWPS Door Panic Hardware (1)											
40	*Panic hardware package*	2	$1,950									
	Add CHEM Exit Door ContainTrays											
27	*SS overhead chem pipe trays w/ drain-4' x 4'*	2	$1,795									
	EQ SHEET TOTAL		**$58,520**	316	$19,206	$68,282	**$87,488**	**$304,700**	441	$26,135	$70,338	**$96,473**

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DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item *(NIS-not in scope)*	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
	Install New CHEM Ozone Generator											
58	*Ozone generator skid package-400 PPD*	1	$400,000	258	$15,689	$63,044	$78,733					
58	*LCP*	1							74	$4,366	$11,752	$16,118
58	*480 VAC power*	1							58	$3,464	$9,323	$12,787
	Procure ACT Shelf Spare Pump											
6	*HC solids pump-155 gpm @ 70'-10 hp*	1	$18,500									
	Install 2nd ACT Flash Mix Pump											
7	*HC flash mix pump-1,000 gpm @ 16' (1+1)*	1	$27,500	68	$4,123	$15,239	$19,362					
7	*480 VAC power (7.5 hp)*	1							38	$2,241	$6,032	$8,274
7	*120 VAC signal*	2							16	$960	$2,584	$3,545
7	*PS & PI assembly (pipe mount w/ valve)*	1		3	$206	$762	$968	$750				
7	*120 VAC signal*	1							12	$728	$1,959	$2,686
7	*½" seal water solenoid assembly*	1		7	$448	$1,801	$2,250	$250				
7	*120 VAC power*	1							7	$437	$1,175	$1,612
7	*½" seal water FS*	1		2	$137	$508	$645	$100				
7	*120 VAC FS signal*	1							2	$146	$392	$537
	Replace ACT Flash Mix Pumps											
69	*HC flash mix pump-1,000 gpm @ 16' (1+1)*	2	$55,000	136	$8,247	$30,477	$38,724					
69	*480 VAC power (7.5 hp)*	2							76	$4,483	$12,065	$16,548
69	*120 VAC signal*	4							32	$1,921	$5,169	$7,089
69	*PS & PI assembly (pipe mount w/ valve)*	2		7	$412	$1,524	$1,936	$1,500				
69	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
69	*½" seal water solenoid assembly*	2		15	$897	$3,603	$4,499	$500				
69	*120 VAC power*	2							15	$873	$2,350	$3,224
69	*½" seal water FS*	2		5	$275	$1,016	$1,291	$200				
69	*120 VAC FS signal*	2							5	$291	$783	$1,075
	Install Shelf Spare SOL Mix Pump											
8	*HC mix pump-600 gpm @ 6'*	1		68	$4,123	$15,239	$19,362					
8	*480 VAC power (5 hp)*	1							34	$2,038	$5,484	$7,522
8	*120 VAC signal*	2							16	$960	$2,584	$3,545
8	*PS & PI assembly (pipe mount w/ valve)*	1		3	$206	$762	$968	$750				
8	*120 VAC signal*	1							12	$728	$1,959	$2,686
8	*½" seal water solenoid assembly*	1		7	$448	$1,801	$2,250	$250				
8	*120 VAC power*	1							7	$437	$1,175	$1,612
8	*½" seal water FS*	1		2	$137	$508	$645	$100				
8	*120 VAC FS signal*	1							2	$146	$392	$537
	Replace DEW Solids Transfer Pumps											
72	*PC solids transfer pump-60 gpm @ 70'*	2	$30,000	72	$4,398	$16,255	$20,653					
72	*480 VAC power*	2							69	$4,075	$10,968	$15,043
72	*120 VAC signal*	4							32	$1,921	$5,169	$7,089
72	*VFD (5 hp)*	2						$12,000	34	$2,037	$5,483	$7,520
72	*PS & PI assembly (pipe mount w/ valve)*	2		7	$412	$1,524	$1,936	$1,500				
72	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
72	*½" seal water solenoid assembly*	2		15	$897	$3,603	$4,499	$500				
72	*120 VAC power*	2							15	$873	$2,350	$3,224
72	*½" seal water FS*	2		5	$275	$1,016	$1,291	$200				
72	*120 VAC FS signal*	2							5	$291	$783	$1,075
	Replace ACT Settling Tubes											
18	*19' x 19' x 4' deep tube assembly*	2	$90,250									
EQ SHEET TOTAL			**$621,250**	680	$41,331	$158,680	**$200,011**	**$18,600**	613	$36,326	$97,765	**$134,092**

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Equipment Scope

DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item (*NIS-not in scope*)	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
	Replace FWPS 4 MGD Pump with 7.5											
9	*VT HSPS pump-7.5 MGD @ 312'*	1	$320,000	124	$7,559	$27,938	$35,497					
9	*4160 VAC power*	1							69	$4,075	$10,968	$15,043
9	*120 VAC signal*	2							16	$960	$2,584	$3,545
9	*VFD unit (500 hp)*	1						$70,000	52	$3,056	$8,224	$11,280
9	*PS & PI assembly (pipe mount w/ valve)*	1		3	$206	$762	$968	$750				
9	*120 VAC signal*	1							12	$728	$1,959	$2,686
9	*½" seal water solenoid assembly*	1		7	$448	$1,801	$2,250	$250				
9	*120 VAC power*	1							7	$437	$1,175	$1,612
9	*½" seal water FS*	1		2	$137	$508	$645	$100				
9	*120 VAC FS signal*	1							2	$146	$392	$537
9	*4" air/vacuum release assembly*	2	$4,300	14	$825	$3,048	$3,872					
9	*14" BFV-motorized-AW*	1	$7,500	32	$1,924	$7,111	$9,036					
9	*120 VAC power & signal*	1							20	$1,164	$3,134	$4,298
	Replace FWPS 7.5 MGD Pumps with 12											
63	*VT HSPS pump-12 MGD @ 312'*	3	$1,260,000	390	$23,680	$95,156	$118,836					
63	*4160 VAC power*	3							237	$14,060	$37,840	$51,900
63	*120 VAC signal*	6							49	$2,881	$7,753	$10,634
63	*VFD unit (800 hp)*	3						$375,000	206	$12,223	$32,896	$45,118
63	*PS & PI assembly (pipe mount w/ valve)*	3		10	$618	$2,286	$2,904	$2,250				
63	*120 VAC signal*	3							37	$2,183	$5,876	$8,059
63	*½" seal water solenoid assembly*	3		22	$1,345	$5,404	$6,749	$750				
63	*120 VAC power*	3							22	$1,310	$3,525	$4,835
63	*½" seal water FS*	3		7	$412	$1,524	$1,936	$300				
63	*120 VAC FS signal*	3							7	$437	$1,175	$1,612
63	*4" air/vacuum release assembly*	6	$12,900	41	$2,474	$9,143	$11,617					
63	*18" BFV-motorized-AW*	3	$28,500	129	$7,834	$28,953	$36,788					
63	*120 VAC power & signal*	3							59	$3,493	$9,401	$12,894
	Install 5th FWPS 7.5 MGD Pump											
64	*VT HSPS pump-7.5 MGD @ 312'*	1	$320,000	124	$7,559	$27,938	$35,497					
64	*4160 VAC power*	1							69	$4,075	$10,968	$15,043
64	*120 VAC signal*	2							16	$960	$2,584	$3,545
64	*VFD unit (500 hp)*	1						$70,000	52	$3,056	$8,224	$11,280
64	*PS & PI assembly (pipe mount w/ valve)*	1		3	$206	$762	$968	$750				
64	*120 VAC signal*	1							12	$728	$1,959	$2,686
64	*½" seal water solenoid assembly*	1		7	$448	$1,801	$2,250	$250				
64	*120 VAC power*	1							7	$437	$1,175	$1,612
64	*½" seal water FS*	1		2	$137	$508	$645	$100				
64	*120 VAC FS signal*	1							2	$146	$392	$537
64	*4" air/vacuum release assembly*	2	$4,300	14	$825	$3,048	$3,872					
64	*14" BFV-motorized-AW*	1	$7,500	32	$1,924	$7,111	$9,036					
64	*120 VAC power & signal*	1							20	$1,164	$3,134	$4,298
	EQ SHEET TOTAL		**$1,965,000**	964	$58,564	$224,801	**$283,365**	**$520,500**	974	$57,718	$155,337	**$213,055**

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Equipment Scope

DIVS 11-17 EQ & Related Components			*DIVS 11-15 EQ Buyout*	*DIV 15 EQ & Piping Installation*				*DIVS 16-17 EQ Buyout*	*DIVS 16-17 Power and I&C Installation*			
WBS	Item *(NIS-not in scope)*	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
	Replace RWPS 7.5 MGD Pumps with 15											
65	*VT pump-15 MGD @ 107'*	2	$350,000	425	$25,839	$95,495	$121,335					
65	*480 VAC power*	2							131	$7,743	$20,839	$28,583
65	*120 VAC signal*	4							32	$1,921	$5,169	$7,089
65	*VFD unit (400 hp)*	2						$140,000	92	$5,432	$14,620	$20,053
65	*PS & PI assembly (pipe mount w/ valve)*	2		7	$412	$1,524	$1,936	$1,500				
65	*120 VAC signal*	2							25	$1,455	$3,917	$5,373
65	*½" seal water solenoid assembly*	2		15	$897	$3,603	$4,499	$500				
65	*120 VAC power*	2							15	$873	$2,350	$3,224
65	*½" seal water FS*	2		5	$275	$1,016	$1,291	$200				
65	*120 VAC FS signal*	2							5	$291	$783	$1,075
65	*4" air/vacuum release assembly*	2	$4,300	14	$825	$3,048	$3,872					
	Replace CHEM Metering Pumps											
15	*Hydraulic diaphragm meter pump-2 gph*											
15	*480 VAC power (0.5hp)*											
15	*120 VAC signal*											
15	*Hydraulic diaphragm meter pump-6 gph*											
15	*480 VAC power (0.5 hp)*											
15	*120 VAC signal*											
15	*Hydraulic diaphragm meter pump-39 gph*											
15	*480 VAC power (1 hp)*											
15	*120 VAC signal*											
15	*Hydraulic diaphragm meter pump-77 gph*											
15	*480 VAC power (1½ hp)*											
15	*120 VAC signal*											
15	*1" flush water solenoid assembly*											
15	*120 VAC power*											
	Replace CHEM Metering Pumps											
68	*Hydraulic diaphragm meter pump-2 gph*											
68	*480 VAC power (0.5hp)*											
68	*120 VAC signal*											
68	*Hydraulic diaphragm meter pump-6 gph*											
68	*480 VAC power (0.5 hp)*											
68	*120 VAC signal*											
68	*Hydraulic diaphragm meter pump-39 gph*											
68	*480 VAC power (1 hp)*											
68	*120 VAC signal*											
68	*Hydraulic diaphragm meter pump-77 gph*											
68	*480 VAC power (1½ hp)*											
68	*120 VAC signal*											
68	*1" flush water solenoid assembly*											
68	*120 VAC power*											
EQ SHEET TOTAL			**$354,300**	465	$28,248	$104,685	**$132,933**	**$142,200**	299	$17,716	$47,679	**$65,395**

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DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item *(NIS-not in scope)*	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
	Add 3rd Solids Pump & Centrifuge											
66	*PC solids transfer pump-60 gpm @ 70'*	1	$15,000	59	$3,586	$14,410	$17,996					
66	*480 VAC power*	1							34	$2,038	$5,484	$7,522
66	*120 VAC signal*	2							16	$960	$2,584	$3,545
66	*VFD (5 hp)*	1						$6,000	17	$1,019	$2,741	$3,760
66	*PS & PI assembly (pipe mount w/ valve)*	1		3	$206	$762	$968	$750				
66	*120 VAC signal*	1							12	$728	$1,959	$2,686
66	*½" seal water solenoid assembly*	1		7	$448	$1,801	$2,250	$250				
66	*120 VAC power*	1							7	$437	$1,175	$1,612
66	*½" seal water FS*	1		2	$137	$508	$645	$100				
66	*120 VAC FS signal*	1							2	$146	$392	$537
66	*Centrifuge skid package*	1	$450,000	271	$16,493	$60,955	$77,448					
66	*LCP*	1							123	$7,277	$19,586	$26,863
66	*480 VAC power-Main drive*	1							48	$2,853	$7,678	$10,530
66	*480 VAC VFD (40 hp)*	1						$12,000	23	$1,358	$3,655	$5,013
66	*480 VAC power-Backdrive*	1							41	$2,445	$6,581	$9,026
66	*480 VAC VFD (15 hp)*	1						$7,000	17	$1,019	$2,741	$3,760
66	*SS discharge chute & gate assembly*	1	$9,500	40	$2,429	$1,927	$4,356					
66	*120 VAC power*	1							20	$1,164	$3,134	$4,298
66	*1" flush water solenoid assembly*	1		15	$897	$3,603	$4,499	$350				
66	*120 VAC power*	1							7	$437	$1,175	$1,612
66	*2" flush water solenoid assembly*	1		17	$1,009	$4,053	$5,061	$650				
66	*120 VAC power*	1							7	$437	$1,175	$1,612
	EQ SHEET TOTAL		**$474,500**	415	$25,205	$88,018	**$113,223**	**$27,100**	377	$22,316	$60,060	**$82,376**

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Equipment Scope

DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item *(NIS-not in scope)*	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
	Balance of 480V Loads for New MCC's											
	2-MCC-A											
10	*Main*	1										
10	*Vent fans, dewatering pumps, & cooling fans*	5										
	2-DP-B											
10	*Main*	1										
10	*MOV's*	2										
	4-MCC-B											
10	*Main*	1										
10	*Sand pumps*	2										
10	*Mixers*	2										
10	*Mixer*	1										
10	*Destruct unit & MOV's*	2										
10	*Ozone water pump*	1										
10	*4-LP-B*	1										
	6-DP-B											
10	*Main*	7										
10	*MOV's, Xfrmer, & mix pump*	7										
	13-DP-B											
10	*Main*	1										
10	*Ozone generator*	1										
10	*Compressor, poly feeder, fan, MOV, spares*	6										
10	*Admin HVAC*	1										
10	*18-LP-B & 13-LP-B*	2										
	19-MCC-A											
10	*Main*	1										
10	*Recycle pumps, solids pumps, MOV, spares*	7										
10	*Recycle pump, mix pump, thickener*	3										
EQ SHEET TOTAL												

MWH CONSTRUCTORS

DIVS 11-17 (40-45) PROCESS EQUIPMENT

CLASS 4 OPCC - PRIVILEGED & CONFIDENTIAL

Project Name	Location	Estimator	Date	Version	Job #
Willamette River WTP Master Plan	Wilsonville, OR	Jim Ward	30-Nov-17	002	30503765

Equipment Scope

DIVS 11-17 EQ & Related Components			DIVS 11-15 EQ Buyout	DIV 15 EQ & Piping Installation				DIVS 16-17 EQ Buyout	DIVS 16-17 Power and I&C Installation			
WBS	Item *(NIS-not in scope)*	Qty	TOTAL	MH	MH $	M&CE $	TOTAL	TOTAL	MH	MH $	M&CE $	TOTAL
	Additions per 17Nov17 Email											
	Add SWGR Door Panic Hardware (2)											
85	*Panic hardware package*	2	$1,950									
	Add SITE Plate Hatch Fall Protection											
87	*4' x 4' FRP grate protection package*	10	$12,000									
	Add WWEQ Ladder Fall Restraint											
88	*20' ladder fall restraint package*	1	$1,500									
	Add CHEM Meter Pump Strainers											
77	*1½" Ø PVC y-strainers*	17	$2,465									
	Install FILT stairwell Fire Door											
82	*3' x 7' metal fire door*	1	$850									
82	*Magnetic door closer/holder*	1	$150									
	Convert Wet NaOCl System to Dry											
93	*Super sack hoist assembly-3 ton*	1	$4,500	50	$3,036	$2,409	$5,445					
93	*LCP*	1							25	$1,455	$3,917	$5,373
93	*480 VAC power (3 hp)*	1							28	$1,630	$4,387	$6,017
93	*Super sack frame & auger assembly*	1	$17,500	67	$4,048	$3,211	$7,260					
93	*LCP*	1							37	$2,183	$5,876	$8,059
93	*480 VAC power (3 hp)*	1							28	$1,630	$4,387	$6,017
93	*Dry chlorine mix & transfer unit-50 LB/HR*	1	$131,500	104	$6,322	$23,366	$29,688					
93	*LCP*	1							49	$2,911	$7,834	$10,745
93	*480 VAC power*	1							38	$2,241	$6,032	$8,274
93	*2" transfer control valve with pneumatic actua*	2	$3,000	32	$1,924	$7,111	$9,036					
93	*120 VAC power*	2							29	$1,747	$4,701	$6,447
	END											
EQ SHEET TOTAL			**$175,415**	252	$15,331	$36,097	**$51,428**		233	$13,798	$37,135	**$50,933**

VEOLIA COST FACTORING

System Name	Item	Type	Phase	Year In Service	QTY	Veolia Cost Estimate (Total Direct EQ Cost)	JSW Install & Burdens Multiply Factor	JSW OPCC for Installation & Burdens	GRAND TOTAL Veolia Cost + JSW Class 5 OPCC	Estimate Class
Chemical Storage/ Ozone Generation	Confirm Storage durations	Capacity Upgrades	20 MGD	2022						
Chemical Storage/ Ozone Generation	Replace existing chemical lines (Recommend extending utilidoor to southern half of plant. Portion between utilidoors will be run along east wall of WWEQ basin)	Capacity Upgrades	20 MGD	2022						
Chemical Storage/ Ozone Generation	Purchase larger LOX storage tank (12,000 to 15,000 gallons)	Capacity Upgrades	20 MGD	2022	1	$ 175,000	0.500	$ 87,500	$ 262,500	4
Chemical Storage/ Ozone Generation	PLC upgrade on polymer units	Repair & Replace	20 MGD	2022						
Chemical Storage/ Ozone Generation	Chemical metering pump replacement	Repair & Replace	20 MGD	2022						
Chemical Storage/ Ozone Generation	Inspect tanks	Repair & Replace	20 MGD	2022						
Chemical Storage/ Ozone Generation	Replace ozone generators (Recommend upsizing to 400 PPD units)	Repair & Replace	20 MGD	2022	2	$ 960,000	0.8250	$ 792,000	$ 1,752,000	4
Chemical Storage/ Ozone Generation	Provide Seismic bracing of chemical, ozone, and LOX pipes	Seismic Retrofits	20 MGD	2022						
Chemical Storage/ Ozone Generation	Replace faded NFPA signage	Life-Safety Repairs	20 MGD	2022						
Chemical Storage/ Ozone Generation	Provide panic hardware on 3 exterior doors	Life-Safety Repairs	20 MGD	2022						
Chemical Storage/ Ozone Generation	Change swing direction of door between Ozone Generation Room and Admin buildng	Life-Safety Repairs	20 MGD	2022						
Chemical Storage/ Ozone Generation	Add secondary containment pans over exit routes	Life-Safety Repairs	20 MGD	2022						
Chemical Storage/ Ozone Generation	Install emergency shut-off at other two Ozone Generation Room exits	Life-Safety Repairs	20 MGD	2022						
Chemical Storage/ Ozone Generation	Add third ozone generator	Capacity Upgrades	30 MGD	2036						
Chemical Storage/ Ozone Generation	Purchase of second dry polymer feed	Capacity Upgrades	30 MGD	2032	1	$ 50,000	3.800	$ 190,000	$ 240,000	5
Chemical Storage/ Ozone Generation	Chemical metering pump replacement	Repair & Replace	30 MGD	2036						
Chemical Storage/ Ozone Generation	Replace sodium hypochlorite tank	Repair & Replace	30 MGD	2022	1	$ 15,000	2.500	$ 37,500	$ 52,500	4
Chemical Storage/ Ozone Generation	T-05ME01 Evaporator,LOX 1, North	Equipment - Mechanical		2035		$ 37,500	0.500	$ 18,750	$ 56,250	5
Chemical Storage/ Ozone Generation	T-05ME02 Evaporator,LOX 2, South	Equipment - Mechanical		2035		$ 37,500	0.500	$ 18,750	$ 56,250	5
Chemical Storage/ Ozone Generation	T-13T01 Tank,Caustic Soda	Caustic Soda Feed System		2022		$ 15,000	2.500	$ 37,500	$ 52,500	4
Chemical Storage/ Ozone Generation	T-13T04 Tank,Liquid Alum 4	Liquid Alum System		2022		$ 15,000	2.500	$ 37,500	$ 52,500	4
Chemical Storage/ Ozone Generation	T-13T05 Tank,Liquid Alum 5	Liquid Alum System		2022		$ 15,000	2.500	$ 37,500	$ 52,500	4
Actiflo™	Purchase additional shelf spare solid pump	Capacity Upgrades	20 MGD	2022						
Actiflo™	Vendor PLC upgrade	Repair & Replace	20 MGD	2022						
Actiflo™	Replace Solids pumps	Repair & Replace	20 MGD	2022	5	$ 200,000	2.200	$ 440,000	$ 640,000	4
Actiflo™	Replace flash mix **pumps** (T-03P02)	Repair & Replace	20 MGD	2022	2	$ 57,200	5.600	$ 320,320	$ 377,520	4
Actiflo™	Install second flash mix pump	Redundancy	20 MGD	2022	1					
Actiflo™	Replace mixers	Repair & Replace	20 MGD	2022	6	$ 144,000	1.100	$ 158,400	$ 302,400	4
Actiflo™	Replace hydrocyclones	Repair & Replace	20 MGD	2019	4	$ 120,000	1.650	$ 198,000	$ 318,000	4
Actiflo™	Replace sample pumps	Repair & Replace	20 MGD	2022						
Actiflo™	Replace guardrail	Life-Safety Repairs	20 MGD	2022						
Actiflo™	Inject sealant into active leaks and apply exterior waterstop on join surface	Life-Safety Repairs	20 MGD	2022						
Actiflo™	Provide panic hardware on exit doors	Life-Safety Repairs	20 MGD	2022						
Actiflo™	Install new kickplate on west guardrail	Life-Safety Repairs	20 MGD	2022						
Actiflo™	Upgrade electrical outlets to GFCIs	Life-Safety Repairs	20 MGD	2022						
Actiflo™	Install one new Actiflo™ basin	Capacity Upgrades	30 MGD	2036						
Actiflo™	Replace flash mix pumps	Repair & Replace	30 MGD	2036						
Actiflo™	Replace mixers	Repair & Replace	30 MGD	2036	6	$ 144,000	1.475	$ 212,400	$ 356,400	5
Actiflo™	Replace hydrocyclones	Repair & Replace	30 MGD	2036	4	$ 120,000	2.075	$ 249,000	$ 369,000	5
Actiflo™	T-13ME01 Dry Polymer Batching System	Equipment - Mechanical		2027		$ 50,000	2.975	$ 148,750	$ 198,750	5
Actiflo™	T-04LCP01 Panel, Local Control,Actiflo, & PLC	Equipment - Electrical		2027		$ 30,000	1.800	$ 54,000	$ 84,000	5

VEOLIA COST FACTORING

System Name	Item	Type	Phase	Year In Service	QTY	Veolia Cost Estimate (Total Direct EQ Cost)	JSW Install & Burdens Multiply Factor	JSW OPCC for Installation & Burdens	GRAND TOTAL Veolia Cost + JSW Class 5 OPCC	Estimate Class
Actiflo™	T-03AIT005 Analyzer,Streaming Current,Actiflo Inlet	Initial Chemical Mixing & Application Sys		2020		$ 10,000	1.350	$ 13,500	$ 23,500	4
Ozonation	Replace diffusers in Ozone basin	Capacity Upgrades	20 MGD	2022	6	$ 40,000	0.825	$ 33,000	$ 73,000	4
Ozonation	Provide seismic bracing of ozone destruct pipe down to concrete deck	Seismic Retrofits	20 MGD	2022						
Ozonation	Replace settling tubes	Repair & Replace	20 MGD	2022						
Ozonation	Replace guardrail	Life-Safety Repairs	20 MGD	2022						
Ozonation	Inject sealant into active leaks and apply exterior waterstop on joint surface	Life-Safety Repairs	20 MGD	2022						
Ozonation	Upgrade electrical outlets to GFCIs	Life-Safety Repairs	20 MGD	2022						
Ozonation	Confirm if ventilation is sufficient	Life-Safety Repairs	20 MGD	2022						
Ozonation	Construct one new ozonation basin	Capacity Upgrades	30 MGD	2036						
Solids/Gravity Thickener	Install shelf spare mixing pump	Capacity Upgrades	20 MGD	2022						
Solids/Gravity Thickener	Replace sludge mixing pumps	Repair & Replace	20 MGD	2017	2	$ 65,000	3.000	$ 195,000	$ 260,000	4
Solids/Gravity Thickener	Install spare mixing pump and centrifuge	Repair & Replace	20 MGD	2022						
Solids/Gravity Thickener	Construct one new gravity thickener	Capacity Upgrades	30 MGD	2036						
Solids/Gravity Thickener	Replace thickener drive	Repair & Replace	30 MGD	2036						
Solids/Gravity Thickener	Replace sludge mixing pumps ~~and centrifuges~~	Repair & Replace	30 MGD	2032	2	$ 65,000	3.000	$ 195,000	$ 260,000	5
Filters	Filtration pilot	Capacity Upgrades	20 MGD	2022						
Filters	GAC changeouts every 4 years	Repair & Replace	20 MGD	2022						
Filters	GAC changeouts every 4 years	Repair & Replace		2026						
Filters	GAC changeouts every 4 years	Repair & Replace		2030						
Filters	GAC changeouts every 4 years	Repair & Replace	30 MGD	2034						
Filters	Replace air scour blowers and motors	Repair & Replace	20 MGD	2022	2	$ 120,000	1.925	$ 231,000	$ 351,000	4
Filters	Electrical wiring upgrade	Repair & Replace	20 MGD	2022						
Filters	Replace guardrail	Life-Safety Repairs	20 MGD	2022						
Filters	Inject sealant into active leaks and apply exterior waterstop on joint surface	Life-Safety Repairs	20 MGD	2022						
Filters	Install new kickplate on top side of ladder pit	Life-Safety Repairs	20 MGD	2022						
Filters	Upgrade electrical outlets to GFCIs	Life-Safety Repairs	20 MGD	2022						
Filters	Construct two new filters	Capacity Upgrades	30 MGD	2036						
Filters	Replace air scour blowers and motors	Repair & Replace	30 MGD	2036	2	$ 120,000	2.350	$ 282,000	$ 402,000	5
Filters	T-06FILT01 Filter 1	Equipment - Mechanical		2032		$ 62,500.00				
Filters	T-06FILT02 Filter 2	Equipment - Mechanical		2032		$ 62,500.00				
Filters	T-06FILT03 Filter 3	Equipment - Mechanical		2032		$ 62,500.00				
Filters	T-06FILT04 Filter 4	Equipment - Mechanical		2032		$ 62,500.00				
Filters	T-06FCW01 Weir,Filter Control	Equipment - Electrical		2035		$ 25,000.00				
Filters	T-06MCC-A MCC, Filter Gallery	Equipment - Mechanical		2035		$ 25,000	1.800	$ 45,000	$ 70,000	5
WWEQ Basin	Replace recycle pumps	Repair & Replace	20 MGD	2017	3	$ 75,000	3.000	$ 225,000	$ 300,000	4
WWEQ Basin	Modifications to support chemical lines along western basin wall	Repair & Replace	20 MGD	2022						
WWEQ Basin	3 concrete braces on N and S walls w/ intermediate column support	Seismic Retrofits	20 MGD	2022						
WWEQ Basin	3 concrete braces across width of basin w/ intermediate column support	Seismic Retrofits	20 MGD	2022						
WWEQ Basin	Verify fall restraint provisions when using ladder	Life-Safety Repairs	20 MGD	2022						
WWEQ Basin	Replace recycle pumps	Repair & Replace	30 MGD	2032	3	$ 75,000	1.200	$ 90,000	$ 165,000	5
Finished Water Pump Station	Replace 4 MGD pump with 7.5 MGD	Capacity Upgrades	20 MGD	2022						

VEOLIA COST FACTORING

System Name	Item	Type	Phase	Year In Service	QTY	Veolia Cost Estimate (Total Direct EQ Cost)	JSW Install & Burdens Multiply Factor	JSW OPCC for Installation & Burdens	GRAND TOTAL Veolia Cost + JSW Class 5 OPCC	Estimate Class
Finished Water Pump Station	Install second 4 MGD pump	Capacity Upgrades	20 MGD	2022	1	$ 400,000	2.450	$ 980,000	**$ 1,380,000**	**4**
Finished Water Pump Station	Replace VFDs	Repair & Replace	20 MGD	2022						
Finished Water Pump Station	Replace flowmeter (plant-wide)	Repair & Replace	20 MGD	2022	3	$ 46,000	0.800	$ 36,800	**$ 82,800**	**4**
Finished Water Pump Station	New wall anchorage along W and E walls midway between existing roof joists	Seismic Retrofits	20 MGD	2022						
Finished Water Pump Station	Replace deficient deck sections w/ 16 GA corrugated steel decking	Seismic Retrofits	20 MGD	2022						
Finished Water Pump Station	Strengthen existing chord connections	Seismic Retrofits	20 MGD	2022						
Finished Water Pump Station	Add new top plate over interior shear walls w/ epoxied anchors	Seismic Retrofits	20 MGD	2022						
Finished Water Pump Station	Provide longitudinal seismic bracing for cable trays	Seismic Retrofits	20 MGD	2022						
Finished Water Pump Station	Provide panic hardware on exit doors	Life-Safety Repairs	20 MGD	2022						
Finished Water Pump Station	Replace three 7.5 MGD pumps with three 12 MGD pumps	Capacity Upgrades	30 MGD	2036						
Finished Water Pump Station	Install fifth pump for low-flow redundancy	Capacity Upgrades	30 MGD	2036						
Finished Water Pump Station	Replace all pumps by 30 MGD expansion. Recommend two 7.5 MGD and three 12 MGD pumps	Repair & Replace	30 MGD	2036						
Finished Water Pump Station	Replace flowmeter (plant-wide)	Repair & Replace	30 MGD	2036	3	$ 46,000	1.200	$ 55,200	**$ 101,200**	**5**
Finished Water Pump Station	T-09VFD01 VFD, High Service Pump 1	Equipment - Electrical		2027		$ 120,000	1.825	$ 219,000	**$ 339,000**	**5**
Finished Water Pump Station	T-09VFD02 VFD, High Service Pump 2	Equipment - Electrical		2027		$ 120,000	1.825	$ 219,000	**$ 339,000**	**5**
Finished Water Pump Station	T-09VFD03 - Soft Start Controller, High Service Pump 3	Equipment - Electrical		2027		$ 30,000	1.800	$ 54,000	**$ 84,000**	**5**
Finished Water Pump Station	T-09VFD04 VFD, High Service Pump 4	Equipment - Electrical		2027		$ 30,000	1.800	$ 54,000	**$ 84,000**	**5**
Finished Water Pump Station	T-07P01 Pump, Backwash Suppy 1	Equipment - Mechanical		2032		$ 300,000	2.300	$ 690,000	**$ 990,000**	**5**
Finished Water Pump Station	T-07P02 Pump, Backwash Suppy 2	Equipment - Mechanical		2032		$ 300,000	2.300	$ 690,000	**$ 990,000**	**5**
Raw Water Pump Station	Replace 4 MGD pump **& VFD** with 7.5 MGD pump **& VFD**	Capacity Upgrades	20 MGD	2022	1	$ 175,000	2.800	$ 490,000	**$ 665,000**	**4**
Raw Water Pump Station	Replace VFDs	Repair & Replace	20 MGD	2022	3	$ 41,000	1.375	$ 56,375	**$ 97,375**	**4**
Raw Water Pump Station	Replace flowmeter (plant-wide)	Repair & Replace	20 MGD	2022	1	$ 18,000	0.825	$ 14,850	**$ 32,850**	**4**
Raw Water Pump Station	Replace two 7.5 MGD pumps **& VFD's** and two 15 MGD pumps **& VFD's**	Capacity Upgrades	30 MGD	2036						
Raw Water Pump Station	Replace reamining constant speed 7.5 MGD pump **with new 7.5 MGD pump & VFD**	Repair & Replace	30 MGD	2036	1	$ 175,000	2.900	$ 507,500	**$ 682,500**	**5**
Raw Water Pump Station	T-01ME01 Compressor, Air Burst 1	Equipment - Mechanical		2027		$ 50,000	2.950	$ 147,500	**$ 197,500**	**5**
Raw Water Pump Station	T-01ME02 Compressor, Air Burst 2	Equipment - Mechanical		2027		$ 50,000	2.950	$ 147,500	**$ 197,500**	**5**
Raw Water Pump Station	T-02P05 Pump,Sump,Raw Water	Intake Pump St Bldg - Mechanical		2017		$ 25,000	3.000	$ 75,000	**$ 100,000**	**4**
Raw Water Pump Station	T-01LCP01 Panel,Local Control,Air Burst & PLC	Equipment - Electrical		2027		$ 15,000	1.825	$ 27,375	**$ 42,375**	**5**
Solids Dewatering/Treatment	Steel braced frames at east-side exterior that braces second floor	Seismic Retrofits	20 MGD	2022						
Solids Dewatering/Treatment	Add new wall anchorage along E and W walls mid-way between existing roof joists	Seismic Retrofits	20 MGD	2022						
Solids Dewatering/Treatment	Tie existing floor slab to walls w/ stainless steel angles and epoxy anchors	Seismic Retrofits	20 MGD	2022						
Solids Dewatering/Treatment	Cut out notch in parapet wall and install a scupper and downspout	Life-Safety Repairs	20 MGD	2022						
Solids Dewatering/Treatment	Install third centrifuge and connected solids transfer pump	Capacity Upgrades	30 MGD	2036						
Solids Dewatering/Treatment	Replace centrifuges	Repair & Replace	30 MGD	2027	2	$ 1,400,000	1.500	$ 2,100,000	**$ 3,500,000**	**5**
Solids Dewatering/Treatment	Replace solids transfer pumps	Repair & Replace	30 MGD	2036						
Solids Dewatering/Treatment	T-12ME03 Conveyor, Screw, Dewatered Sludge	Equipment - Mechanical		2022		$ 30,000	1.900	$ 57,000	**$ 87,000**	**4**
Solids Dewatering/Treatment	T-12LCP01 Panel,Local Control,Centrifuge 1, & PLC	Equipment - Electrical		2027		$ 15,000	1.800	$ 27,000	**$ 42,000**	**5**
Solids Dewatering/Treatment	T-12LCP02 Panel,Local Control,Centrifuge 2, & PLC	Equipment - Electrical		2027		$ 15,000	1.800	$ 27,000	**$ 42,000**	**5**
Sitewide	Provide seismic bracing for space heaters (approx. 8 locations)	Seismic Retrofits	20 MGD	2022						

VEOLIA COST FACTORING

System Name	Item	Type	Phase	Year In Service	QTY	Veolia Cost Estimate (Total Direct EQ Cost)	JSW Install & Burdens Multiply Factor	JSW OPCC for Installation & Burdens	GRAND TOTAL Veolia Cost + JSW Class 5 OPCC	Estimate Class
Electrical	Replace existing switchgear	Capacity Upgrades	20 MGD	2022						
Electrical	Replace existing transformer	Capacity Upgrades	20 MGD	2022	8	$ 120,000	0.500	$ 60,000	**$ 180,000**	**4**
Electrical	Rewire existing system as necessary to support emegency power supply	Capacity Upgrades	20 MGD	2022						
Electrical	2MW emergency generator (sufficient to power plant through 30 MGD)	Capacity Upgrades	20 MGD	2022						
Electrical	T-99PCM01 PCM01, Admin Panel RM 103A	Industrial Control Network System		2017		$ 30,000	1.400	$ 42,000	**$ 72,000**	**4**
Electrical	T-99PCM02 PCM02, Admin Electrical RM 106	Industrial Control Network System		2017		$ 30,000	1.400	$ 42,000	**$ 72,000**	**4**
Electrical	T-99FILTERPLCB PCM 5 PLC B	Industrial PLC System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Electrical	T-99FILTERPLCC PCM 5 PLC C	Industrial PLC System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Electrical	T-99PCM03 PCM03,Ozone Gallery	Industrial Control Network System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Electrical	T-99PCM04 PCM04,WW Recovery	Industrial Control Network System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Electrical	T-99PCM05 PCM05,Filter Gallery	Industrial Control Network System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Electrical	T-99PCM06 PCM06,High Service Elec Room	Industrial Control Network System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Electrical	T-99PLCA PCM 1 PLC A	Industrial PLC System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Electrical	T-99PLCA Backup PCM 1 PLC Back-up	Industrial PLC System		2017		$ 15,000	1.400	$ 21,000	**$ 36,000**	**4**
Miscellaneous	T-30P01 Pump, Water Feature	Grounds System - Mechanical		2024		$ 50,000	2.400	$ 120,000	**$ 170,000**	**5**
Miscellaneous	T-30P02 SPARE Pump, Water Feature	Grounds System - Mechanical		2035		$ 30,000	3.500	$ 105,000	**$ 135,000**	**5**
Miscellaneous	T-30P02 Pump #1, Waste, Irrigation	Grounds System - Mechanical		2022		$ 30,000	3.000	$ 90,000	**$ 120,000**	**4**
Miscellaneous	T-30P03 Pump #2, Waste Irrigation	Grounds System - Mechanical		2022		$ 30,000	3.000	$ 90,000	**$ 120,000**	**4**
Miscellaneous	T-32YARD001 Company Truck	Support Vehicles System		2020		$ 25,000	0.500	$ 12,500	**$ 37,500**	**4**
Miscellaneous	T-32YARD002 Mule Kawasaki 550	Support Vehicles System		2017		$ 10,000	0.500	$ 5,000	**$ 15,000**	**4**
Miscellaneous	T-18FACP01 Fire Alarm System-**Yearly Maintenance + Parts**	Fire and Security Monitoring System		2017		$ 4,000	0.750	$ 3,000	**$ 7,000**	**4**
Miscellaneous	T-18FASS01 Sprinkler System, Fire Alarm-**Yearly Maintenance + Parts**	Fire and Security Monitoring System		2017		$ 2,500	0.750	$ 1,875	**$ 4,375**	**4**
Miscellaneous	T-18SECUR01 Security Monitoring System	Fire and Security Monitoring System		2017		$ 10,000	1.350	$ 13,500	**$ 23,500**	**4**
Miscellaneous	T-32YARD015 Signs, Safety and Warning	Grounds System		2017		$ 10,000	0.500	$ 5,000	**$ 15,000**	**4**
Miscellaneous	T-33TOOLS08 Fire Extinguishers	Safety Equipment System		2022		$ 10,000	0.500	$ 5,000	**$ 15,000**	**4**
Miscellaneous	T-18HVAC01 HVAC Unit #1, Rooftop,Admin, Confer.Rm	Admin Bldg System - Mechanical		2027		$ 20,000	2.350	$ 47,000	**$ 67,000**	**5**
Miscellaneous	T-18HVAC02 HVAC Unit #2, Rooftop,Admin, Control Rm	Admin Bldg System - Mechanical		2027		$ 20,000	2.350	$ 47,000	**$ 67,000**	**5**
Miscellaneous	T-18HVAC03 HVAC Unit #3, Rooftop,Admin, Lab	Admin Bldg System - Bldg 18		2027		$ 15,000	2.350	$ 35,250	**$ 50,250**	**5**
						$ 7,022,700		**$ 11,914,595**	**$ 18,662,295**	

PROJECT MEMORANDUM

WRWTP – 2017 MPU

Client Name

Date: March 30, 2018
Project No.: 10721.A00

Prepared By: Meghann Chell
Reviewed By: Jude Grounds
Subject: Modification to OPCC and Cost Factoring Workbook

MWH Constructors prepared a Class 4/5 opinion of probably construction cost (OPCC) for capital improvement projects (CIPs) associated with the Willamette River Water Treatment Plant (WRWTP) 2017 Master Plan Update (2017 MPU). During the 2017 MPU review, there were several changes requested by the City of Wilsonville, plant operations staff (Veolia), or the project engineer (Carollo Engineers, Inc.) that required revisions to the OPCC.

The changes in the CIP table (Appendix E) that deviate from the OPCC are listed below. Note that Task #s indicated below are captured in the CIP Table; WBS #s indicated below are captured in the OPCC; CFW indicates that the item was estimated in the cost factoring workbook.

Additions

- Task # 173 (temporary pump station) was added to the 30 mgd expansion CIP for drinking water supply resiliency. Cost was estimated using the cost for two 15 mgd pumps and assuming no permanent structures would be necessary.
- Task #174 (tracer study) was added to the 20 mgd expansion CIP for support of the ozone coalition waiver. Cost was estimated at $50,000 based on pricing for previous tracer studies performed at WRWTP.
- Tasks #141 through 172 (CFW) are assumed yearly maintenance assumptions for the fire alarm and sprinkler system, so they are applied annually in the repair and replace CIP.

Revisions

- Task #11 (CFW) was updated to reflect operator comment that the streaming current analyzer needs to be relocated to be used for chemical dosing. The equipment cost was multiplied by 3 to account for installation fees.
- Task #14 (WBS 69) was reduced by half to reflect operator input that one flash mix pump was recently replaced.
- Task #83 (WBS 22) was reduced by one-third to reflect operator comment that only two pumps (not three pumps) have Robocon VFDs.

Appendix E

CIP WORKBOOK

WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
CAPITAL IMPROVEMENT PLAN WORKBOOK

CIP SUMMARY TABLE

CIP Project Stage #	CIP Project Stage	Type of Cost Projection	Estimated Construction Cost	Design + Admin Cost	Total Estimated Project Cost$^{(1)}$	Project Completion Year	ENR @ Project Year	Future Value in Project Year - Escalation	Project Duration (Years)	Project Duration (Years)	Project Start Year	Design Duration (Months)	Construction Duration (Months)	Schedule Float (Months)	Design Start	Construction Start	Actual Project Cost
1	20 MGD Expansion	Escalation	$ 12,580,000	$ 3,150,000	$ 15,730,000	2021		$ 17,710,000	3	0	2018	12	18	6	2018	2019	$ -
2	Life-Safety Repairs	Escalation	$ 570,000	$ 60,000	$ 630,000	2022		$ 720,000	2	0	2020	6	6	3	2020	2021	$ -
3	Seismic Retrofits	Escalation	$ 930,000	$ 240,000	$ 1,170,000	2022		$ 1,340,000	2	0	2020	6	6	3	2020	2021	$ -
4	30 MGD Expansion	Escalation	$ 30,920,000	$ 7,730,000	$ 38,650,000	2034		$ 63,870,000	3	0	2031	12	18	6	2031	2032	$ -
	TOTAL COSTS		**$ 45,020,000**	**$ 11,170,000**	**$ 56,190,000**												

Notes:
(1) In 09/17 dollars. Assuming 15% contingency for Design and 10% for legal and administration costs.
(2) All costs in the CIP Summary table are rounded up to nearest $10,000. For more detailed costs, see the CIP Full table.

Ongoing Repair and Replacement Activities Summary (by Project Completion Year)

Type of Cost Projection	Escalation
Construction Duration (months)	6
Schedule Float (months)	6

CIP Project Stage #	CIP Project Stage	Year	ENR @ Project Year	Estimated Construction Cost	Etimated Administrative Cost	Estimated Task Cost$^{(1)}$	Future Value in Project Year - Escalation	Admin Cost in Project Year - Escalation	Construction Cost in Project Year - Escalation	Actual Project Cost
5	*Repair & Replace - Year 1*	2019		$ 1,360,000	$ 140,000	$ 1,500,000	$ 1,590,000	$ 160,000	$ 1,430,000	$ -
5	*Repair & Replace - Year 2*	2020		$ 1,450,000	$ 150,000	$ 1,600,000	$ 1,740,000	$ 180,000	$ 1,560,000	$ -
5	*Repair & Replace - Year 3*	2021		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 4*	2022		$ 3,110,000	$ 320,000	$ 3,430,000	$ 3,970,000	$ 400,000	$ 3,570,000	$ -
5	*Repair & Replace - Year 5*	2023		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 6*	2024		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 7*	2025		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 8*	2026		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 9*	2027		$ 4,740,000	$ 480,000	$ 5,220,000	$ 7,010,000	$ 710,000	$ 6,300,000	$ -
5	*Repair & Replace - Year 10*	2028		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 11*	2029		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 12*	2030		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 13*	2031		$ 20,000	$ 10,000	$ 30,000	$ 20,000	$ 10,000	$ 10,000	$ -
5	*Repair & Replace - Year 14*	2032		$ 2,260,000	$ 230,000	$ 2,490,000	$ 3,860,000	$ 390,000	$ 3,470,000	$ -
5	*Repair & Replace - Year 15*	2033		$ 20,000	$ 10,000	$ 30,000	$ 30,000	$ 10,000	$ 20,000	$ -
5	*Repair & Replace - Year 16*	2034		$ 20,000	$ 10,000	$ 30,000	$ 30,000	$ 10,000	$ 20,000	$ -
5	*Repair & Replace - Year 17*	2035		$ 20,000	$ 10,000	$ 30,000	$ 30,000	$ 10,000	$ 20,000	$ -
5	*Repair & Replace - Year 18*	2036		$ 3,090,000	$ 310,000	$ 3,400,000	$ 5,960,000	$ 600,000	$ 5,360,000	$ -
5	**Repair & Replace Total**			**$ 16,130,000**	**$ 1,610,000**	**$ 17,740,000**	**$ 24,320,000**	**$ 2,210,000**	**$ -**	**$ -**

Notes:
(1) In 09/17 dollars. Assuming 15% contingency for Design and 10% for legal and administration
(2) All costs in the CIP Summary table are rounded up to nearest $10,000. For more detailed costs, see the CIP Full table.

DETAIL CIP SUMMARY

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Type of Cost Projection	Estimated Design Cost	Estimated Administrative Cost	Estimated Total Cost$^{(1)}$	Project Completion Year	ENR @ Project Year	Future Value in Project Year - Escalation	Future Design Cost - Escalation	Future Administrative Cost - Escalation	Design Duration (Months)	Construction Duration (Months)	Schedule Float (Months)	Design Start	Construction Start
1	20 MGD Expansion	Actiflo™	Install second flash mix pump to give system installed redundancy (1+1) rather than shelf spare.	$ 169,791	Yes	Escalation	$ 25,469	$ 16,979	$ 212,239	2021	0	$ 238,877	$ 28,665	$ 19,110	12	18	6	2018	2019
2	20 MGD Expansion	Actiflo™	Purchase additional shelf spare solid pump	$ 42,275	Yes	Escalation	$ 6,341	$ 4,228	$ 52,844	2021	0	$ 59,476	$ 7,137	$ 4,758	12	18	6	2018	2019
3	30 MGD Expansion	Actiflo™	Construct an additional Actiflo basin for the 30 MGD capacity upgrade. With the addition of a third basin, the WRWTP will have three 10 MGD basins and can run two basins at 15 MGD in the event one basin requires maintenance.	$ 4,864,843	Yes	Escalation	$ 729,726	$ 486,484	$ 6,081,054	2034	0	$ 10,051,055	$ 1,206,127	$ 804,084	12	18	6	2031	2032
4	Life-Safety Repairs	Actiflo™	Exterior stair guardrail height is less than 42" and has no dedicated handrail. Replace with current code-compliant installation. (LS3)	$ 6,427	No	Escalation	$ -	$ 643	$ 7,070	2022	0	$ 8,196	$ -	$ 745	6	6	3	2020	2021
5	Life-Safety Repairs	Actiflo™	Active leaks observed in the ozone gallery, creating a slip hazard. Pressure inject hydrophobic sealant into active leaks. Leaking joints may require negative side joint covers. (LS9)	$ 36,136	No	Escalation	$ -	$ 3,614	$ 39,750	2022	0	$ 46,081	$ -	$ 4,189	6	6	3	2020	2021
6	Life-Safety Repairs	Actiflo™	The rated electrical service is 1200 amps or greater requiring two exits with panic hardware. Install panic hardware on doors. (LS4)	$ 7,011	No	Escalation	$ -	$ 701	$ 7,712	2022	0	$ 8,940	$ -	$ 813	6	6	3	2020	2021
7	Life-Safety Repairs	Actiflo™	The west guardrail on top of the Actiflo™ tanks does not have continuous kickplates. Install new kickplates as required. (LS8)	$ 2,305	No	Escalation	$ -	$ 231	$ 2,536	2022	0	$ 2,939	$ -	$ 267	6	6	3	2020	2021
8	Life-Safety Repairs	Actiflo™	Electrical outlets on gallery walls are in a wet area. Replace with GFCI protected outlets. (LS10)	$ 2,425	No	Escalation	$ -	$ 243	$ 2,668	2022	0	$ 3,092	$ -	$ 281	6	6	3	2020	2021
9	Life-Safety Repairs	Actiflo™	The doors were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required at Actiflo™ building. (LS7)	$ 33,171	No	Escalation	$ -	$ 3,317	$ 36,488	2022	0	$ 42,300	$ -	$ 3,845	6	6	3	2020	2021
10	Repair & Replace	Actiflo™	Replace the four hydrocyclones installed in the two existing Actiflo Basins	$ 318,000	No	Escalation	$ -	$ 31,800	$ 349,800	2020	0	$ 382,236	$ -	$ 34,749	0	6	6	2019	2019
11	20 MGD Expansion	Actiflo™	Replace and reinstall existing streaming current analyzer on Actiflo inlet so it can be used for chemical dosing	$ 70,500	Yes	Escalation	$ 10,575	$ 7,050	$ 88,125	2020	0	$ 96,297	$ 11,556	$ 7,704	12	18	6	2017	2018
12	Repair & Replace	Actiflo™	Replace lamella settling tubes in the two existing Actiflo basins, which are damaged due to UV exposure.	$ 245,656	No	Escalation	$ -	$ 24,566	$ 270,222	2020	0	$ 295,278	$ -	$ 26,843	0	6	6	2019	2019
13	Repair & Replace	Actiflo™	Upgrade vendor PLC components in the two existing Actiflo basins	$ 62,108	No	Escalation	$ -	$ 6,211	$ 68,319	2022	0	$ 79,200	$ -	$ 7,200	0	6	6	2021	2021
14	Repair & Replace	Actiflo™	Replace the two flash mix pumps (installed and standby)	$ 188,760	No	Escalation	$ -	$ 18,876	$ 207,636	2020	0	$ 226,889	$ -	$ 20,626	0	6	6	2019	2019
15	Repair & Replace	Actiflo™	Replace the six mixers installed in the two existing Actiflo Basins	$ 302,400	No	Escalation	$ -	$ 30,240	$ 332,640	2022	0	$ 385,621	$ -	$ 35,056	0	6	6	2021	2021
16	Repair & Replace	Actiflo™	Replace the two sample pumps installed in the two existing Actiflo Basins	$ 46,051	No	Escalation	$ -	$ 4,605	$ 50,656	2022	0	$ 58,724	$ -	$ 5,339	0	6	6	2021	2021
17	Repair & Replace	Actiflo™	Replace original dry polymer batching system (T-13ME01)	$ 198,750	No	Escalation	$ -	$ 19,875	$ 218,625	2027	0	$ 293,814	$ -	$ 26,710	0	6	6	2026	2026
18	Repair & Replace	Actiflo™	PLC upgrade for Actiflo Local Control Panels	$ 84,000	No	Escalation	$ -	$ 8,400	$ 92,400	2027	0	$ 124,178	$ -	$ 11,289	0	6	6	2026	2026
19	Repair & Replace	Actiflo™	Replace existing streaming current analyzer on Actiflo inlet	$ 23,500	No	Escalation	$ -	$ 2,350	$ 25,850	2036	0	$ 45,328	$ -	$ 4,121	0	6	6	2035	2035
20	Repair & Replace	Actiflo™	Replace the five solids pumps (installed and standby) on the existing Actiflo basins	$ 640,000	No	Escalation	$ -	$ 64,000	$ 704,000	2036	0	$ 1,234,468	$ -	$ 112,224	0	6	6	2035	2035
21	30 MGD Expansion	Actiflo™	Replace the two installed flash mix pumps	$ 378,229	Yes	Escalation	$ 56,734	$ 37,823	$ 472,786	2034	0	$ 781,444	$ 93,773	$ 62,515	12	18	6	2031	2032
22	Repair & Replace	Actiflo™	Replace the six mixers installed in the two existing Actiflo Basins	$ 302,400	No	Escalation	$ -	$ 30,240	$ 332,640	2036	0	$ 583,286	$ -	$ 53,026	0	6	6	2035	2035
23	Repair & Replace	Actiflo™	Replace the four hydrocyclones installed in the two existing Actiflo Basins	$ 369,000	No	Escalation	$ -	$ 36,900	$ 405,900	2036	0	$ 711,748	$ -	$ 64,704	0	6	6	2035	2035
24	20 MGD Expansion	Chemical Storage/ Ozone Generation	Existing chemical lines are inaccessible south of the utilidor and cannot be inspected or replaced. Abandon existing lines in-place, extend utilidor to the southern end of the plant, and install chemical lines in the extended utilidor.	$ 566,752	Yes	Escalation	$ 85,013	$ 56,675	$ 708,440	2022	0	$ 821,276	$ 98,553	$ 65,702	12	18	6	2019	2020
25	30 MGD Expansion	Chemical Storage/ Ozone Generation	Replace existing 6,000 gallon LOX storage tank with larger tank (12,000 to 15,000 gallons) to ensure sufficient storage with 20 MGD plant capacity. Recommend purchasing LOX tank (rather than leasing from vendor) so LOX can be purchased from different vendors.	$ 262,500	Yes	Escalation	$ 39,375	$ 26,250	$ 328,125	2034	0	$ 542,341	$ 65,081	$ 43,387	12	18	6	2031	2032
26	20 MGD Expansion	Chemical Storage/ Ozone Generation	On existing hypochlorite system, add ventilation line that returns to tank to prevent offgassing to atmosphere.	$ 7,144	Yes	Escalation	$ 1,072	$ 714	$ 8,930	2021	0	$ 10,051	$ 1,206	$ 804	12	18	6	2018	2019
27	20 MGD Expansion	Chemical Storage/ Ozone Generation	On all existing chemical systems, add wye or basket strainers to all pump suction lines	$ 10,978	Yes	Escalation	$ 1,647	$ 1,098	$ 13,723	2021	0	$ 15,445	$ 1,853	$ 1,236	12	18	6	2018	2019
28	30 MGD Expansion	Chemical Storage/ Ozone Generation	Install a second dry polymer feeder to provide redundancy to plant chemical operations	$ 240,000	Yes	Escalation	$ 36,000	$ 24,000	$ 300,000	2034	0	$ 495,854	$ 59,503	$ 39,668	12	18	6	2031	2032
29	30 MGD Expansion	Chemical Storage/ Ozone Generation	Install a third 400 PPD ozone generator to support plant capacity expansion	$ 1,193,917	Yes	Escalation	$ 179,088	$ 119,392	$ 1,492,396	2034	0	$ 2,466,704	$ 296,004	$ 197,336	12	18	6	2031	2032
30	30 MGD Expansion	Chemical Storage/ Ozone Generation	Convert hypochlorite system from liquid chemical storage to dry sodium hypochlorite process system for increased storage capacity and plant resiliency.	$ 637,883	Yes	Escalation	$ 95,682	$ 63,788	$ 797,354	2034	0	$ 1,317,904	$ 158,149	$ 105,432	12	18	6	2031	2032
31	30 MGD Expansion	Chemical Storage/ Ozone Generation	Modify existing Chemical Storage Room to increase usable space for existing chemical systems. Recommendations include installation of roll-up door, removal of aqueous ammonia system, modifications necessary to expand hypochlorite system, and modifications to chemical containment to allow additional tanks.	$ 160,350	Yes	Escalation	$ 24,053	$ 16,035	$ 200,438	2034	0	$ 331,293	$ 39,755	$ 26,503	12	18	6	2031	2032
32	Life-Safety Repairs	Chemical Storage/ Ozone Generation	The chemical pipes that run through the center of the Chemical Storage Room are not seismically braced. Ozone and LOX piping in the Ozone Generation Room are not sesimically braced. Provide seismic bracing for these lines. (LS19, LS20)	$ 36,926	No	Escalation	$ -	$ 3,693	$ 40,619	2022	0	$ 47,088	$ -	$ 4,281	6	6	3	2020	2021
33	Life-Safety Repairs	Chemical Storage/ Ozone Generation	Color-coded NFPA placards have faded. Replace all faded NFPA placards (LS2)	$ 9,205	No	Escalation	$ -	$ 921	$ 10,126	2022	0	$ 11,738	$ -	$ 1,067	6	6	3	2020	2021
34	Life-Safety Repairs	Chemical Storage/ Ozone Generation	Chemical Storage and Ozone Generation Rooms are Group H occupancy or rated electrical service of 1200 A. Install panic hardware on three exit doors in the chemical storage and ozone generation building. (LS4; LS5)	$ 10,517	No	Escalation	$ -	$ 1,052	$ 11,569	2022	0	$ 13,411	$ -	$ 1,219	6	6	3	2020	2021
35	Life-Safety Repairs	Chemical Storage/ Ozone Generation	Change swing direction on exit door between the ozone generation and administration building (LS5)	$ 5,067	No	Escalation	$ -	$ 507	$ 5,574	2022	0	$ 6,461	$ -	$ 587	6	6	3	2020	2021
36	Life-Safety Repairs	Chemical Storage/ Ozone Generation	Chemical lines pass above egress routes. Add containment pans to chemical conveyance lines that are located above doorways in the chemical storage and ozone generation building (LS6)	$ 11,985	No	Escalation	$ -	$ 1,199	$ 13,184	2022	0	$ 15,283	$ -	$ 1,389	6	6	3	2020	2021

DETAIL CIP SUMMARY

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Type of Cost Projection	Estimated Design Cost	Estimated Administrative Cost	Estimated Total Cost$^{(1)}$	Project Completion Year	ENR @ Project Year	Future Value in Project Year - Escalation	Future Design Cost - Escalation	Future Administrative Cost - Escalation	Design Duration (Months)	Construction Duration (Months)	Schedule Float (Months)	Design Start	Construction Start
37	Life-Safety Repairs	Chemical Storage/ Ozone Generation	Install emergency shut-off at the two other exits in the Ozone Generation Room exits (LS15)	$ 11,664	No	Escalation	$ -	$ 1,166	$ 12,830	2022	0	$ 14,874	$ -	$ 1,352	6	6	3	2020	2021
38	Repair & Replace	Chemical Storage/ Ozone Generation	Upgrade vendor PLC components in the existing dry polymer blending unit	$ 22,060	No	Escalation	$ -	$ 2,206	$ 24,266	2022	0	$ 28,131	$ -	$ 2,557	0	6	6	2021	2021
40	Repair & Replace	Chemical Storage/ Ozone Generation	Replate two existing 300 PPD ozone generators with 400 PPD units	$ 1,752,000	No	Escalation	$ -	$ 175,200	$ 1,927,200	2022	0	$ 2,234,153	$ -	$ 203,105	0	6	6	2021	2021
41	20 MGD Expansion	Chemical Storage/ Ozone Generation	Replace existing 4,400 gallon XLPE sodium hypochlorite tank with a 3,900 gallon tank	$ 52,500	Yes	Escalation	$ 7,875	$ 5,250	$ 65,625	2021	0	$ 73,862	$ 8,863	$ 5,909	12	18	6	2018	2019
42	Repair & Replace	Chemical Storage/ Ozone Generation	Inspect existing alum tank and repair as needed	$ 52,500	No	Escalation	$ -	$ 5,250	$ 57,750	2022	0	$ 66,948	$ -	$ 6,086	0	6	6	2021	2021
43	Repair & Replace	Chemical Storage/ Ozone Generation	Inspect existing caustic soda tank and repair as needed	$ 52,500	No	Escalation	$ -	$ 5,250	$ 57,750	2022	0	$ 66,948	$ -	$ 6,086	0	6	6	2021	2021
44	Repair & Replace	Chemical Storage/ Ozone Generation	Replace the LOX evaporator equipment	$ 112,500	No	Escalation	$ -	$ 11,250	$ 123,750	2036	0	$ 216,996	$ -	$ 19,727	0	6	6	2035	2035
46	20 MGD Expansion	Electrical	Install 15 KV/1,200 A metering/distribution switchgear	$ 4,147,606	Yes	Escalation	$ 622,141	$ 414,761	$ 5,184,508	2021	0	$ 5,835,209	$ 700,225	$ 466,817	12	18	6	2018	2019
47	20 MGD Expansion	Electrical	Install new 5,000 KVA transformer to control power distribution to raw and finished water pumps	$ 180,000	Yes	Escalation	$ 27,000	$ 18,000	$ 225,000	2021	0	$ 253,239	$ 30,389	$ 20,259	12	18	6	2018	2019
48	20 MGD Expansion	Electrical	Rewire existing electrical system to install new switchgear and transformer, connect all raw and finished water pumps to new transformer, connect new 2 MW emergency generator to switchgear, and upgrade existing electrical connections as needed to support new layout.	$ 285,988	Yes	Escalation	$ 42,898	$ 28,599	$ 357,485	2021	0	$ 402,353	$ 48,282	$ 32,188	12	18	6	2018	2019
49	20 MGD Expansion	Electrical	Replace existing 1 MW generator with 2 MW generator	$ 4,014,088	Yes	Escalation	$ 602,113	$ 401,409	$ 5,017,610	2021	0	$ 5,647,364	$ 677,684	$ 451,789	12	18	6	2018	2019
60	30 MGD Expansion	Filters	Construct two new media filters to support plant expansion to 30 MGD	$ 4,185,194	Yes	Escalation	$ 627,779	$ 418,519	$ 5,231,493	2034	0	$ 8,646,860	$ 1,037,623	$ 691,749	12	18	6	2031	2032
61	Life-Safety Repairs	Filters	Exterior stair guardrail height is less than 42" and has no dedicated handrail. Replace with current code-compliant installation. (LS3)	$ 6,427	No	Escalation	$ -	$ 643	$ 7,070	2022	0	$ 8,196	$ -	$ 745	6	6	3	2020	2021
62	Life-Safety Repairs	Filters	Active leaks observed in the ozone gallery, creating a slip hazard. Pressure inject hydrophobic sealant into active leaks. Leaking joints may require negative side joint covers. (LS9)	$ 34,854	No	Escalation	$ -	$ 3,485	$ 38,339	2022	0	$ 44,446	$ -	$ 4,041	6	6	3	2020	2021
63	Life-Safety Repairs	Filters	The west guardrail on top of the the Filter ladder pit does not have continuous kickplates. Install new kickplates as required. (LS8)	$ 2,305	No	Escalation	$ -	$ 231	$ 2,536	2022	0	$ 2,939	$ -	$ 267	6	6	3	2020	2021
64	Life-Safety Repairs	Filters	Electrical outlets on gallery walls are in a wet area. Replace with GFCI protected outlets. (LS10)	$ 4,851	No	Escalation	$ -	$ 485	$ 5,336	2022	0	$ 6,186	$ -	$ 562	6	6	3	2020	2021
65	Life-Safety Repairs	Filters	Add a fire-rated door at the bottom of the filter gallery stairs and add signage to existing ladder pit door to clarify that it is not an exit. (LS12)	$ 3,505	No	Escalation	$ -	$ 351	$ 3,856	2022	0	$ 4,470	$ -	$ 406	6	6	3	2020	2021
66	Life-Safety Repairs	Filters	The doors for various rooms were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required in the air scour blower room. (LS7)	$ 43,493	No	Escalation	$ -	$ 4,349	$ 47,842	2022	0	$ 55,462	$ -	$ 5,042	6	6	3	2020	2021
68	Repair & Replace	Filters	Replace existing air scour blowers and motors on existing media filtration system	$ 351,000	No	Escalation	$ -	$ 35,100	$ 386,100	2022	0	$ 447,596	$ -	$ 40,691	0	6	6	2021	2021
69	20 MGD Expansion	Filters	Upgrade electrical wiring as necessary to support plant-wide electrical upgrades	$ 238,323	Yes	Escalation	$ 35,748	$ 23,832	$ 297,904	2021	0	$ 335,293	$ 40,235	$ 26,823	12	18	6	2018	2019
73	Repair & Replace	Filters	Replace aging MCC in existing filter gallery	$ 70,000	No	Escalation	$ -	$ 7,000	$ 77,000	2036	0	$ 135,020	$ -	$ 12,275	0	6	6	2035	2035
74	Repair & Replace	Filters	Replace air scour blowers and motors on existing media filtration system	$ 402,000	No	Escalation	$ -	$ 40,200	$ 442,200	2036	0	$ 775,400	$ -	$ 70,491	0	6	6	2035	2035
75	20 MGD Expansion	Finished Water Pump Station	Replace existing 4 MGD pump with 7.5 MGD pump to ensure plant meets 20 MGD firm capacity. Alternately, install a fifth pump that is at least 5 MGD.	$ 1,212,081	Yes	Escalation	$ 181,812	$ 121,208	$ 1,515,101	2021	0	$ 1,705,260	$ 204,631	$ 136,421	12	18	6	2018	2019
76	30 MGD Expansion	Finished Water Pump Station	Upgrade three existing 7.5 MGD finished water pumps with three 12 MGD pumps	$ 4,896,098	Yes	Escalation	$ 734,415	$ 489,610	$ 6,120,123	2034	0	$ 10,115,630	$ 1,213,876	$ 809,250	12	18	6	2031	2032
77	30 MGD Expansion	Finished Water Pump Station	Install a fifth finished water pump as part of the 30 MGD upgrade. Recommend 7.5 MGD pump (only valid if not installed during 20 MGD expansion)	$ 1,185,023	Yes	Escalation	$ 177,753	$ 118,502	$ 1,481,279	2034	0	$ 2,448,328	$ 293,799	$ 195,866	12	18	6	2031	2032
79	Life-Safety Repairs	Finished Water Pump Station	The cable trays lack longitudinal bracing. Add bracing to existing cable trays. (LS18)	$ 14,553	No	Escalation	$ -	$ 1,455	$ 16,008	2022	0	$ 18,558	$ -	$ 1,687	6	6	3	2020	2021
80	Life-Safety Repairs	Finished Water Pump Station	The rated electrical service is 1200 amps or greater requiring two exits with panic hardware. Install panic hardware on doors. (LS4)	$ 7,011	No	Escalation	$ -	$ 701	$ 7,712	2022	0	$ 8,940	$ -	$ 813	6	6	3	2020	2021
81	Life-Safety Repairs	Finished Water Pump Station	The doors for various rooms were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required in the finished water pump station. (LS7)	$ 81,982	No	Escalation	$ -	$ 8,198	$ 90,180	2022	0	$ 104,544	$ -	$ 9,504	6	6	3	2020	2021
82	Life-Safety Repairs	Finished Water Pump Station	Switchgear Room has rated electrical service is 1200 amps or greater requiring two exits with panic hardware. Install panic hardware on doors. (LS4)	$ 7,011	No	Escalation	$ -	$ 701	$ 7,712	2022	0	$ 8,940	$ -	$ 813	6	6	3	2020	2021
83	Repair & Replace	Finished Water Pump Station	Replace VFDs on three Finished Water Pumps	$ 596,336	No	Escalation	$ -	$ 59,634	$ 655,970	2019	0	$ 695,918	$ -	$ 63,265	0	6	6	2018	2018
84	Repair & Replace	Finished Water Pump Station	Replace existing soft-start controller on High Service Pump 3	$ 84,000	No	Escalation	$ -	$ 8,400	$ 92,400	2027	0	$ 124,178	$ -	$ 11,289	0	6	6	2026	2026
85	Repair & Replace	Finished Water Pump Station	Replace two existing backwash supply pumps in the Wastewater Equalization Basin	$ 1,980,000	No	Escalation	$ -	$ 198,000	$ 2,178,000	2032	0	$ 3,393,253	$ -	$ 308,478	0	6	6	2031	2031
86	Seismic Retrofits	Finished Water Pump Station	The roof joist wall anchorage along the east and west walls of the High Service PS have a DCR of 1.55. Add new wall anchorage along the east and west walls between the existing roof joists. (S3)	$ 144,364	Yes	Escalation	$ 21,655	$ 14,436	$ 180,455	2022	0	$ 209,197	$ 25,104	$ 16,736	6	6	3	2020	2021
87	Seismic Retrofits	Finished Water Pump Station	The roof diaphragm shear at the High Service PS has a DCR of 1.82 to 2.25. Replace existing deficient deck sections with 16 GA corrugated steel decking. (S4)	$ 125,618	Yes	Escalation	$ 18,843	$ 12,562	$ 157,023	2022	0	$ 182,032	$ 21,844	$ 14,563	6	6	3	2020	2021

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P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Type of Cost Projection	Estimated Design Cost	Estimated Administrative Cost	Estimated Total Cost(1)	Project Completion Year	ENR @ Project Year	Future Value in Project Year - Escalation	Future Design Cost - Escalation	Future Administrative Cost - Escalation	Design Duration (Months)	Construction Duration (Months)	Schedule Float (Months)	Design Start	Construction Start
88	Seismic Retrofits	Finished Water Pump Station	Tension capacity of the diaphragm chords at the High Service PS has a DCR of 1.20 at connections at the east windows. Strengthen chord splices as required. (S5)	$ 12,159	Yes	Escalation	$ 1,824	$ 1,216	$ 15,199	2022	0	$ 17,620	$ 2,114	$ 1,410	6	6	3	2020	2021
89	Seismic Retrofits	Finished Water Pump Station	Roof deck shear transfer to interior wall ledger bolts at the High Service PS have DCR's of 3.20 to 3.90. Add new top plate over exterior shear wall and install epoxied anchors. (S6)	$ 87,647	Yes	Escalation	$ 13,147	$ 8,765	$ 109,559	2022	0	$ 127,009	$ 15,241	$ 10,161	6	6	3	2020	2021
92	Repair & Replace	Miscellaneous	Replace the existing safety and warning signs throughout the site	$ 15,000	No	Escalation	$ -	$ 1,500	$ 16,500	2022	0	$ 19,128	$ -	$ 1,739	0	6	6	2021	2021
93	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2020	0	$ 8,414	$ -	$ 765	0	6	6	2019	2019
94	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2020	0	$ 5,259	$ -	$ 478	0	6	6	2019	2019
95	Repair & Replace	Miscellaneous	Upgrade site security monitoring system camera and computer	$ 23,500	No	Escalation	$ -	$ 2,350	$ 25,850	2020	0	$ 28,247	$ -	$ 2,568	0	6	6	2019	2019
96	Repair & Replace	Miscellaneous	Replace sitewide fire extinguishers	$ 15,000	No	Escalation	$ -	$ 1,500	$ 16,500	2022	0	$ 19,128	$ -	$ 1,739	0	6	6	2021	2021
97	Repair & Replace	Miscellaneous	Replace the two existing irrigation waste pumps (T-30P01/2)	$ 340,000	No	Escalation	$ -	$ 34,000	$ 374,000	2022	0	$ 433,569	$ -	$ 39,415	0	6	6	2021	2021
98	Repair & Replace	Miscellaneous	Replace the two existing water feature pumps (T-30P01/2)	$ 340,000	No	Escalation	$ -	$ 34,000	$ 374,000	2027	0	$ 502,625	$ -	$ 45,693	0	6	6	2026	2026
99	20 MGD Expansion	Miscellaneous	Replace two existing rooftop HVAC units in the Administration Building (Conference Room and Control Room) and repair ventilation in Laboratory (T-18HVAC01 through 3)	$ 184,250	Yes	Escalation	$ 27,638	$ 18,425	$ 230,313	2019	0	$ 244,339	$ 29,321	$ 19,547	12	18	6	2016	2017
100	20 MGD Expansion	Ozonation	Replace the diffusers in the two existing ozone basins to support 30 MGD capacity expansion	$ 73,000	Yes	Escalation	$ 10,950	$ 7,300	$ 91,250	2021	0	$ 102,703	$ 12,324	$ 8,216	12	18	6	2018	2019
101	30 MGD Expansion	Ozonation	Construct a third ozone basin and gallery to support 30 MGD expansion	$ 3,420,955	Yes	Escalation	$ 513,143	$ 342,096	$ 4,276,194	2034	0	$ 7,067,897	$ 848,148	$ 565,432	12	18	6	2031	2032
102	Life-Safety Repairs	Ozonation	The ozone destruct pipe on the top side is not seismically braced or marked. Add chemical service label and provide seismic bracing down to the concrete deck. (LS17)	$ 11,809	No	Escalation	$ -	$ 1,181	$ 12,990	2022	0	$ 15,059	$ -	$ 1,369	6	6	3	2020	2021
103	Life-Safety Repairs	Ozonation	Exterior stair guardrail height is less than 42" and has no dedicated handrail. Replace with current code-compliant installation. (LS3)	$ 6,427	No	Escalation	$ -	$ 643	$ 7,070	2022	0	$ 8,196	$ -	$ 745	6	6	3	2020	2021
104	Life-Safety Repairs	Ozonation	Active leaks observed in the ozone gallery, creating a slip hazard. Pressure inject hydrophobic sealant into active leaks. Leaking joints may require negative side joint covers. (LS9)	$ 44,468	No	Escalation	$ -	$ 4,447	$ 48,915	2022	0	$ 56,706	$ -	$ 5,155	6	6	3	2020	2021
105	Life-Safety Repairs	Ozonation	Electrical outlets on gallery walls are in a wet area. Replace with GFCI protected outlets. (LS10)	$ 2,425	No	Escalation	$ -	$ 243	$ 2,668	2022	0	$ 3,092	$ -	$ 281	6	6	3	2020	2021
106	Life-Safety Repairs	Ozonation	The south stairwell does not have any ventilation system serving it directly. Investigate and repair as required. (LS11)	$ 10,499	No	Escalation	$ -	$ 1,050	$ 11,549	2022	0	$ 13,388	$ -	$ 1,217	6	6	3	2020	2021
107	20 MGD Expansion	Raw Water Pump Station	Replace existing 4 MGD pump with 7.5 MGD pump to ensure plant meets 20 MGD firm capacity with three dedicated pumps	$ 665,000	Yes	Escalation	$ 99,750	$ 66,500	$ 831,250	2021	0	$ 935,579	$ 112,270	$ 74,846	12	18	6	2018	2019
108	30 MGD Expansion	Raw Water Pump Station	Replace two existing 7.5 MGD pumps with 15 MGD pumps	$ 1,772,847	Yes	Escalation	$ 265,927	$ 177,285	$ 2,216,059	2034	0	$ 3,662,807	$ 439,537	$ 293,025	12	18	6	2031	2032
109	Repair & Replace	Raw Water Pump Station	Replace existing raw water sump pump	$ 100,000	No	Escalation	$ -	$ 10,000	$ 110,000	2020	0	$ 120,200	$ -	$ 10,927	0	6	6	2019	2019
110	Repair & Replace	Raw Water Pump Station	Replace osbsolete Robocon VFDs on three Raw Water Pumps	$ 97,375	No	Escalation	$ -	$ 9,738	$ 107,113	2019	0	$ 113,636	$ -	$ 10,331	0	6	6	2018	2018
111	Repair & Replace	Raw Water Pump Station	Replace two existing Air Burst Compressors	$ 395,000	No	Escalation	$ -	$ 39,500	$ 434,500	2027	0	$ 583,932	$ -	$ 53,085	0	6	6	2026	2026
112	Repair & Replace	Raw Water Pump Station	Replace existing air burst control panel PLC and local control panel	$ 42,375	No	Escalation	$ -	$ 4,238	$ 46,613	2027	0	$ 62,643	$ -	$ 5,695	0	6	6	2026	2026
113	Repair & Replace	Raw Water Pump Station	Replace the existing constant-speed 7.5 MGD pump with a VFD-controlled pump	$ 682,500	No	Escalation	$ -	$ 68,250	$ 750,750	2036	0	$ 1,316,445	$ -	$ 119,677	0	6	6	2035	2035
114	20 MGD Expansion	Sitewide	Sitewide lighting upgrade to support continued nighttime operations. For purpose of cost estimate, assuming that sitewide external lighting is replaced with high efficiency LED system.	$ 156,532	Yes	Escalation	$ 23,480	$ 15,653	$ 195,665	2021	0	$ 220,223	$ 26,427	$ 17,618	12	18	6	2018	2019
115	Life-Safety Repairs	Sitewide	The space heaters throughout the plant are laterally braced above their center of gravity. The space heaters at the Switchgear Room are not braced. Provide additional seismic bracing to approximately eight locations. (LS16)	$ 11,827	No	Escalation	$ -	$ 1,183	$ 13,010	2022	0	$ 15,082	$ -	$ 1,371	6	6	3	2020	2021
116	Life-Safety Repairs	Sitewide	Tread plate hatches do not have provisions for installing temporary fall protection barriers. Install sleeves or other hardware for temporary fall protection. (LS1)	$ 42,284	No	Escalation	$ -	$ 4,228	$ 46,512	2022	0	$ 53,921	$ -	$ 4,902	6	6	3	2020	2021
117	Repair & Replace	Sitewide	Replace obsolete ABB magnetic flow meters installed throughout the WRWTP and at Wilsonville Road	$ 662,400	No	Escalation	$ -	$ 66,240	$ 728,640	2019	0	$ 773,014	$ -	$ 70,274	0	6	6	2018	2018
118	30 MGD Expansion	Solids - Dewatering	Install a third 60 GPM centrifuge and solids transfer pump to support the 30 MGD plant expansion	$ 1,665,316	Yes	Escalation	$ 249,797	$ 166,532	$ 2,081,645	2034	0	$ 3,440,642	$ 412,877	$ 275,251	12	18	6	2031	2032
119	Life-Safety Repairs	Solids - Dewatering	The Solids Handling Building roof does not appear to have an overflow scupper. Provide an overflow scupper with downspout. (LS14)	$ 8,855	No	Escalation	$ -	$ 886	$ 9,741	2022	0	$ 11,292	$ -	$ 1,027	6	6	3	2020	2021
120	Repair & Replace	Solids - Dewatering	Replace the existing dewatered sludge screw conveyor in the Solids Handling Building	$ 87,000	No	Escalation	$ -	$ 8,700	$ 95,700	2022	0	$ 110,943	$ -	$ 10,086	0	6	6	2021	2021
121	Repair & Replace	Solids - Dewatering	Replace two existing 60 GPM centrifuges and transfer pumps	$ 3,500,000	No	Escalation	$ -	$ 350,000	$ 3,850,000	2027	0	$ 5,174,078	$ -	$ 470,371	0	6	6	2026	2026
122	Repair & Replace	Solids - Dewatering	Replace existing PLC and local control panel for two dewatering centrifuges	$ 84,000	No	Escalation	$ -	$ 8,400	$ 92,400	2027	0	$ 124,178	$ -	$ 11,289	0	6	6	2026	2026
123	Repair & Replace	Solids - Dewatering	Replace two existing 60 GPM solids transfer pumps	$ 316,059	No	Escalation	$ -	$ 31,606	$ 347,665	2036	0	$ 609,633	$ -	$ 55,421	0	6	6	2035	2035
124	Seismic Retrofits	Solids - Dewatering	The Solids Handling Building has no lateral load resisting system in the transverse direction at the lower level. Provide structural bracing in the east-west direction by installation of shear wall extensions or exterior steel bracing. (S7)	$ 47,722	Yes	Escalation	$ 7,158	$ 4,772	$ 59,653	2022	0	$ 69,154	$ 8,298	$ 5,532	6	6	3	2020	2021
125	Seismic Retrofits	Solids - Dewatering	The roof joist wall anchorage along the east and west walls of the Solids Handling Building have a DCR of 1.17. Add new wall anchorage along the east and west walls between the existing roof joists. (S8)	$ 62,761	Yes	Escalation	$ 9,414	$ 6,276	$ 78,451	2022	0	$ 90,947	$ 10,914	$ 7,276	6	6	3	2020	2021
126	Seismic Retrofits	Solids - Dewatering	The foundation elements at the Solids Handling Building do not have adequate ties. The floor slab is not doweled into the walls or the footings. Tie the existing slab to the walls with stainless steel angles and epoxy anchors. (S9)	$ 24,672	Yes	Escalation	$ 3,701	$ 2,467	$ 30,840	2022	0	$ 35,752	$ 4,290	$ 2,860	6	6	3	2020	2021

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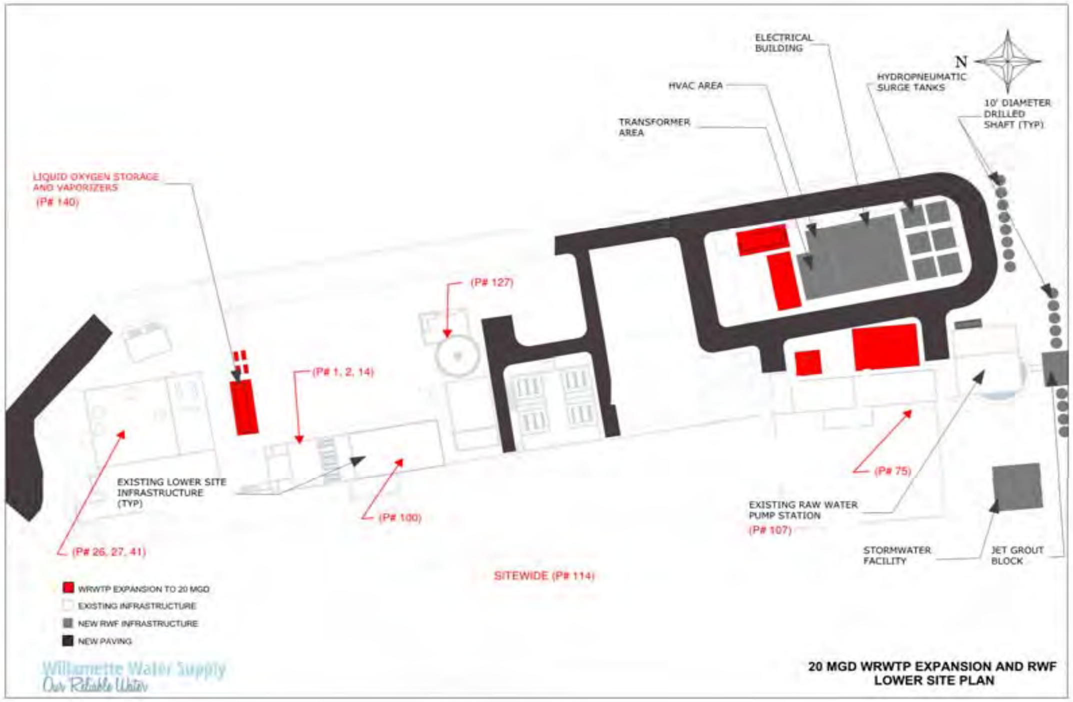
P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Type of Cost Projection	Estimated Design Cost	Estimated Administrative Cost	Estimated Total Cost[(1)]	Project Completion Year	ENR @ Project Year	Future Value in Project Year - Escalation	Future Design Cost - Escalation	Future Administrative Cost - Escalation	Design Duration (Months)	Construction Duration (Months)	Schedule Float (Months)	Design Start	Construction Start
127	20 MGD Expansion	Solids - Gravity Thickener	To increase solids mixing redundancy, recommend purchasing and installing a second mixing pump to give 1+1 configuration	$ 104,385	Yes	Escalation	$ 15,658	$ 10,439	$ 130,481	2021	0	$ 146,858	$ 17,623	$ 11,749	12	18	6	2018	2019
128	30 MGD Expansion	Solids - Gravity Thickener	Construct a second 35-ft diameter gravity thickener to support the 30 MGD plant expansion and provide solids handling redundancy	$ 870,475	Yes	Escalation	$ 130,571	$ 87,048	$ 1,088,094	2034	0	$ 1,798,453	$ 215,814	$ 143,876	12	18	6	2031	2032
129	Repair & Replace	Solids - Gravity Thickener	Replace two existing sludge mixing pumps (one installed, one shelf spare)	$ 260,000	No	Escalation	$ -	$ 26,000	$ 286,000	2020	0	$ 312,520	$ -	$ 28,411	0	6	6	2019	2019
130	Repair & Replace	Solids - Gravity Thickener	Replace the two existing sludge mixing pumps	$ 260,000	No	Escalation	$ -	$ 26,000	$ 286,000	2032	0	$ 445,579	$ -	$ 40,507	0	6	6	2031	2031
131	Repair & Replace	Solids - Gravity Thickener	Replace the existing gravity thickener drive	$ 114,264	No	Escalation	$ -	$ 11,426	$ 125,690	2036	0	$ 220,399	$ -	$ 20,036	0	6	6	2035	2035
132	30 MGD Expansion	WWEQ Basin	Install fourth washwater recycle pump for additional redundancy at 30 MGD expansion	$ 281,250	Yes	Escalation	$ 42,188	$ 28,125	$ 351,563	2034	0	$ 581,079	$ 69,730	$ 46,486	12	18	6	2031	2032
133	Life-Safety Repairs	WWEQ Basin	Verify how fall restraint is provided when using the ladder into the waste washwaster equalization basin and provide additional hardware as required. (LS13)	$ 7,546	No	Escalation	$ -	$ 755	$ 8,301	2022	0	$ 9,623	$ -	$ 875	6	6	3	2020	2021
134	Life-Safety Repairs	WWEQ Basin	The doors for various rooms were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required at waste washwater equalization basin. (LS7)	$ 35,168	No	Escalation	$ -	$ 3,517	$ 38,685	2022	0	$ 44,846	$ -	$ 4,077	6	6	3	2020	2021
135	Repair & Replace	WWEQ Basin	Replace three existing filter waste washwater recycle pumps	$ 300,000	No	Escalation	$ -	$ 30,000	$ 330,000	2020	0	$ 360,600	$ -	$ 32,782	0	6	6	2019	2019
136	20 MGD Expansion	WWEQ Basin	Modifications necessary to support chemical pipelines along western WWEQ Basin wall	$ 300,000	Yes	Escalation	$ 45,000	$ 30,000	$ 375,000	2022	0	$ 434,728	$ 52,167	$ 34,778	12	18	6	2019	2020
137	Repair & Replace	WWEQ Basin	Replace three existing filter waste washwater recycle pumps	$ 43,036	No	Escalation	$ -	$ 4,304	$ 47,340	2036	0	$ 83,010	$ -	$ 7,546	0	6	6	2035	2035
138	Seismic Retrofits	WWEQ Basin	Waste Washwater EQ Basin North & South Walls: Horizontal reinforcing steel at east corners (#8 @ 12" OC) have a DCR of 1.53 for soil seismic loads. Recommend adding additional reinforced shotcrete to wall or adding three concete/steel braces across the basin. (S1)	$ 219,386	Yes	Escalation	$ 32,908	$ 21,939	$ 274,233	2022	0	$ 317,911	$ 38,149	$ 25,433	6	6	3	2020	2021
139	Seismic Retrofits	WWEQ Basin	Waste Washwater EQ Basin North & South Walls: Wall shear at the concrete beam has a DCR of 1.67 for soil seismic loads. Recommend addition of reinforced shotcrete to wall or addition of concrete/steel braces across the basin. (S2)	$ 197,164	Yes	Escalation	$ 29,575	$ 19,716	$ 246,455	2022	0	$ 285,709	$ 34,285	$ 22,857	6	6	3	2020	2021
140	20 MGD Expansion	Chemical Storage/ Ozone Generation	Replace 6,000-gallon rented LOX tank with larger tank	$ 88,917	Yes	Escalation	$ 13,338	$ 8,892	$ 111,146	2021	0	$ 125,096	$ 15,012	$ 10,008	12	18	6	2018	2019
141	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2021	0	$ 8,666	$ -	$ 788	0	6	6	2020	2020
142	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2021	0	$ 5,417	$ -	$ 492	0	6	6	2020	2020
143	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2022	0	$ 8,926	$ -	$ 811	0	6	6	2021	2021
144	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2022	0	$ 5,579	$ -	$ 507	0	6	6	2021	2021
145	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2023	0	$ 9,194	$ -	$ 836	0	6	6	2022	2022
146	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2023	0	$ 5,746	$ -	$ 522	0	6	6	2022	2022
147	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2024	0	$ 9,470	$ -	$ 861	0	6	6	2023	2023
148	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2024	0	$ 5,919	$ -	$ 538	0	6	6	2023	2023
149	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2025	0	$ 9,754	$ -	$ 887	0	6	6	2024	2024
150	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2025	0	$ 6,096	$ -	$ 554	0	6	6	2024	2024
151	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2026	0	$ 10,047	$ -	$ 913	0	6	6	2025	2025
152	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2026	0	$ 6,279	$ -	$ 571	0	6	6	2025	2025
153	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2027	0	$ 10,348	$ -	$ 941	0	6	6	2026	2026
154	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2027	0	$ 6,468	$ -	$ 588	0	6	6	2026	2026
155	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2028	0	$ 10,659	$ -	$ 969	0	6	6	2027	2027
156	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2028	0	$ 6,662	$ -	$ 606	0	6	6	2027	2027
157	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2029	0	$ 10,978	$ -	$ 998	0	6	6	2028	2028
158	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2029	0	$ 6,861	$ -	$ 624	0	6	6	2028	2028
159	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2030	0	$ 11,308	$ -	$ 1,028	0	6	6	2029	2029
160	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2030	0	$ 7,067	$ -	$ 642	0	6	6	2029	2029
161	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2031	0	$ 11,647	$ -	$ 1,059	0	6	6	2030	2030
162	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2031	0	$ 7,279	$ -	$ 662	0	6	6	2030	2030
163	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2032	0	$ 11,996	$ -	$ 1,091	0	6	6	2031	2031
164	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2032	0	$ 7,498	$ -	$ 682	0	6	6	2031	2031
165	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2033	0	$ 12,356	$ -	$ 1,123	0	6	6	2032	2032
166	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2033	0	$ 7,723	$ -	$ 702	0	6	6	2032	2032
167	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2034	0	$ 12,727	$ -	$ 1,157	0	6	6	2033	2033
168	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2034	0	$ 7,954	$ -	$ 723	0	6	6	2033	2033
169	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2035	0	$ 13,109	$ -	$ 1,192	0	6	6	2034	2034
170	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2035	0	$ 8,193	$ -	$ 745	0	6	6	2034	2034
171	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	Escalation	$ -	$ 700	$ 7,700	2036	0	$ 13,502	$ -	$ 1,227	0	6	6	2035	2035
172	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	Escalation	$ -	$ 438	$ 4,813	2036	0	$ 8,439	$ -	$ 767	0	6	6	2035	2035
173	30 MGD Expansion	Finished Water Pump Station	Temporary pump station to supply 15 MGD from the WWSP Treatment Plant to the WRWTP distribution system in the event of a service distruption.	$ 4,896,098	Yes	Escalation	$ 734,415	$ 489,610	$ 6,120,123	2034	0	$ 10,115,630	$ 1,213,876	$ 809,250	12	18	6	2031	2032
174	20 MGD Expansion	Finished Water Pump Station	Conduct tracer study in support of receiving OHA ozonation waiver	$ 50,000	Yes	Escalation	$ 7,500	$ 5,000	$ 62,500	2021	0	$ 70,344	$ 8,441	$ 5,628	12	18	6	2018	2019
			TOTAL COSTS	**$ 56,193,027**					**$67,738,302**										

Notes:
(1) In 09/17 dollars. Assuming 15% contingency for Design and 10% for legal and administration costs.

WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
CAPITAL IMPROVEMENT PLAN WORKBOOK
PROJECT NO. 1

Project Title	20 MGD Expansion
Project Category	Capacity Improvement
Project Description	The existing treatment processes will be uprated for the 20 mgd WRWTP expansion. For the primary treatment processes, the uprating will include the following: • Increasing the Actiflo® flow rate from 7.5 mgd per basin to 10 mgd per basin. • Increasing the ozonation basin flow rate from 7.5 mgd per basin to 10 mgd per basin. This will decrease the ozone contact time from 15 to 11 minutes, which still allows sufficient contact time for 1-log Cryptosporidium inactivation, provided increased levels of ozone can be dosed in the contactor. • Increasing the filtration rate to a nominal rate of 5.7 gpm/sf and a maximum rate of 7.5 gpm/sf when one filter is off-line, and to a nominal rate of 7.5 gpm/sf and a maximum rate of 10 gpm/sf when one basin is offline. This increased filtration rate will require approval from OHA prior to increasing plant capacity. To support OHA approval, a full scale pilot study should be conducted in which the filtration rate is gradually increased and water quality is closely monitored. • To meet the 2022 site capacity of nominally 20 mgd, the plant's electrical supply and distribution system will need significant upgrades. Preliminary engineering for the capacity expansion will require detailed analysis of electrical supply alternatives, including backup power requirements. Improving the "backbone" of electrical and standby power is recommended in parallel with the expansion project.



WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
CAPITAL IMPROVEMENT PLAN WORKBOOK
PROJECT NO. 1

Project Summary Table

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Total Cost(1)	Future Value in Project Year - Escalation	Actual Construction Cost
1	20 MGD Expansion	Actiflo™	Install second flash mix pump to give system installed redundancy (1+1) rather than shelf spare.	$ 169,791	Yes	$ 212,239	$ 238,877	
2	20 MGD Expansion	Actiflo™	Purchase additional shelf spare solid pump	$ 42,275	Yes	$ 52,844	$ 59,476	
11	20 MGD Expansion	Actiflo™	Replace and reinstall existing streaming current analyzer on Actiflo inlet so it can be used for chemical dosing	$ 70,500	Yes	$ 88,125	$ 96,297	
24	20 MGD Expansion	Chemical Storage/ Ozone Generation	Existing chemical lines are inaccessible south of the utilidor and cannot be inspected or replaced. Abandon existing lines in-place, extend utilidor to the southern end of the plant, and install chemical lines in the extended utilidor.	$ 566,752	Yes	$ 708,440	$ 821,276	
26	20 MGD Expansion	Chemical Storage/ Ozone Generation	On existing hypochlorite system, add ventilation line that returns to tank to prevent offgassing to atmosphere.	$ 7,144	Yes	$ 8,930	$ 10,051	
27	20 MGD Expansion	Chemical Storage/ Ozone Generation	On all existing chemical systems, add wye or basket strainers to all pump suction lines	$ 10,978	Yes	$ 13,723	$ 15,445	
41	20 MGD Expansion	Chemical Storage/ Ozone Generation	Replace existing 4,400 gallon XLPE sodium hypochlorite tank with a 3,900 gallon tank	$ 52,500	Yes	$ 65,625	$ 73,862	
46	20 MGD Expansion	Electrical	Install 15 KV/1,200 A metering/distribution switchgear	$ 4,147,606	Yes	$5,184,508	$ 5,835,209	
47	20 MGD Expansion	Electrical	Install new 5,000 KVA transformer to control power distribution to raw and finished water pumps	$ 180,000	Yes	$ 225,000	$ 253,239	
48	20 MGD Expansion	Electrical	Rewire existing electrical system to install new switchgear and transformer, connect all raw and finished water pumps to new transformer, connect new 2 MW emergency generator to switchgear, and upgrade existing electrical connections as needed to support new layout.	$ 285,988	Yes	$ 357,485	$ 402,353	
49	20 MGD Expansion	Electrical	Replace existing 1 MW generator with 2 MW generator	$ 4,014,088	Yes	$5,017,610	$ 5,647,364	
69	20 MGD Expansion	Filters	Upgrade electrical wiring as necessary to support plant-wide electrical upgrades	$ 238,323	Yes	$ 297,904	$ 335,293	
75	20 MGD Expansion	Finished Water Pump Station	Replace existing 4 MGD pump with 7.5 MGD pump to ensure plant meets 20 MGD firm capacity. Alternately, install a fifth pump that is at least 5 MGD.	$ 1,212,081	Yes	$1,515,101	$ 1,705,260	
99	20 MGD Expansion	Miscellaneous	Replace two existing rooftop HVAC units in the Administration Building (Conference Room and Control Room) and repair ventilation in Laboratory (T-18HVAC01 through 3)	$ 184,250	Yes	$ 230,313	$ 244,339	
100	20 MGD Expansion	Ozonation	Replace the diffusers in the two existing ozone basins to support 30 MGD capacity expansion	$ 73,000	Yes	$ 91,250	$ 102,703	
107	20 MGD Expansion	Raw Water Pump Station	Replace existing 4 MGD pump with 7.5 MGD pump to ensure plant meets 20 MGD firm capacity with three dedicated pumps	$ 665,000	Yes	$ 831,250	$ 935,579	
114	20 MGD Expansion	Sitewide	Sitewide lighting upgrade to support continued nighttime operations. For purpose of cost estimate, assuming that sitewide external lighting is replaced with high efficiency LED system.	$ 156,532	Yes	$ 195,665	$ 220,223	
127	20 MGD Expansion	Solids - Gravity Thickener	To increase solids mixing redundancy, recommend purchasing and installing a second mixing pump to give 1+1 configuration	$ 104,385	Yes	$ 130,481	$ 146,858	
136	20 MGD Expansion	WWEQ Basin	Modifications necessary to support chemical pipelines along western WWEQ Basin wall	$ 300,000	Yes	$ 375,000	$ 434,728	
140	20 MGD Expansion	Chemical Storage/ Ozone Generation	Replace 6,000-gallon rented LOX tank with larger tank	$ 88,917	Yes	$ 111,146	$ 125,096	
174	20 MGD Expansion	Finished Water Pump Station	Conduct tracer study in support of receiving OHA ozonation waiver	$ 50,000	Yes	$ 62,500	$ 70,344	

Notes:
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WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
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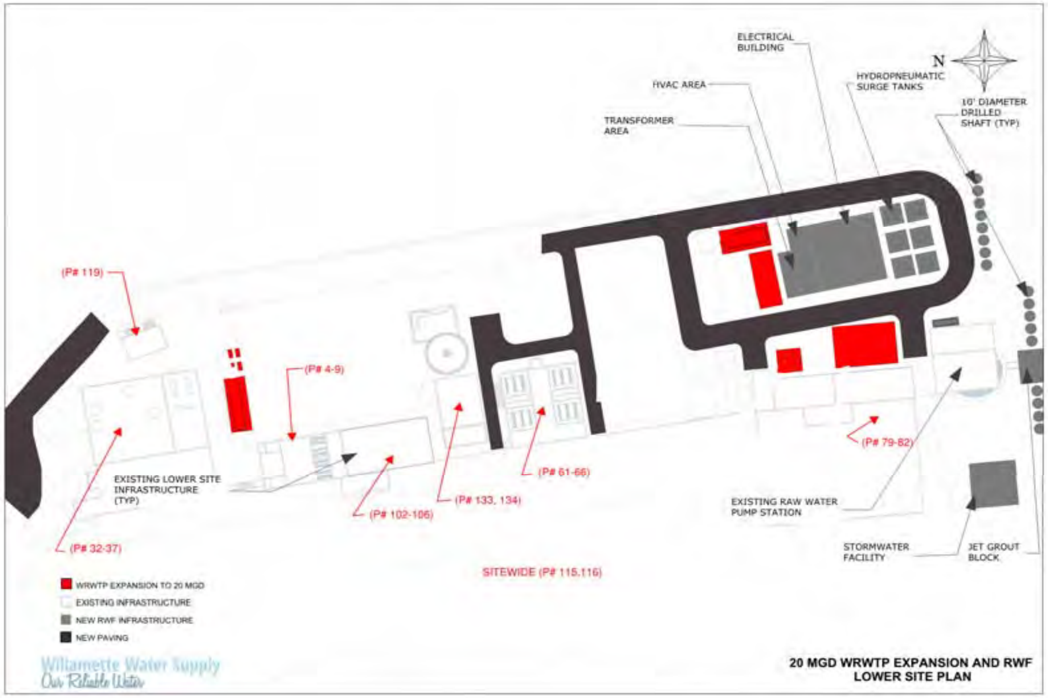
PROJECT NO. 2

Project Title	Life-Safety Repairs
Project Category	Renewal and Replacement
Project Description	The preliminary life-safety analysis identified issues about building code compliance and structural improvements. This 2017 MPU recommends modifications to support worker safety after a catastrophic seismic event.



WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
CAPITAL IMPROVEMENT PLAN WORKBOOK
PROJECT NO. 2

Project Summary Table

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost(1)	Future Value in Project Year - Escalation	Actual Construction Cost
4	Life-Safety Repairs	Actiflo™	Exterior stair guardrail height is less than 42” and has no dedicated handrail. Replace with current code-compliant installation. (LS3)	$ 6,427	No	$ 7,070	$ 8,196	
5	Life-Safety Repairs	Actiflo™	Active leaks observed in the ozone gallery, creating a slip hazard. Pressure inject hydrophobic sealant into active leaks. Leaking joints may require negative side joint covers. (LS9)	$ 36,136	No	$ 39,750	$ 46,081	
6	Life-Safety Repairs	Actiflo™	The rated electrical service is 1200 amps or greater requiring two exits with panic hardware. Install panic hardware on doors. (LS4)	$ 7,011	No	$ 7,712	$ 8,940	
7	Life-Safety Repairs	Actiflo™	The west guardrail on top of the Actiflo™ tanks does not have continuous kickplates. Install new kickplates as required. (LS8)	$ 2,305	No	$ 2,536	$ 2,939	
8	Life-Safety Repairs	Actiflo™	Electrical outlets on gallery walls are in a wet area. Replace with GFCI protected outlets. (LS10)	$ 2,425	No	$ 2,668	$ 3,092	
9	Life-Safety Repairs	Actiflo™	The doors were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required at Actiflo™ building. (LS7)	$ 33,171	No	$ 36,488	$ 42,300	
32	Life-Safety Repairs	Chemical Storage/ Ozone Generation	The chemical pipes that run through the center of the Chemical Storage Room are not seismically braced. Ozone and LOX piping in the Ozone Generation Room are not sesimically braced. Provide seismic bracing for these lines. (LS19, LS20)	$ 36,926	No	$ 40,619	$ 47,088	
33	Life-Safety Repairs	Chemical Storage/ Ozone Generation	Color-coded NFPA placards have faded. Replace all faded NFPA placards (LS2)	$ 9,205	No	$ 10,126	$ 11,738	
34	Life-Safety Repairs	Chemical Storage/	Chemical Storage and Ozone Generation Rooms are Group H occupancy or rated electrical service of 1200 A. Install panic hardware on three exit doors in the chemical storage and ozone generation building. (LS4; LS5)	$ 10,517	No	$ 11,569	$ 13,411	
35	Life-Safety Repairs	Chemical Storage/	Change swing direction on exit door between the ozone generation and administration building (LS5)	$ 5,067	No	$ 5,574	$ 6,461	
36	Life-Safety Repairs	Chemical Storage/	Chemical lines pass above egress routes. Add containment pans to chemical conveyance lines that are located above doorways in the chemical storage and ozone generation building (LS6)	$ 11,985	No	$ 13,184	$ 15,283	
37	Life-Safety Repairs	Chemical Storage/	Install emergency shut-off at the two other exits in the Ozone Generation Room exits (LS15)	$ 11,664	No	$ 12,830	$ 14,874	
61	Life-Safety Repairs	Filters	Exterior stair guardrail height is less than 42” and has no dedicated handrail. Replace with current code-compliant installation. (LS3)	$ 6,427	No	$ 7,070	$ 8,196	
62	Life-Safety Repairs	Filters	Active leaks observed in the ozone gallery, creating a slip hazard. Pressure inject hydrophobic sealant into active leaks. Leaking joints may require negative side joint covers. (LS9)	$ 34,854	No	$ 38,339	$ 44,446	
63	Life-Safety Repairs	Filters	The west guardrail on top of the the Filter ladder pit does not have continuous kickplates. Install new kickplates as required. (LS8)	$ 2,305	No	$ 2,536	$ 2,939	
64	Life-Safety Repairs	Filters	Electrical outlets on gallery walls are in a wet area. Replace with GFCI protected outlets. (LS10)	$ 4,851	No	$ 5,336	$ 6,186	
65	Life-Safety Repairs	Filters	Add a fire-rated door at the bottom of the filter gallery stairs and add signage to existing ladder pit door to clarify that it is not an exit. (LS12)	$ 3,505	No	$ 3,856	$ 4,470	
66	Life-Safety Repairs	Filters	The doors for various rooms were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required in the air scour blower room. (LS7)	$ 43,493	No	$ 47,842	$ 55,462	
79	Life-Safety Repairs	Finished Water Pump Station	The cable trays lack longitudinal bracing. Add bracing to existing cable trays. (LS18)	$ 14,553	No	$ 16,008	$ 18,558	

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PROJECT NO. 2

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost[1]	Future Value in Project Year - Escalation	Actual Construction Cost
80	Life-Safety Repairs	Finished Water Pump Station	The rated electrical service is 1200 amps or greater requiring two exits with panic hardware. Install panic hardware on doors. (LS4)	$ 7,011	No	$ 7,712	$ 8,940	
81	Life-Safety Repairs	Finished Water Pump Station	The doors for various rooms were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required in the finished water pump station. (LS7)	$ 81,982	No	$ 90,180	$ 104,544	
82	Life-Safety Repairs	Finished Water Pump Station	Switchgear Room has rated electrical service is 1200 amps or greater requiring two exits with panic hardware. Install panic hardware on doors. (LS4)	$ 7,011	No	$ 7,712	$ 8,940	
102	Life-Safety Repairs	Ozonation	The ozone destruct pipe on the top side is not seismically braced or marked. Add chemical service label and provide seismic bracing down to the concrete deck. (LS17)	$ 11,809	No	$ 12,990	$ 15,059	
103	Life-Safety Repairs	Ozonation	Exterior stair guardrail height is less than 42" and has no dedicated handrail. Replace with current code-compliant installation. (LS3)	$ 6,427	No	$ 7,070	$ 8,196	
104	Life-Safety Repairs	Ozonation	Active leaks observed in the ozone gallery, creating a slip hazard. Pressure inject hydrophobic sealant into active leaks. Leaking joints may require negative side joint covers. (LS9)	$ 44,468	No	$ 48,915	$ 56,706	
105	Life-Safety Repairs	Ozonation	Electrical outlets on gallery walls are in a wet area. Replace with GFCI protected outlets. (LS10)	$ 2,425	No	$ 2,668	$ 3,092	
106	Life-Safety Repairs	Ozonation	The south stairwell does not have any ventilation system serving it directly. Investigate and repair as required. (LS11)	$ 10,499	No	$ 11,549	$ 13,388	
115	Life-Safety Repairs	Sitewide	The space heaters throughout the plant are laterally braced above their center of gravity. The space heaters at the Switchgear Room are not braced. Provide additional seismic bracing to approximately eight locations. (LS16)	$ 11,827	No	$ 13,010	$ 15,082	
116	Life-Safety Repairs	Sitewide	Tread plate hatches do not have provisions for installing temporary fall protection barriers. Install sleeves or other hardware for temporary fall protection. (LS1)	$ 42,284	No	$ 46,512	$ 53,921	
119	Life-Safety Repairs	Solids - Dewatering	The Solids Handling Building roof does not appear to have an overflow scupper. Provide an overflow scupper with downspout. (LS14)	$ 8,855	No	$ 9,741	$ 11,292	
133	Life-Safety Repairs	WWEQ Basin	Verify how fall restraint is provided when using the ladder into the waste washwaster equalization basin and provide additional hardware as required. (LS13)	$ 7,546	No	$ 8,301	$ 9,623	
134	Life-Safety Repairs	WWEQ Basin	The doors for various rooms were propped open and appear to be their normal position. Suspect that ventilation in the room is not adequate. Investigate ventilation and correct as required at waste washwater equalization basin. (LS7)	$ 35,168	No	$ 38,685	$ 44,846	

Notes:
(1) In 09/17 dollars. Assuming 10% for legal and administration costs.

WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
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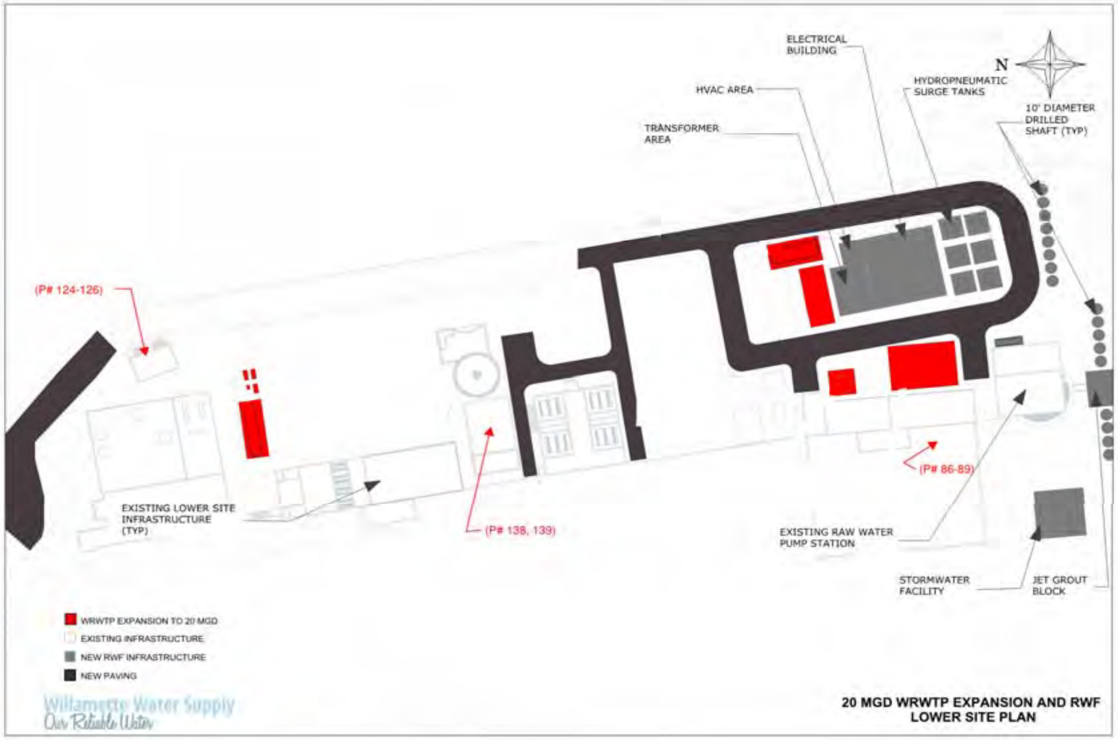
PROJECT NO. 3

Project Title	Seismic Retrofits
Project Category	Risk Mitigation
Project Description	The preliminary structural analysis identified both structural and non-structural vulnerabilities that may affect plant performance in a regional catastrophic seismic event. We recommend including seismic retrofits to minimize infrastructure downtime and ensure plant performance after a catastrophic event.



WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
CAPITAL IMPROVEMENT PLAN WORKBOOK
PROJECT NO. 3

Project Summary Table

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost(1)	Future Value in Project Year - Escalation	Actual Construction Cost
86	Seismic Retrofits	Finished Water Pump Station	The roof joist wall anchorage along the east and west walls of the High Service PS have a DCR of 1.55. Add new wall anchorage along the east and west walls between the existing roof joists. (S3)	$ 144,364	Yes	$ 180,455	$ 209,197	
87	Seismic Retrofits	Finished Water Pump Station	The roof diaphragm shear at the High Service PS has a DCR of 1.82 to 2.25. Replace existing deficient deck sections with 16 GA corrugated steel decking. (S4)	$ 125,618	Yes	$ 157,023	$ 182,032	
88	Seismic Retrofits	Finished Water Pump Station	Tension capacity of the diaphragm chords at the High Service PS has a DCR of 1.20 at connections at the east windows. Strengthen chord splices as required. (S5)	$ 12,159	Yes	$ 15,199	$ 17,620	
89	Seismic Retrofits	Finished Water Pump Station	Roof deck shear transfer to interior wall ledger bolts at the High Service PS have DCR’s of 3.20 to 3.90. Add new top plate over exterior shear wall and install epoxied anchors. (S6)	$ 87,647	Yes	$ 109,559	$ 127,009	
124	Seismic Retrofits	Solids - Dewatering	The Solids Handling Building has no lateral load resisting system in the transverse direction at the lower level. Provide structural bracing in the east-west direction by installation of shear wall extensions or exterior steel bracing. (S7)	$ 47,722	Yes	$ 59,653	$ 69,154	
125	Seismic Retrofits	Solids - Dewatering	The roof joist wall anchorage along the east and west walls of the Solids Handling Building have a DCR of 1.17. Add new wall anchorage along the east and west walls between the existing roof joists. (S8)	$ 62,761	Yes	$ 78,451	$ 90,947	
126	Seismic Retrofits	Solids - Dewatering	The foundation elements at the Solids Handling Building do not have adequate ties. The floor slab is not doweled into the walls or the footings. Tie the existing slab to the walls with stainless steel angles and epoxy anchors. (S9)	$ 24,672	Yes	$ 30,840	$ 35,752	
138	Seismic Retrofits	WWEQ Basin	Waste Washwater EQ Basin North & South Walls: Horizontal reinforcing steel at east corners (#8 @ 12” OC) have a DCR of 1.53 for soil seismic loads. Recommend adding additional reinforced shotcrete to wall or adding three concete/steel braces across the basin. (S1)	$ 219,386	Yes	$ 274,233	$ 317,911	
139	Seismic Retrofits	WWEQ Basin	Waste Washwater EQ Basin North & South Walls: Wall shear at the concrete beam has a DCR of 1.67 for soil seismic loads. Recommend addition of reinforced shotcrete to wall or addition of concrete/steel braces across the basin. (S2)	$ 197,164	Yes	$ 246,455	$ 285,709	

Notes:
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WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
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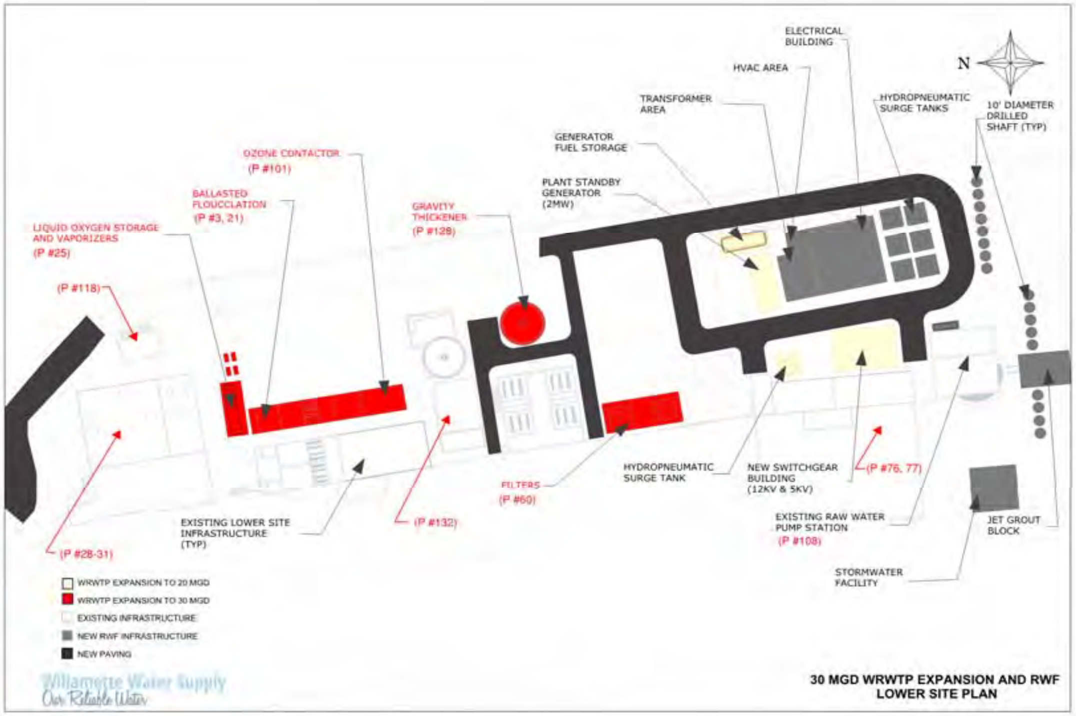
PROJECT NO. 4

Project Title	30 MGD Expansion
Project Category	Capacity Improvement
Project Description	To maximize the available space at the WRWTP with the goal of achieving a total capacity of 60 mgd in the existing site boundary, the 30-mgd capacity expansion will be designed based on updated process design criteria for the 20-mgd capacity expansion. This will allow the plant to maximize the available space at the WRWTP with the intention of achieving a total capacity of 60 mgd within the existing site boundary. Additionally, using the uprated criteria will allow the WRWTP to deliver high-quality finished water to the cities of Wilsonville, Sherwood, and any potential distribution partners while minimizing rate increases. The 30 mgd expansion requires the following major construction projects: • One Actiflo® basin. • One ozonation basin. • Two filters. • One 35-foot diameter gravity thickener.



30 MGD WRWTP EXPANSION AND RWF LOWER SITE PLAN

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PROJECT NO. 4

Project Summary Table

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost[(1)]	Future Value in Project Year - Escalation	Actual Construction Cost
3	30 MGD Expansion	Actiflo™	Construct an additional Actiflo basin for the 30 MGD capacity upgrade. With the addition of a third basin, the WRWTP will have three 10 MGD basins and can run two basins at 15 MGD in the event one basin requires maintenance.	$ 4,864,843	Yes	$ 6,081,054	$ 10,051,055	
21	30 MGD Expansion	Actiflo™	Replace the two installed flash mix pumps	$ 378,229	Yes	$ 472,786	$ 781,444	
25	30 MGD Expansion	Chemical Storage/ Ozone Generation	Replace existing 6,000 gallon LOX storage tank with larger tank (12,000 to 15,000 gallons) to ensure sufficient storage with 20 MGD plant capacity. Recommend purchasing LOX tank (rather than leasing from vendor) so LOX can be purchased from different vendors.	$ 262,500	Yes	$ 328,125	$ 542,341	
28	30 MGD Expansion	Chemical Storage/ Ozone Generation	Install a second dry polymer feeder to provide redundancy to plant chemical operations	$ 240,000	Yes	$ 300,000	$ 495,854	
29	30 MGD Expansion	Chemical Storage/ Ozone Generation	Install a third 400 PPD ozone generator to support plant capacity expansion	$ 1,193,917	Yes	$ 1,492,396	$ 2,466,704	
30	30 MGD Expansion	Chemical Storage/ Ozone Generation	Convert hypochlorite system from liquid chemical storage to dry sodium hypochlorite process system for increased storage capacity and plant resiliency.	$ 637,883	Yes	$ 797,354	$ 1,317,904	
31	30 MGD Expansion	Chemical Storage/ Ozone Generation	Modify existing Chemical Storage Room to increase usable space for existing chemical systems. Recommendations include installation of roll-up door, removal of aqueous ammonia system, modifications necessary to expand hypochlorite system, and modifications to chemical containment to allow additional tanks.	$ 160,350	Yes	$ 200,438	$ 331,293	
60	30 MGD Expansion	Filters	Construct two new media filters to support plant expansion to 30 MGD	$ 4,185,194	Yes	$ 5,231,493	$ 8,646,860	
76	30 MGD Expansion	Finished Water Pump Station	Upgrade three existing 7.5 MGD finished water pumps with three 12 MGD pumps	$ 4,896,098	Yes	$ 6,120,123	$ 10,115,630	
77	30 MGD Expansion	Finished Water Pump Station	Install a fifth finished water pump as part of the 30 MGD upgrade. Recommend 7.5 MGD pump (only valid if not installed during 20 MGD expansion)	$ 1,185,023	Yes	$ 1,481,279	$ 2,448,328	
101	30 MGD Expansion	Ozonation	Construct a third ozone basin and gallery to support 30 MGD expansion	$ 3,420,955	Yes	$ 4,276,194	$ 7,067,897	
108	30 MGD Expansion	Raw Water Pump Station	Replace two existing 7.5 MGD pumps with 15 MGD pumps	$ 1,772,847	Yes	$ 2,216,059	$ 3,662,807	
118	30 MGD Expansion	Solids - Dewatering	Install a third 60 GPM centrifuge and solids transfer pump to support the 30 MGD plant expansion	$ 1,665,316	Yes	$ 2,081,645	$ 3,440,642	
128	30 MGD Expansion	Solids - Gravity Thickener	Construct a second 35-ft diameter gravity thickener to support the 30 MGD plant expansion and provide solids handling redundancy	$ 870,475	Yes	$ 1,088,094	$ 1,798,453	
132	30 MGD Expansion	WWEQ Basin	Install fourth washwater recycle pump for additional redundancy at 30 MGD expansion	$ 281,250	Yes	$ 351,563	$ 581,079	
173	30 MGD Expansion	Finished Water Pump Station	Temporary pump station to supply 15 MGD from the WWSP Treatment Plant to the WRWTP distribution system in the event of a service distruption.	$ 4,896,098	Yes	$ 6,120,123	$ 10,115,630	

Notes:
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WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
CAPITAL IMPROVEMENT PLAN UPDATE
PROJECT NO. 5

Project Title	Operations - Repair & Replace
Project Category	Renewal and Replacement
Project Description	The WRWTP requires ongoing maintenance/repair and replacement (R&R) of its existing infrastructure to meet service goals. This 2017 MPU summarizes repair and replacement projects for the next 20 years.

Project Summary Table

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost(1)	Project Completion Year	Future Value in Project Year - Escalation	Actual Construction Cost
10	Repair & Replace	Actiflo™	Replace the four hydrocyclones installed in the two existing Actiflo Basins	$ 318,000	No	$ 349,800	2020	$ 382,236	
12	Repair & Replace	Actiflo™	Replace lamella settling tubes in the two existing Actiflo basins, which are damaged due to UV exposure.	$ 245,656	No	$ 270,222	2020	$ 295,278	
13	Repair & Replace	Actiflo™	Upgrade vendor PLC components in the two existing Actiflo basins	$ 62,108	No	$ 68,319	2022	$ 79,200	
14	Repair & Replace	Actiflo™	Replace the two flash mix pumps (installed and standby)	$ 188,760	No	$ 207,636	2020	$ 226,889	
15	Repair & Replace	Actiflo™	Replace the six mixers installed in the two existing Actiflo Basins	$ 302,400	No	$ 332,640	2022	$ 385,621	
16	Repair & Replace	Actiflo™	Replace the two sample pumps installed in the two existing Actiflo Basins	$ 46,051	No	$ 50,656	2022	$ 58,724	
17	Repair & Replace	Actiflo™	Replace original dry polymer batching system (T-13ME01)	$ 198,750	No	$ 218,625	2027	$ 293,814	
18	Repair & Replace	Actiflo™	PLC upgrade for Actiflo Local Control Panels	$ 84,000	No	$ 92,400	2027	$ 124,178	
19	Repair & Replace	Actiflo™	Replace existing streaming current analyzer on Actiflo inlet	$ 23,500	No	$ 25,850	2036	$ 45,328	
20	Repair & Replace	Actiflo™	Replace the five solids pumps (installed and standby) on the existing Actiflo basins	$ 640,000	No	$ 704,000	2036	$ 1,234,468	
22	Repair & Replace	Actiflo™	Replace the six mixers installed in the two existing Actiflo Basins	$ 302,400	No	$ 332,640	2036	$ 583,286	
23	Repair & Replace	Actiflo™	Replace the four hydrocyclones installed in the two existing Actiflo Basins	$ 369,000	No	$ 405,900	2036	$ 711,748	
38	Repair & Replace	Chemical Storage/ Ozone Generation	Upgrade vendor PLC components in the existing dry polymer blending unit	$ 22,060	No	$ 24,266	2022	$ 28,131	
40	Repair & Replace	Chemical Storage/ Ozone Generation	Replate two existing 300 PPD ozone generators with 400 PPD units	$ 1,752,000	No	$ 1,927,200	2022	$ 2,234,153	
42	Repair & Replace	Chemical Storage/ Ozone Generation	Inspect existing alum tank and repair as needed	$ 52,500	No	$ 57,750	2022	$ 66,948	
43	Repair & Replace	Chemical Storage/ Ozone Generation	Inspect existing caustic soda tank and repair as needed	$ 52,500	No	$ 57,750	2022	$ 66,948	
44	Repair & Replace	Chemical Storage/ Ozone Generation	Replace the LOX evaporator equipment	$ 112,500	No	$ 123,750	2036	$ 216,996	
68	Repair & Replace	Filters	Replace existing air scour blowers and motors on existing media filtration system	$ 351,000	No	$ 386,100	2022	$ 447,596	
73	Repair & Replace	Filters	Replace aging MCC in existing filter gallery	$ 70,000	No	$ 77,000	2036	$ 135,020	
74	Repair & Replace	Filters	Replace air scour blowers and motors on existing media filtration system	$ 402,000	No	$ 442,200	2036	$ 775,400	

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PROJECT NO. 5

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost(1)	Project Completion Year	Future Value in Project Year - Escalation	Actual Construction Cost
83	Repair & Replace	Finished Water Pump Station	Replace VFDs on three Finished Water Pumps	$ 596,336	No	$ 655,970	2019	$ 695,918	
84	Repair & Replace	Finished Water Pump Station	Replace existing soft-start controller on High Service Pump 3	$ 84,000	No	$ 92,400	2027	$ 124,178	
85	Repair & Replace	Finished Water Pump Station	Replace two existing backwash supply pumps in the Wastewater Equalization Basin	$ 1,980,000	No	$ 2,178,000	2032	$ 3,393,253	
92	Repair & Replace	Miscellaneous	Replace the existing safety and warning signs throughout the site	$ 15,000	No	$ 16,500	2022	$ 19,128	
93	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2020	$ 8,414	
94	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2020	$ 5,259	
95	Repair & Replace	Miscellaneous	Upgrade site security monitoring system camera and computer	$ 23,500	No	$ 25,850	2020	$ 28,247	
96	Repair & Replace	Miscellaneous	Replace sitewide fire extinguishers	$ 15,000	No	$ 16,500	2022	$ 19,128	
97	Repair & Replace	Miscellaneous	Replace the two existing irrigation waste pumps (T-30P01/2)	$ 340,000	No	$ 374,000	2022	$ 433,569	
98	Repair & Replace	Miscellaneous	Replace the two existing water feature pumps (T-30P01/2)	$ 340,000	No	$ 374,000	2027	$ 502,625	
109	Repair & Replace	Raw Water Pump Station	Replace existing raw water sump pump	$ 100,000	No	$ 110,000	2020	$ 120,200	
110	Repair & Replace	Raw Water Pump Station	Replace osbsolete Robocon VFDs on three Raw Water Pumps	$ 97,375	No	$ 107,113	2019	$ 113,636	
111	Repair & Replace	Raw Water Pump Station	Replace two existing Air Burst Compressors	$ 395,000	No	$ 434,500	2027	$ 583,932	
112	Repair & Replace	Raw Water Pump Station	Replace existing air burst control panel PLC and local control panel	$ 42,375	No	$ 46,613	2027	$ 62,643	
113	Repair & Replace	Raw Water Pump Station	Replace the existing constant-speed 7.5 MGD pump with a VFD-controlled pump	$ 682,500	No	$ 750,750	2036	$ 1,316,445	
117	Repair & Replace	Sitewide	Replace obsolete ABB magnetic flow meters installed throughout the WRWTP and at Wilsonville Road	$ 662,400	No	$ 728,640	2019	$ 773,014	
120	Repair & Replace	Solids - Dewatering	Replace the existing dewatered sludge screw conveyor in the Solids Handling Building	$ 87,000	No	$ 95,700	2022	$ 110,943	
121	Repair & Replace	Solids - Dewatering	Replace two existing 60 GPM centrifuges and transfer pumps	$ 3,500,000	No	$ 3,850,000	2027	$ 5,174,078	
122	Repair & Replace	Solids - Dewatering	Replace existing PLC and local control panel for two dewatering centrifuges	$ 84,000	No	$ 92,400	2027	$ 124,178	
123	Repair & Replace	Solids - Dewatering	Replace two existing 60 GPM solids transfer pumps	$ 316,059	No	$ 347,665	2036	$ 609,633	
129	Repair & Replace	Solids - Gravity Thickener	Replace two existing sludge mixing pumps (one installed, one shelf spare)	$ 260,000	No	$ 286,000	2020	$ 312,520	
130	Repair & Replace	Solids - Gravity Thickener	Replace the two existing sludge mixing pumps	$ 260,000	No	$ 286,000	2032	$ 445,579	
131	Repair & Replace	Solids - Gravity Thickener	Replace the existing gravity thickener drive	$ 114,264	No	$ 125,690	2036	$ 220,399	
135	Repair & Replace	WWEQ Basin	Replace three existing filter waste washwater recycle pumps	$ 300,000	No	$ 330,000	2020	$ 360,600	
137	Repair & Replace	WWEQ Basin	Replace three existing filter waste washwater recycle pumps	$ 43,036	No	$ 47,340	2036	$ 83,010	

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PROJECT NO. 5

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost$^{(1)}$	Project Completion Year	Future Value in Project Year - Escalation	Actual Construction Cost
141	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2021	$ 8,666	
142	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2021	$ 5,417	
143	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2022	$ 8,926	
144	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2022	$ 5,579	
145	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2023	$ 9,194	
146	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2023	$ 5,746	
147	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2024	$ 9,470	
148	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2024	$ 5,919	
149	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2025	$ 9,754	
150	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2025	$ 6,096	
151	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2026	$ 10,047	
152	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2026	$ 6,279	
153	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2027	$ 10,348	
154	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2027	$ 6,468	
155	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2028	$ 10,659	
156	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2028	$ 6,662	
157	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2029	$ 10,978	
158	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2029	$ 6,861	
159	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2030	$ 11,308	
160	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2030	$ 7,067	
161	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2031	$ 11,647	
162	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2031	$ 7,279	
163	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2032	$ 11,996	
164	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2032	$ 7,498	
165	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2033	$ 12,356	

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PROJECT NO. 5

P#	CIP Project Stage	System Name	CIP - Task Description	Estimated Construction Cost	Design Project?	Estimated Task Cost[(1)]	Project Completion Year	Future Value in Project Year - Escalation	Actual Construction Cost
166	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2033	$ 7,723	
167	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2034	$ 12,727	
168	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2034	$ 7,954	
169	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2035	$ 13,109	
170	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2035	$ 8,193	
171	Repair & Replace	Miscellaneous	Annual maintenance on the existing site fire alarm	$ 7,000	No	$ 7,700	2036	$ 13,502	
172	Repair & Replace	Miscellaneous	Annual maintenance on the existing site sprinkler system	$ 4,375	No	$ 4,813	2036	$ 8,439	

Notes:
(1) In 09/17 dollars. Assuming 15% contingency for Design and 10% for legal and administration costs.

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Financial Summary - CIP Costs in $2017

PROJECT	FY	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
20 MGD Expansion													
Design		$ -	$ 1,885,517	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ 419,004	$ 419,004	$ 419,004	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ 6,285,055	$ 6,285,055	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ 2,304,520	$ 6,704,059	$ 6,704,059	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Life-Safety Repairs													
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ 28,007	$ 28,007	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ -	$ -	$ 560,139	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ -	$ -	$ 28,007	$ 588,146	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Seismic Retrofits													
Design		$ -	$ -	$ -	$ 138,224	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ 46,075	$ 46,075	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ -	$ -	$ 921,493	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ -	$ -	$ 184,299	$ 967,568	$ -	$ -	$ -	$ -	$ -	$ -	$ -
30 MGD Expansion													
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Repair & Replace													
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ 135,611	$ 144,729	$ 1,138	$ 310,899	$ 1,138	$ 1,138	$ 1,138	$ 1,138	$ 473,950	$ 1,138
Construction		$ -	$ -	$ 1,356,111	$ 1,447,291	$ 11,375	$ 3,108,994	$ 11,375	$ 11,375	$ 11,375	$ 11,375	$ 4,739,500	$ 11,375
Total		$ -	$ -	$ 1,491,722	$ 1,592,020	$ 12,513	$ 3,419,893	$ 12,513	$ 12,513	$ 12,513	$ 12,513	$ 5,213,450	$ 12,513
Total		$ -	$ 2,304,520	$ 8,195,781	$ 8,508,384	$ 1,568,226	$ 3,419,893	$ 12,513	$ 12,513	$ 12,513	$ 12,513	$ 5,213,450	$ 12,513
Stakeholders	**Resp.**												
City of Wilsonville		$ -	$ 1,537,115	$ 5,466,586	$ 5,675,092	$ 1,046,007	$ 2,281,069	$ 8,346	$ 8,346	$ 8,346	$ 8,346	$ 3,477,371	$ 8,346
20 MGD Expansion	66.7%	$ -	$ 1,537,115	$ 4,471,607	$ 4,471,607	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Life Safety Repairs	66.7%	$ -	$ -	$ -	$ 18,681	$ 392,293	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Seismic Retrofits	66.7%	$ -	$ -	$ -	$ 122,927	$ 645,368	$ -	$ -	$ -	$ -	$ -	$ -	$ -
30 MGD Expansion	67.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Repair & Replace	66.7%	$ -	$ -	$ 994,979	$ 1,061,877	$ 8,346	$ 2,281,069	$ 8,346	$ 8,346	$ 8,346	$ 8,346	$ 3,477,371	$ 8,346
City of Sherwood		$ -	$ 767,405	$ 2,729,195	$ 2,833,292	$ 522,219	$ 1,138,825	$ 4,167	$ 4,167	$ 4,167	$ 4,167	$ 1,736,079	$ 4,167
20 MGD Expansion	33.3%	$ -	$ 767,405	$ 2,232,452	$ 2,232,452	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Life Safety Repairs	33.3%	$ -	$ -	$ -	$ 9,326	$ 195,853	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Seismic Retrofits	33.3%	$ -	$ -	$ -	$ 61,371	$ 322,200	$ -	$ -	$ -	$ -	$ -	$ -	$ -
30 MGD Expansion	32.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Repair & Replace	33.3%	$ -	$ -	$ 496,743	$ 530,143	$ 4,167	$ 1,138,825	$ 4,167	$ 4,167	$ 4,167	$ 4,167	$ 1,736,079	$ 4,167

Notes

1 For 20 MGD Expansion, Life Safety Repairs, Seismic Retrofits, and 30 MGD Expansion projects, all design costs were assumed to be in the first year of the project and the construction costs were split over the remaining project years.

2 For the Repair and Replace projects, the design and construction costs were assumed to be in the project completion year.

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Financial Summary - CIP Costs in $2017

PROJECT	FY	2029	2030	2031	2032	2033	2034	2035	2036	TOTAL
20 MGD Expansion										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,885,517
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,257,011
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,570,110
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 15,712,638
Life-Safety Repairs										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 56,014
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 560,139
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 616,153
Seismic Retrofits										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 138,224
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 92,149
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 921,493
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,151,866
30 MGD Expansion										
Design		$ -	$ -	$ 4,636,647	$ -	$ -	$ -	$ -	$ -	$ 4,636,647
Administration		$ -	$ -	$ 1,030,366	$ 1,030,366	$ 1,030,366	$ -	$ -	$ -	$ 3,091,098
Construction		$ -	$ -	$ -	$ 15,455,489	$ 15,455,489	$ -	$ -	$ -	$ 30,910,978
Total		$ -	$ -	$ 5,667,013	$ 16,485,855	$ 16,485,855	$ -	$ -	$ -	$ 38,638,723
Repair & Replace										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ 1,138	$ 1,138	$ 1,138	$ 225,138	$ 1,138	$ 1,138	$ 1,138	$ 308,663	$ 1,612,641
Construction		$ 11,375	$ 11,375	$ 11,375	$ 2,251,375	$ 11,375	$ 11,375	$ 11,375	$ 3,086,634	$ 16,126,405
Total		$ 12,513	$ 12,513	$ 12,513	$ 2,476,513	$ 12,513	$ 12,513	$ 12,513	$ 3,395,297	$ 17,739,046
Total		$ 12,513	$ 12,513	$ 5,679,525	$ 18,962,367	$ 16,498,367	$ 12,513	$ 12,513	$ 3,395,297	$ 73,858,425
Stakeholders	**Resp.**									
City of Wilsonville		$ 8,346	$ 8,346	$ 3,844,913	$ 12,812,758	$ 11,169,270	$ 8,346	$ 8,346	$ 2,264,663	$ 48,112,842
20 MGD Expansion	66.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8,943,214
Life Safety Repairs	66.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 410,974
Seismic Retrofits	66.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 768,295
30 MGD Expansion	67.7%	$ -	$ -	$ 3,836,568	$ 11,160,924	$ 11,160,924	$ -	$ -	$ -	$ 26,158,415
Repair & Replace	66.7%	$ 8,346	$ 8,346	$ 8,346	$ 1,651,834	$ 8,346	$ 8,346	$ 8,346	$ 2,264,663	$ 11,831,943
City of Sherwood		$ 4,167	$ 4,167	$ 1,834,612	$ 6,149,610	$ 5,329,098	$ 4,167	$ 4,167	$ 1,130,634	$ 23,441,063
20 MGD Expansion	33.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,464,903
Life Safety Repairs	33.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 205,179
Seismic Retrofits	33.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 383,571
30 MGD Expansion	32.3%	$ -	$ -	$ 1,830,445	$ 5,324,931	$ 5,324,931	$ -	$ -	$ -	$ 12,480,307
Repair & Replace	33.3%	$ 4,167	$ 4,167	$ 4,167	$ 824,679	$ 4,167	$ 4,167	$ 4,167	$ 1,130,634	$ 5,907,102

Notes

1 For 20 MGD Expansion, Life Safety Repair

2 For the Repair and Replace projects, the d

WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
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Financial Summary - CIP Costs in $2017

PROJECT	**FY**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
20 MGD Expansion													
Design		$ -	$ 1,885,517	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ 419,004	$ 419,004	$ 419,004	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ 6,285,055	$ 6,285,055	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ 2,304,520	$ 6,704,059	$ 6,704,059	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Life-Safety Repairs													
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ 28,007	$ 28,007	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ -	$ -	$ 560,139	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ -	$ -	$ 28,007	$ 588,146	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Seismic Retrofits													
Design		$ -	$ -	$ -	$ 138,224	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ 46,075	$ 46,075	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ -	$ -	$ 921,493	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ -	$ -	$ 184,299	$ 967,568	$ -	$ -	$ -	$ -	$ -	$ -	$ -
30 MGD Expansion													
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Repair & Replace													
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ 135,611	$ 144,729	$ 1,138	$ 310,899	$ 1,138	$ 1,138	$ 1,138	$ 1,138	$ 473,950	$ 1,138
Construction		$ -	$ -	$ 1,356,111	$ 1,447,291	$ 11,375	$ 3,108,994	$ 11,375	$ 11,375	$ 11,375	$ 11,375	$ 4,739,500	$ 11,375
Total		$ -	$ -	$ 1,491,722	$ 1,592,020	$ 12,513	$ 3,419,893	$ 12,513	$ 12,513	$ 12,513	$ 12,513	$ 5,213,450	$ 12,513
Total		$ -	$ 2,304,520	$ 8,195,781	$ 8,508,384	$ 1,568,226	$ 3,419,893	$ 12,513	$ 12,513	$ 12,513	$ 12,513	$ 5,213,450	$ 12,513
Stakeholders	**Resp.**												
City of Wilsonville		$ -	$ 1,537,115	$ 5,466,586	$ 5,675,092	$ 1,046,007	$ 2,281,069	$ 8,346	$ 8,346	$ 8,346	$ 8,346	$ 3,477,371	$ 8,346
20 MGD Expansion	66.7%	$ -	$ 1,537,115	$ 4,471,607	$ 4,471,607	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Life Safety Repairs	66.7%	$ -	$ -	$ -	$ 18,681	$ 392,293	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Seismic Retrofits	66.7%	$ -	$ -	$ -	$ 122,927	$ 645,368	$ -	$ -	$ -	$ -	$ -	$ -	$ -
30 MGD Expansion	67.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Repair & Replace	66.7%	$ -	$ -	$ 994,979	$ 1,061,877	$ 8,346	$ 2,281,069	$ 8,346	$ 8,346	$ 8,346	$ 8,346	$ 3,477,371	$ 8,346
City of Sherwood		$ -	$ 767,405	$ 2,729,195	$ 2,833,292	$ 522,219	$ 1,138,825	$ 4,167	$ 4,167	$ 4,167	$ 4,167	$ 1,736,079	$ 4,167
20 MGD Expansion	33.3%	$ -	$ 767,405	$ 2,232,452	$ 2,232,452	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Life Safety Repairs	33.3%	$ -	$ -	$ -	$ 9,326	$ 195,853	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Seismic Retrofits	33.3%	$ -	$ -	$ -	$ 61,371	$ 322,200	$ -	$ -	$ -	$ -	$ -	$ -	$ -
30 MGD Expansion	32.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Repair & Replace	33.3%	$ -	$ -	$ 496,743	$ 530,143	$ 4,167	$ 1,138,825	$ 4,167	$ 4,167	$ 4,167	$ 4,167	$ 1,736,079	$ 4,167

Notes

1 For 20 MGD Expansion, Life Safety Repairs, Seismic Retrofits, and 30 MGD Expansion projects, all design costs were assumed to be in the first year of the project and the construction costs were split over the remaining project years.

2 For the Repair and Replace projects, the design and construction costs were assumed to be in the project completion year.

WILLAMETTE RIVER WATER TREATMENT PLANT - 2017 MASTER PLAN UPDATE
CAPITAL IMPROVEMENT PLAN UPDATE

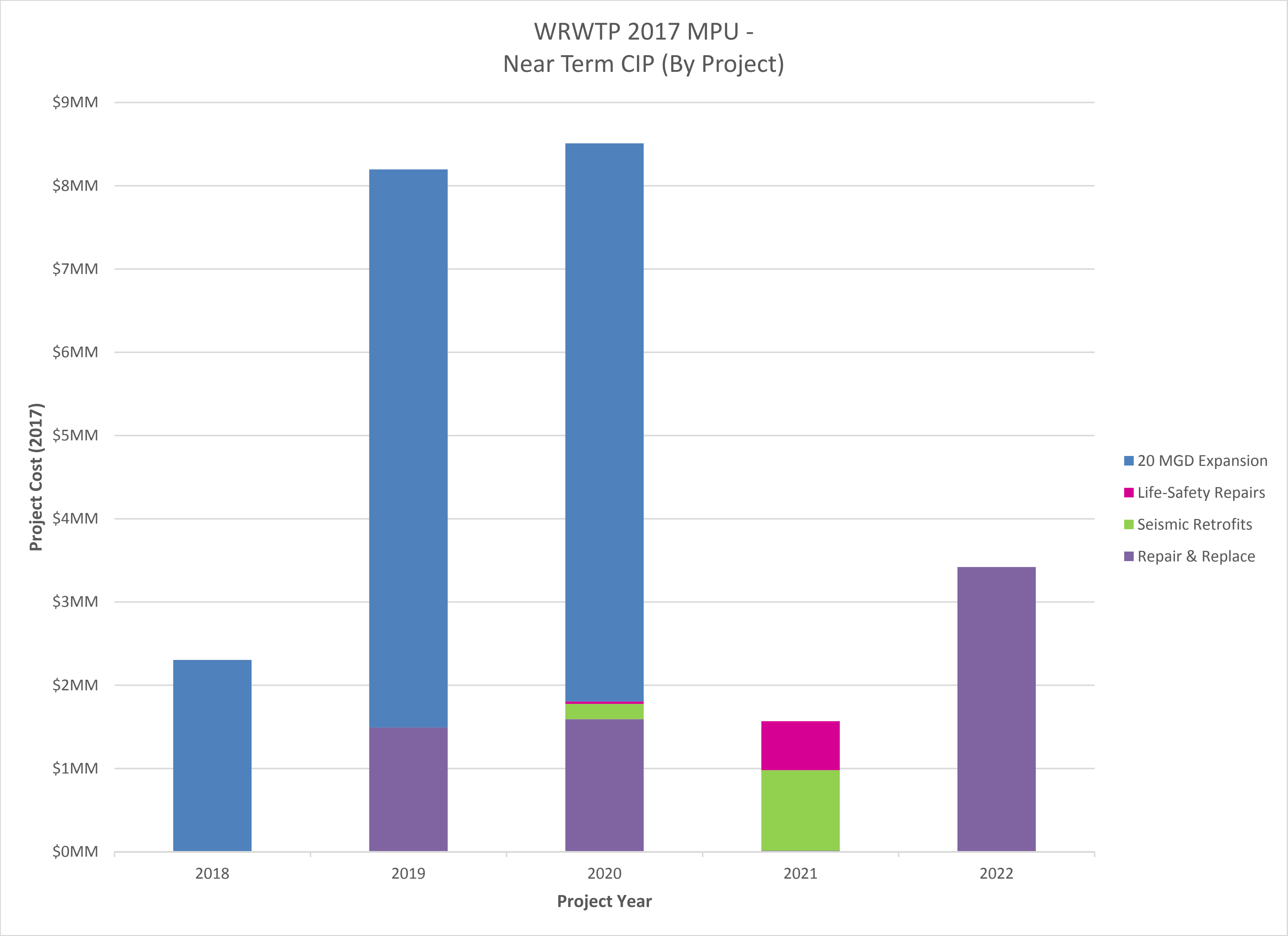
Financial Summary - CIP Costs in $2017

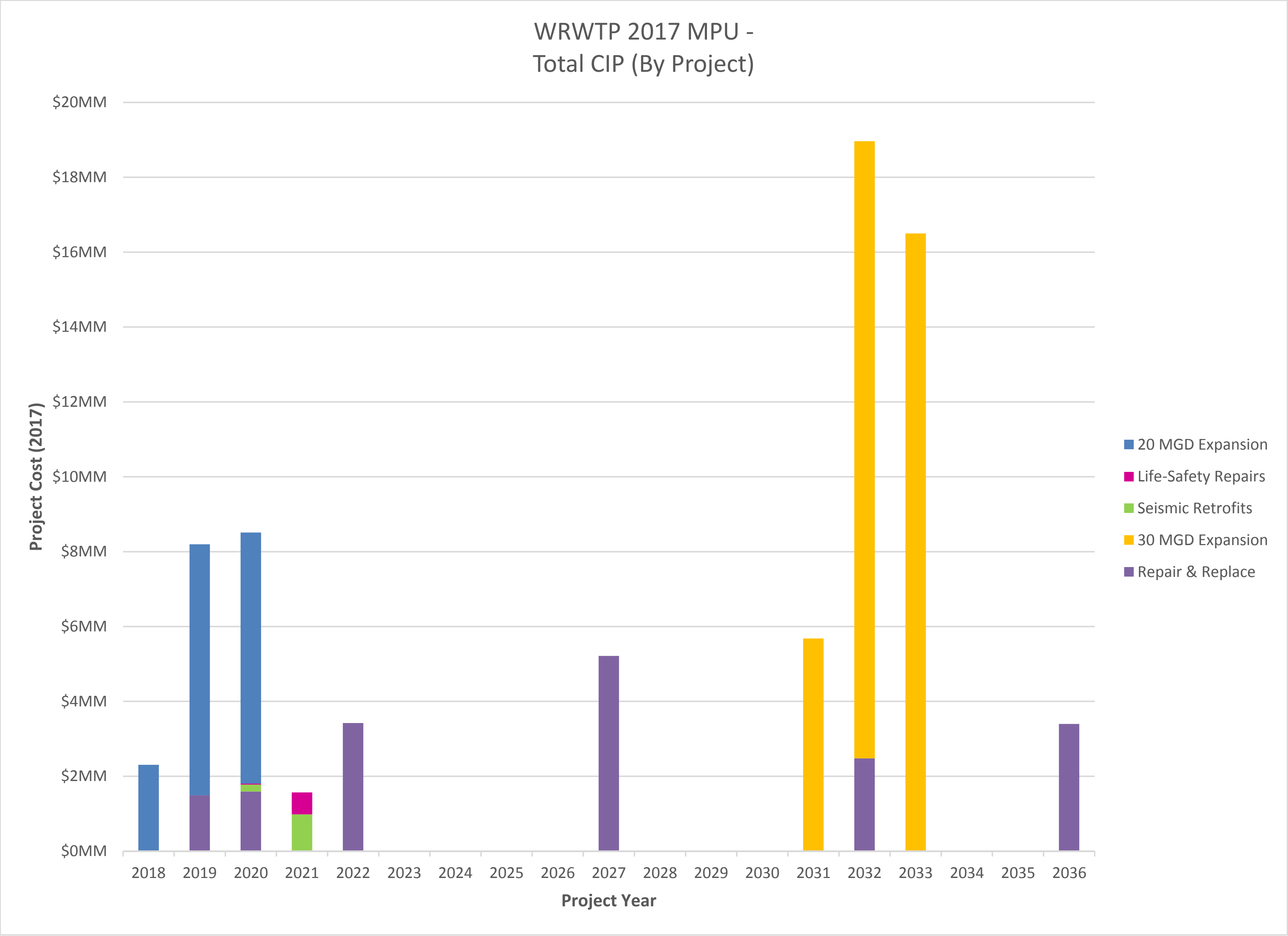
PROJECT	**FY**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**TOTAL**
20 MGD Expansion										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,885,517
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,257,011
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,570,110
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 15,712,638
Life-Safety Repairs										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 56,014
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 560,139
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 616,153
Seismic Retrofits										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 138,224
Administration		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 92,149
Construction		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 921,493
Total		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,151,866
30 MGD Expansion										
Design		$ -	$ -	$ 4,636,647	$ -	$ -	$ -	$ -	$ -	$ 4,636,647
Administration		$ -	$ -	$ 1,030,366	$ 1,030,366	$ 1,030,366	$ -	$ -	$ -	$ 3,091,098
Construction		$ -	$ -	$ -	$ 15,455,489	$ 15,455,489	$ -	$ -	$ -	$ 30,910,978
Total		$ -	$ -	$ 5,667,013	$ 16,485,855	$ 16,485,855	$ -	$ -	$ -	$ 38,638,723
Repair & Replace										
Design		$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Administration		$ 1,138	$ 1,138	$ 1,138	$ 225,138	$ 1,138	$ 1,138	$ 1,138	$ 308,663	$ 1,612,641
Construction		$ 11,375	$ 11,375	$ 11,375	$ 2,251,375	$ 11,375	$ 11,375	$ 11,375	$ 3,086,634	$ 16,126,405
Total		$ 12,513	$ 12,513	$ 12,513	$ 2,476,513	$ 12,513	$ 12,513	$ 12,513	$ 3,395,297	$ 17,739,046
Total		$ 12,513	$ 12,513	$ 5,679,525	$ 18,962,367	$ 16,498,367	$ 12,513	$ 12,513	$ 3,395,297	$ 73,858,425
Stakeholders	**Resp.**									
City of Wilsonville		$ 8,346	$ 8,346	$ 3,844,913	$ 12,812,758	$ 11,169,270	$ 8,346	$ 8,346	$ 2,264,663	$ 48,112,842
20 MGD Expansion	66.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 8,943,214
Life Safety Repairs	66.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 410,974
Seismic Retrofits	66.7%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 768,295
30 MGD Expansion	67.7%	$ -	$ -	$ 3,836,568	$ 11,160,924	$ 11,160,924	$ -	$ -	$ -	$ 26,158,415
Repair & Replace	66.7%	$ 8,346	$ 8,346	$ 8,346	$ 1,651,834	$ 8,346	$ 8,346	$ 8,346	$ 2,264,663	$ 11,831,943
City of Sherwood		$ 4,167	$ 4,167	$ 1,834,612	$ 6,149,610	$ 5,329,098	$ 4,167	$ 4,167	$ 1,130,634	$ 23,441,063
20 MGD Expansion	33.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,464,903
Life Safety Repairs	33.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 205,179
Seismic Retrofits	33.3%	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 383,571
30 MGD Expansion	32.3%	$ -	$ -	$ 1,830,445	$ 5,324,931	$ 5,324,931	$ -	$ -	$ -	$ 12,480,307
Repair & Replace	33.3%	$ 4,167	$ 4,167	$ 4,167	$ 824,679	$ 4,167	$ 4,167	$ 4,167	$ 1,130,634	$ 5,907,102

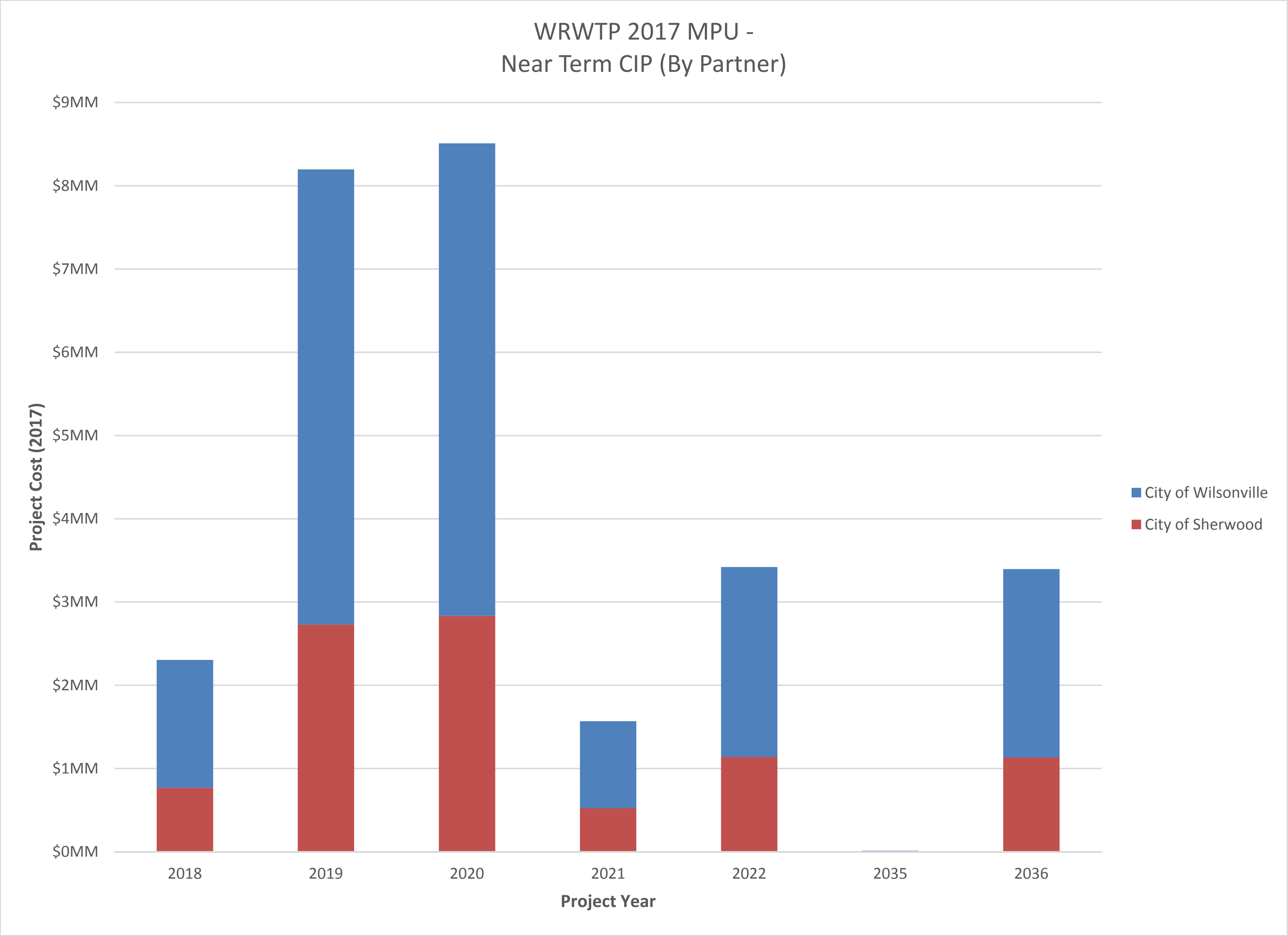
Notes

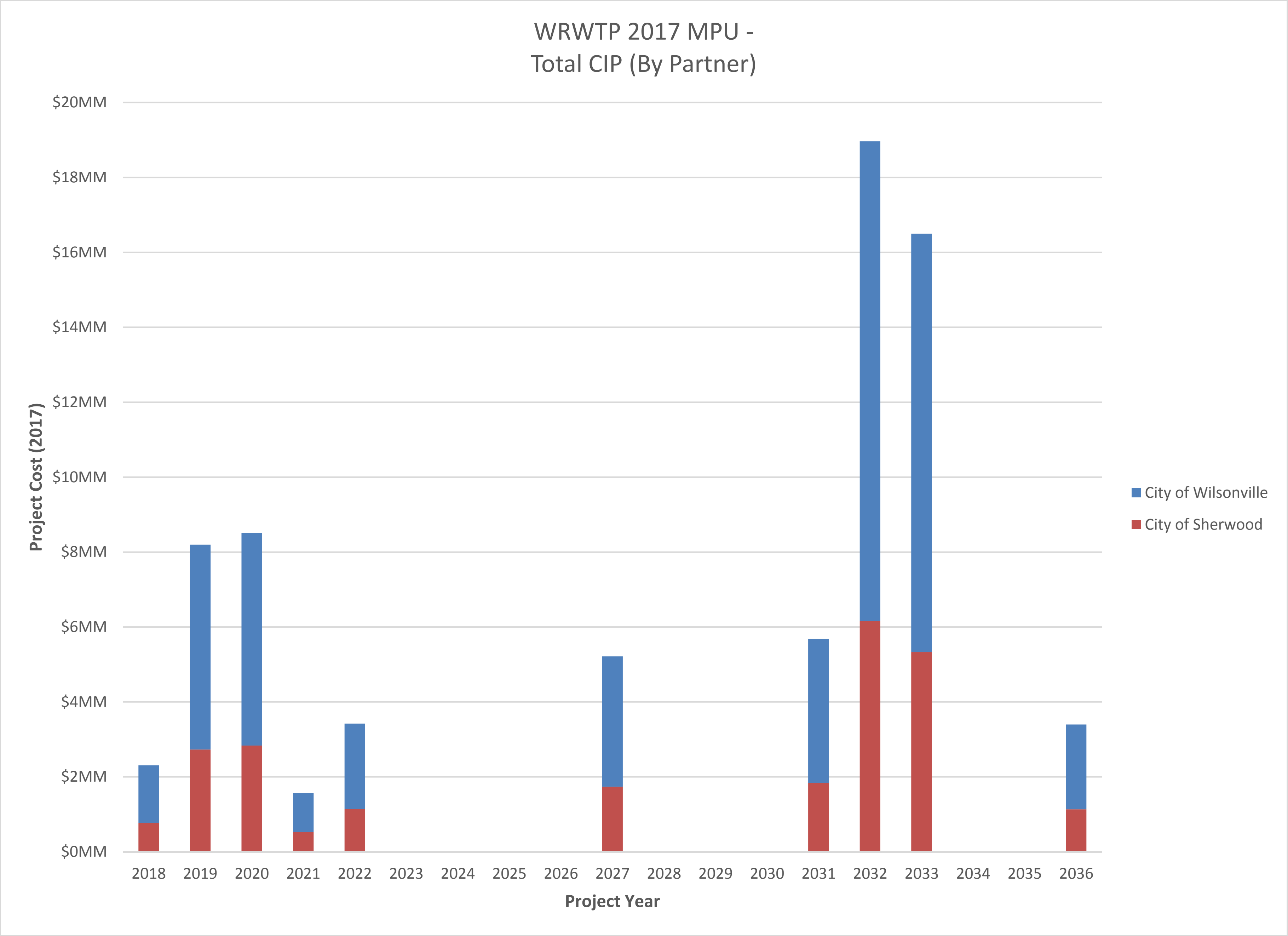
1 For 20 MGD Expansion, Life Safety Repair

2 For the Repair and Replace projects, the d


WRWTP 2017 MPU -
Near Term CIP (By Project)
Project Cost (2017)
$9MM
$8MM
$7MM
$6MM
$5MM
$4MM
$3MM
$2MM
$1MM
$0MM
2018
2019
2020
2021
2022
Project Year
20 MGD Expansion
Life-Safety Repairs
Seismic Retrofits
Repair & Replace


WRWTP 2017 MPU -
Total CIP (By Project)
Project Cost (2017)
$20MM
$18MM
$16MM
$14MM
$12MM
$10MM
$8MM
$6MM
$4MM
$2MM
$0MM
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
Project Year
20 MGD Expansion
Life-Safety Repairs
Seismic Retrofits
30 MGD Expansion
Repair & Replace


WRWTP 2017 MPU -
Near Term CIP (By Partner)
Project Cost (2017)
$9MM
$8MM
$7MM
$6MM
$5MM
$4MM
$3MM
$2MM
$1MM
$0MM
2018
2019
2020
2021
2022
2035
2036
Project Year
City of Wilsonville
City of Sherwood


WRWTP 2017 MPU -
Total CIP (By Partner)
Project Cost (2017)
$20MM
$18MM
$16MM
$14MM
$12MM
$10MM
$8MM
$6MM
$4MM
$2MM
$0MM
2018
2019
2020
2021
2022
2023
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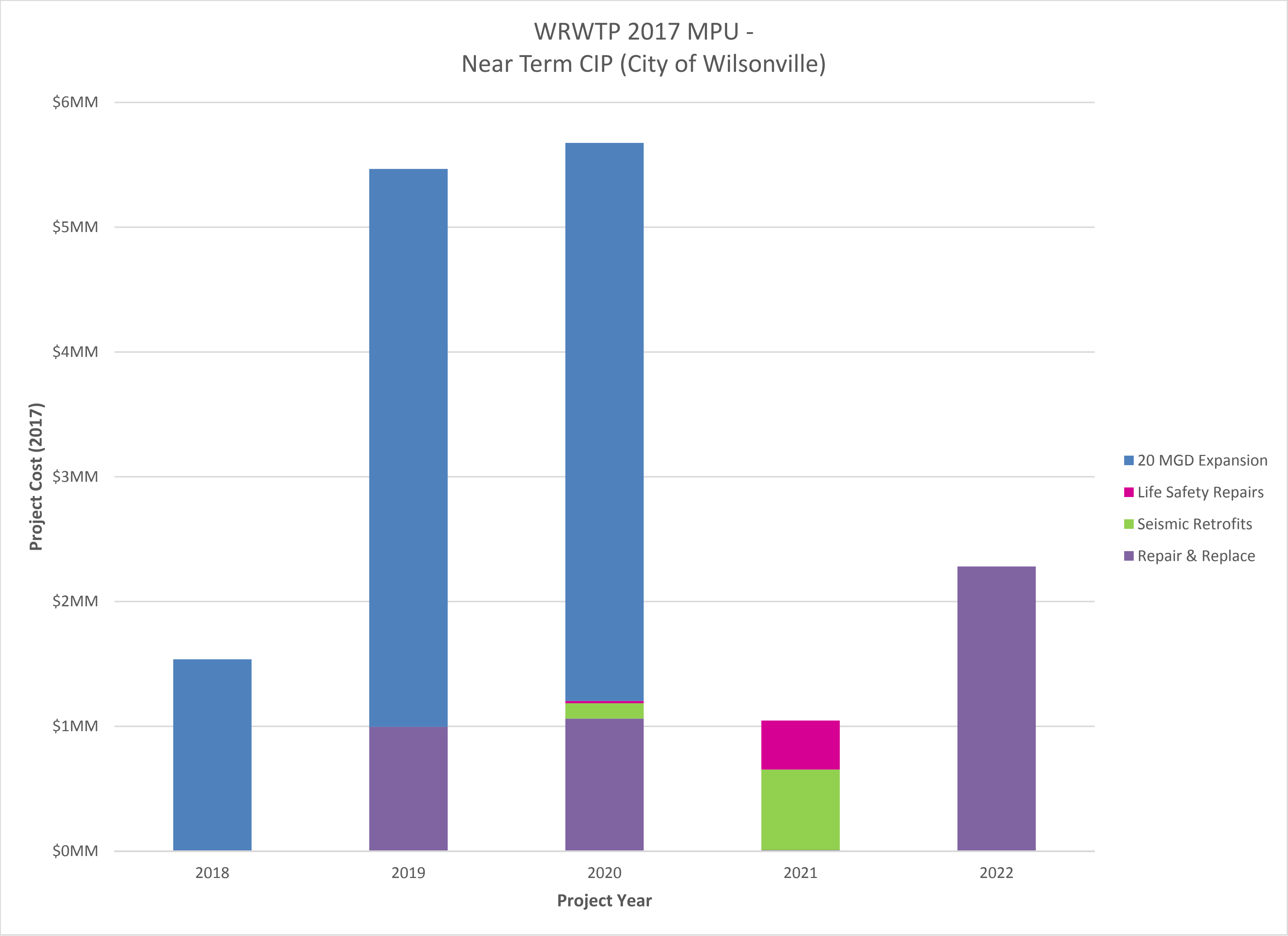
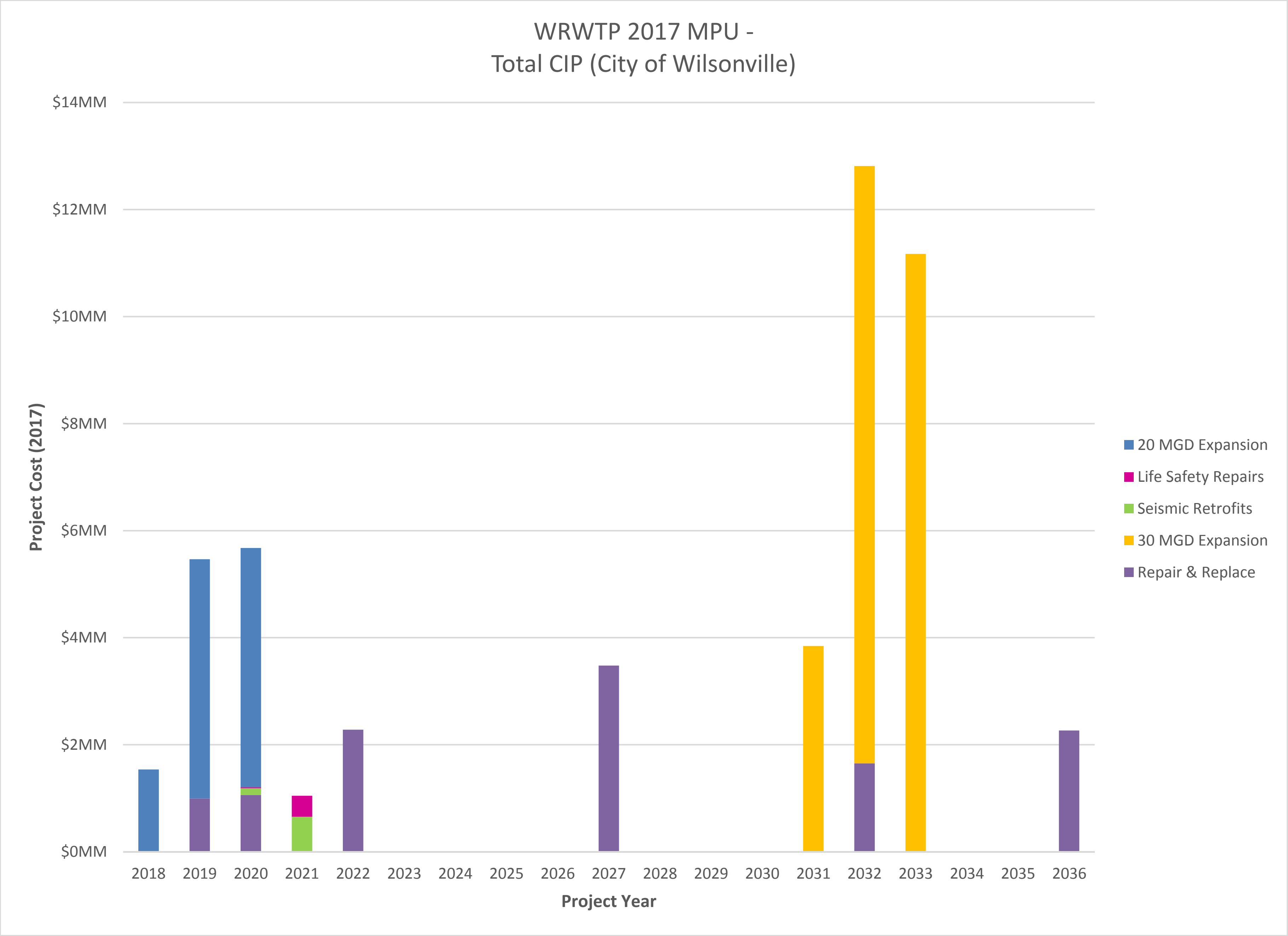
2032
2033
2034
2035
2036
Project Year
City of Wilsonville
City of Sherwood


WRWTP 2017 MPU -
Near Term CIP (City of Wilsonville)
$6MM
$5MM
$4MM
$3MM
$2MM
$1MM
$0MM
Project Cost (2017)
2018
2019
2020
2021
2022
Project Year
20 MGD Expansion
Life Safety Repairs
Seismic Retrofits
Repair & Replace


WRWTP 2017 MPU -
Total CIP (City of Wilsonville)
$14MM
$12MM
$10MM
$8MM
$6MM
$4MM
$2MM
$0MM
Project Cost (2017)
2018
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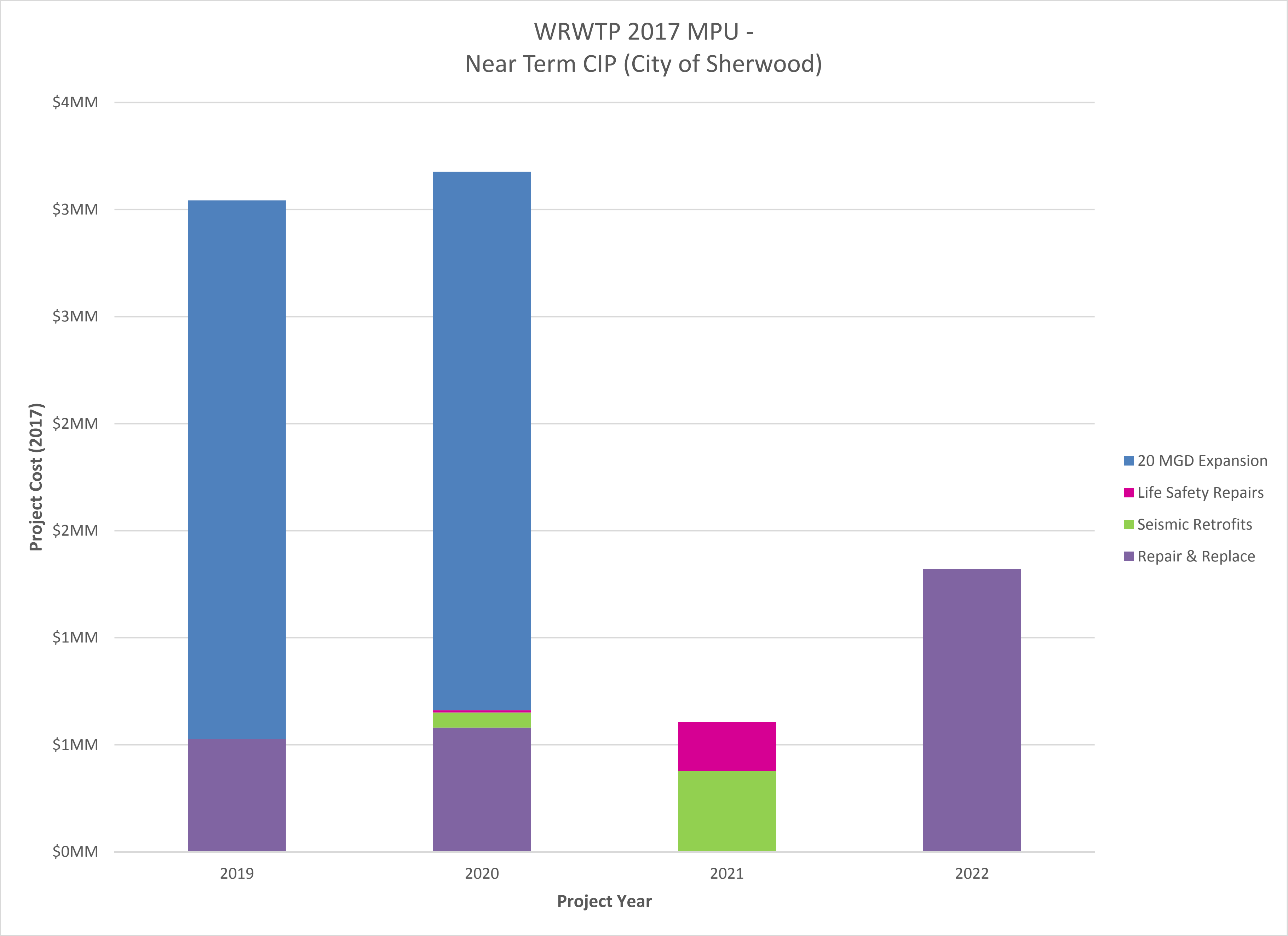
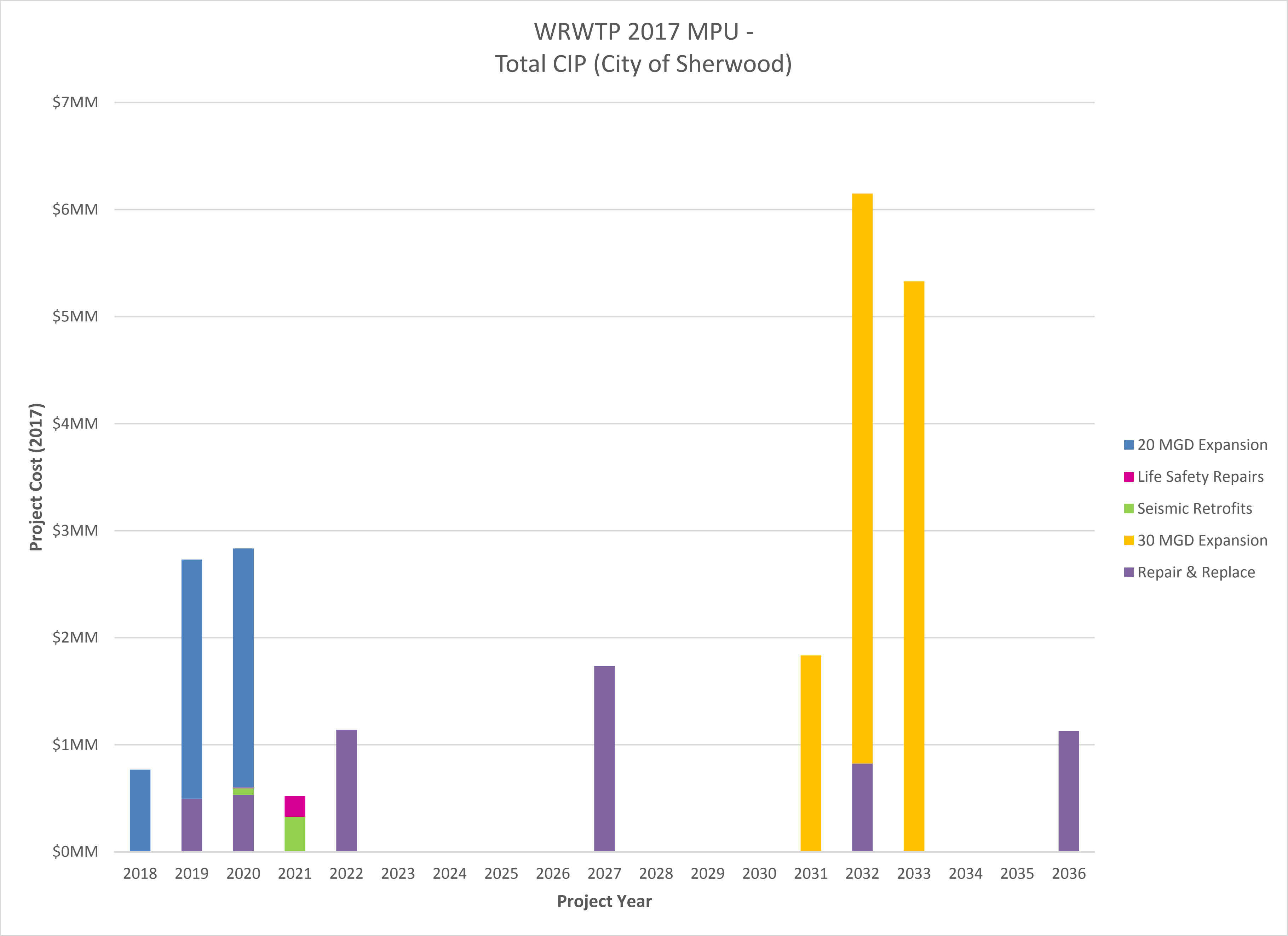
Project Year
20 MGD Expansion
Life Safety Repairs
Seismic Retrofits
30 MGD Expansion
Repair & Replace


WRWTP 2017 MPU -
Near Term CIP (City of Sherwood)
$4MM
$3MM
$3MM
$2MM
$2MM
$1MM
$1MM
$0MM
Project Cost (2017)
2019
2020
2021
2022
Project Year
20 MGD Expansion
Life Safety Repairs
Seismic Retrofits
Repair & Replace


WRWTP 2017 MPU -
Total CIP (City of Sherwood)
$7MM
$6MM
$5MM
$4MM
$3MM
$2MM
$1MM
$0MM
Project Cost (2017)
2018
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Project Year
20 MGD Expansion
Life Safety Repairs
Seismic Retrofits
30 MGD Expansion
Repair & Replace