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60 Percent

Design Documentation Report

The Dalles East Fish Ladder Auxiliary Water Backup System

Columbia River, Oregon-Washington

Prepared by:
U.S. Army Corps of Engineers
Walla Walla District
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EXECUTIVE SUMMARY

The purpose of The Dalles East Fish Ladder Auxiliary Water Backup System Design Documentation Report (DDR) is to develop a design to provide an emergency backup supply of water to the auxiliary water system (AWS). Water is currently supplied to the AWS by two fish turbine units located on the west end of the powerhouse. If one or both fish turbine units fail, water supplied to the AWS would be severely limited or eliminated. The AWS supplies water to the east, west, and south fish ladder entrances in order to attract upstream migrating adult fish. An alternative to provide a backup supply of water to the AWS in case both fish turbine units fail is evaluated in this DDR as a reasonable temporary (maximum 1 year) means of passing fish upstream of The Dalles Project when the design AWS flow is not available.

The alternative evaluated in this DDR provides a flow of 1,400 cubic feet per second (cfs). With a discharge of 1,400 cfs, the west and south fish entrances are closed and two of the three weirs at the east fish ladder (EFL) will be operational. This emergency operating condition was developed by the U.S. Army Corps of Engineers (USACE) and regional fishery agencies. The fish passage system will be operational, but under less than ideal flow conditions.

This DDR evaluates an alternative that was ultimately chosen from almost 20 alternatives. These alternatives were formulated during a brainstorming team meeting between USACE and contractor HDR Engineering, Inc. (HDR). This discussion is documented in *The Dalles East Fish Ladder Auxiliary Water System Emergency Operation Backup System Alternatives – Brainstorm Meeting Report* (February 2011). Several alternatives were then selected for further evaluation in the 2012 Engineering Documentation Report (EDR) by HDR, *The Dalles East Fish Ladder Auxiliary Water Backup System*. The recommendation from the EDR was twofold, and includes improvements to the fish lock water supply valve room and Alternative #2 – Low Level Intake.

Based on the engineering analysis for this DDR, evaluation criteria for this project, and USACE team input, a single 10-foot conduit will convey the entire 1,400 cfs by routing flow through monolith 17 into the existing fish lock approach channel. Flow is released into a modified fish lock approach channel and into the existing AWC via two 6-foot conduits and an 8-foot diffuser culvert. The recommended alternative reduces the required borings and associated setups compared to the proposed EDR alternative. The recommended design also utilizes a buried conduit to eliminate structural supports while providing simplified thrust restraint and reduced impact to project access. A single conduit reduces the number of valves required and the complexity of operation. Replacing the four sleeve valves that include orifice plates with a single Howell Bunger valve will reduce potential for debris clogging. The utilization of the existing fish lock approach channel for energy dissipation closely approximates standard design guidance. Six additional 6-foot conduits provide 1,400 cfs to the auxiliary water supply chamber (AWSC) due to revised water surface elevations and improved energy

dissipation. The recommendation also eliminates the cost to alter the fish lock valve room.

The construction cost with contingency for this design is estimated to be approximately $10,911,000. The Total Fully Funded Project Cost, without Operations and Maintenance, (O&M) is currently estimated to be approximately $TBD.

PERTINENT PROJECT DATA

PERTINENT PROJECT DATA THE DALLES LOCK AND DAM - LAKE CELILO		
GENERAL		
Location	Columbia River, Oregon and Washington, River Mile 192	
Drainage area	Square miles	237,000
RESERVOIR – LAKE CELILO (elevations referenced to 1929 datum 1947 adjustment)		
Normal minimum pool elevation	Feet, msl	155
Normal maximum pool elevation	Feet, msl	160
Maximum pool elevation (PMF regulated, 2009)	Feet, msl	178.4
Minimum tailwater elevation	Feet, msl	76.4
Maximum tailwater elevation (PMF regulated, 2009)	Feet, msl	127.2
Reservoir length (to John Day Dam)	Miles	23.5
Reservoir surface area – normal maximum power pool (EL 160.0)	Acres	9,400
Storage capacity (EL. 160.0)	Acre-feet	332,500
Power drawdown pool (EL. 155)	Acre-feet	53,500
Length of shoreline at full pool (EL. 160.0)	Miles	55
FLOOD CONDITIONS		
Probable maximum flood (unregulated)	- feet^3/s	2,660,000
Probable maximum flood (regulated)	- feet^3/s	2,060,000
Standard project flood (unregulated)	- feet^3/s	1,580,000
Standard project flood (regulated)	- feet^3/s	840,000
100-year flood event (regulated)	- feet^3/s	680,000
SPILLWAY		
Type	Gate-controlled Gravity Overflow	
Length	Feet	1,447
Elevation of crest	Feet, msl	121
Number of gates		23
Height (apron to spillway deck)	Feet	130
NAVIGATION LOCK		
Type	Single Lift	
Lift – normal	Feet	87.5
Lift – maximum	Feet	90
Net clear length	Feet	650
Net clear width	Feet	86
Normal depth over upper sill	Feet	20
Minimum depth over upstream sill	Feet	15
Minimum depth over downstream sill	Feet	15

PERTINENT PROJECT DATA **THE DALLES LOCK AND DAM - LAKE CELILO**		
POWER PLANT		
Powerhouse type	Conventional (indoor)	
Powerhouse width	Feet	239
Powerhouse length	Feet	2,089
Number of Main Generating Units		***22***
Installed power capacity	Kilowatts	1,806,800
Peak generating efficiency flow	- feet^3/s	260,000
Maximum flow capacity	- feet^3/s	320,000
Fishway Units (Not Included Above)		***2***
Installed power capacity	Kilowatts	28,000
Peak generating efficiency flow	- feet^3/s	2,500
Maximum flow capacity	- feet^3/s	2,500
Station Service Units (Not Included Above)		***2***
Installed power capacity	Kilowatts	6,000
Peak generating efficiency flow	- feet^3/s	300
Maximum flow capacity	- feet^3/s	300
FISH FACILITIES		
Adult ladders		2
Ladder designations		North and East
North ladder width	Feet	24
East ladder width	Feet	30
Ladder slope (typical)		1v:16h
Ladder elevation change (typical)	Feet	84
NORTHERN WASCO PEOPLE'S UTILITY DISTRICT POWER PLANT (OPERATING AT THE NORTH FISH LADDER AWS)		
Powerhouse type	Conventional (indoor)	
Powerhouse width	Feet	44
Powerhouse length	Feet	48
Intake Structure width	Feet	25
Intake Structure length	Feet	125
Number of Main Generating Units		***1***
Installed power capacity	Kilowatts	5,000
Peak generating efficiency flow	- feet^3/s	800
Maximum flow capacity	- feet^3/s	800

PREVIOUS MEMORANDUMS

ABBREVIATIONS AND ACRONYMS

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWC	auxiliary water conduit
AWS	auxiliary water supply
AWSC	auxiliary water supply chamber
AWWA	American Water Works Association
cfs	cubic feet per second
CWA	Clean Water Act
DDR	Design Documentation Report
EA	Environmental Assessment
EAWS	Emergency Auxiliary Water Supply
EDR	Engineering Documentation Report
EFL	east fish ladder
EIS	Environmental Impact Statement
EM	Engineering Manual
ER	Engineering Regulation
ESA	Endangered Species Act
FAC	fish lock approach channel
FCC	fish collection channel
fps	feet per second
FFDRWG	Fish Facility Design and Review Work Group
FONSI	Finding of No Significant Impact
fps	feet per second
ft	feet
FTC	fish transportation channel
gpm	gallons per minute
HDR	HDR Engineering, Inc.
HDC	Hydroelectric Design Center
hp	horsepower
HSS	hollow structural sections
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronic Engineers
IES	Illuminating Engineering Society
ISA	International Society of Automation
IWWW	in-water work window
JBS	juvenile bypass system
kips	kilo pounds
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt

MCE	Maximum Credible Earthquake
MDE	Maximum Design Earthquake
msl	mean sea level
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NETA	InterNational Electrical Testing Association
NFPA	National Fire Protection Association
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWP	USACE, Portland District
NWW	USACE, Walla Walla District
O&M	Operations and Maintenance
OBE	Operational Based Earthquake
OSHA	Occupational Safety and Health Administration
PCF	pounds per cubic foot
PGA	peak ground acceleration
PH	phase
psi	pounds per square inch
PUD	People’s Utility District
RCC	Reservoir Control Center
TSW	top spillway weir
USBR	U.S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
V	volt
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

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APPENDIXES

CHAPTER 1 – PURPOSE AND INTRODUCTION

1.1 PURPOSE

Providing backup auxiliary water for the east fish ladder (EFL) is critical to the overall success of adult fish passage at The Dalles Dam.

The issue of providing backup auxiliary water has been studied during the 1990s in several alternative reports. Early concepts in the 1990s revolved around the juvenile bypass system (JBS) dewatering to provide the backup water. But, in the early 2000s, the JBS concept at The Dalles Dam was abandoned. Therefore, a backup auxiliary water supply (AWS) was never implemented at The Dalles Dam for exit attraction flow.

1.2 REFERENCES

a. HDR Engineering, Inc. (HDR). 2009. The Dalles East Fish Ladder Auxiliary Water Backup System. May. Report to U.S. Army Corps of Engineers, Portland District.

b. HDR. 2011. The Dalles East Fish Ladder Auxiliary Water System Emergency Operation Backup System Alternatives – Brainstorm Meeting Report. February. Report to U.S. Army Corps of Engineers, Portland District.

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1.3 BACKGROUND

In 2008, the USACE Hydroelectric Design Center (HDC) conducted a risk failure analysis and report on the fish turbines units (USACE 2008). The HDC concluded that there is a 25 percent probability that at least one of the two fish water units will experience a significant failure in the next 10 years. Furthermore, the probability of failure of both units at the same time is 1.4 percent in the next 10 years.

Subsequently, HDR Engineering, Inc. (HDR), under contract to USACE, completed a letter report (HDR 2009), that investigated in further detail the concept of utilizing the draft tube of a main turbine unit to provide full flow backup water supply of 5,000 cubic feet per second (cfs) for the AWS. The estimated cost of the recommended alternative from the HDR report was much greater than expected. Due to the high cost and risk of draft tube modifications, this alternative was no longer considered.

Recognizing that providing a full flow backup AWS is cost prohibitive, USACE and representatives from fisheries agencies discussed operational options that would require less flow and still provide good fish passage during an "emergency operation." The group agreed that in the event both fish units failed, the duration of the "emergency operation" is 1 year. It was also agreed that the east fish ladder entrance is the priority, and two of the three entrance weirs will remain operational. The south and west entrances will be closed. Based on the east entrance only scenario, USACE estimated 1,400 cfs is needed. With 1,400 cfs established as the minimum hydraulic AWS needs, it was recommended that a brainstorming session be conducted to further develop concepts for this scenario for exit attraction flow.

In late 2010, USACE contracted with HDR to facilitate a brainstorming meeting (HDR 2011) to help identify other sources of water that focused on a collective set of processes to pull water from various sources and volumes, in concert with perhaps a smaller, cost effective alternative feature that could help meet the hydraulic need for the "emergency operation."

A Fish Facility Design Review Work Group (FFDRWG) meeting with regional fisheries agencies and tribes was held in May 2011, with the goal to discuss the brainstorm report and to decide which alternatives from the report should be considered in an Engineering Documentation Report (EDR). It was agreed that several be kept for further investigation. Each alternative was considered to be a stand-alone feature. USACE contracted with HDR to produce an EDR to further develop the chosen alternatives to provide backup AWS (HDR 2012). The preferred alternative selected from the EDR is Alternative #2 – Low Level Intake.

1.4 CHANGES SINCE EDR

The following changes have been made to the proposed layout of the East Fish Ladder Auxiliary Water Backup System since completion of the EDR (HDR 2012).

- Single inlet – Discharge capacity of single inlet capable of conveying entire design discharge, eliminating need for valve room inlets and modifications.
- Cofferdam – Allows for majority of intake work to be performed without the constant need for divers, resulting in lower hourly rates, higher productivity, and lower project overhead.
- Bulkhead – Replaced dual bulkhead design with single emergency bulkhead capable of closure under flow reducing forebay structure and material.

- 10-foot-diameter bore – Replaced two 6-foot-diameter bores with a single 10-foot-diameter bore, reducing the volume of required boring and the associated pipe support structures and the number of setups.

- Below grade piping alignment – Lowering the vertical alignment allows for simplified structural support and thrust restraint. Alignment also reduces long-term impact on project parking and tailrace deck access.

- Single Howell Bunger valve – Reduces the number of valves required to provide design discharge, resulting in simplified operation and reduced maintenance.

- Stilling basin – Flow is routed directly to fish approach channel, allowing for a standardized method for energy dissipation. The new routing eliminates unknown hydraulic characteristics within the fish lock.

- Steel flume – Six 6-foot-diameter flumes were added to convey flow from the approach channel to the AWS conduit. Additional flumes reduce the water surface within the approach channel, preventing cavitation damage to the existing culvert. Flumes also provide open channel flow conditions intended to reduce wave action within the stilling basin while also providing multiple points of outlet within the AWS conduit to assist with energy dissipation.

1.5 SCOPE

The scope of this Design Documentation Report (DDR) involves developing a detailed design of a variation of Alternative #2 – Low Level Intake concept, as described in the EDR. This DDR will include hydraulic, structural, mechanical, electrical, geotechnical, biological, environmental, cost engineering, constructability, and operations and maintenance considerations. Engineering and analysis will be sufficient to develop a complete project schedule and baseline cost estimate with reasonable contingency factors. Reports will be written at 30 percent, 60 percent, 90 percent, and final 100 percent design levels. The report will contain text, photos, charts, diagrams, calculations, assumptions, costs, discussion of constructability and drawings as required fully documenting the design and basis for decisions. USACE Portland District (NWP) and agency review comments will be provided throughout the development for Walla Walla District (NWW) consideration and inclusion, as appropriate. Site visits to the project will be necessary.

1.6 AUTHORIZATION

The 1995 Energy and Water Development Appropriations Act (Public Law 104-46) directed USACE to use additional appropriations to evaluate the effectiveness and efficiency of the bypass systems, reduce mortality by predators, and enhance passage conditions.

1.7 EXISTING FISHWAY FACILITIES

1.7.1 East Fish Ladder

The adult fish passage facilities at The Dalles Dam consist of the north fish ladder and the EFL. This report focuses on the EFL. Attraction and transportation flow for the south, west, and east entrances of the EFL is provided by two fish turbine units (F1 and F2) located on the west end of the powerhouse. Water discharged (5,000 cfs) from the fish turbines enters the auxiliary water conduit (AWC) and is released into the system through diffusers. Water enters the fishway at the junction pool, east entrance including lower ladder diffusers, south entrance, west entrance, and transportation channel after passing through diffusers. It can enter the collection channel, but these diffusers were closed because fish entrances along the collection channel are not currently operational. Fish enter the south and west fish ladders and travel through the transportation and collection channels, respectively, to the EFL (see figures 1-1, 1-2, and 1-3).

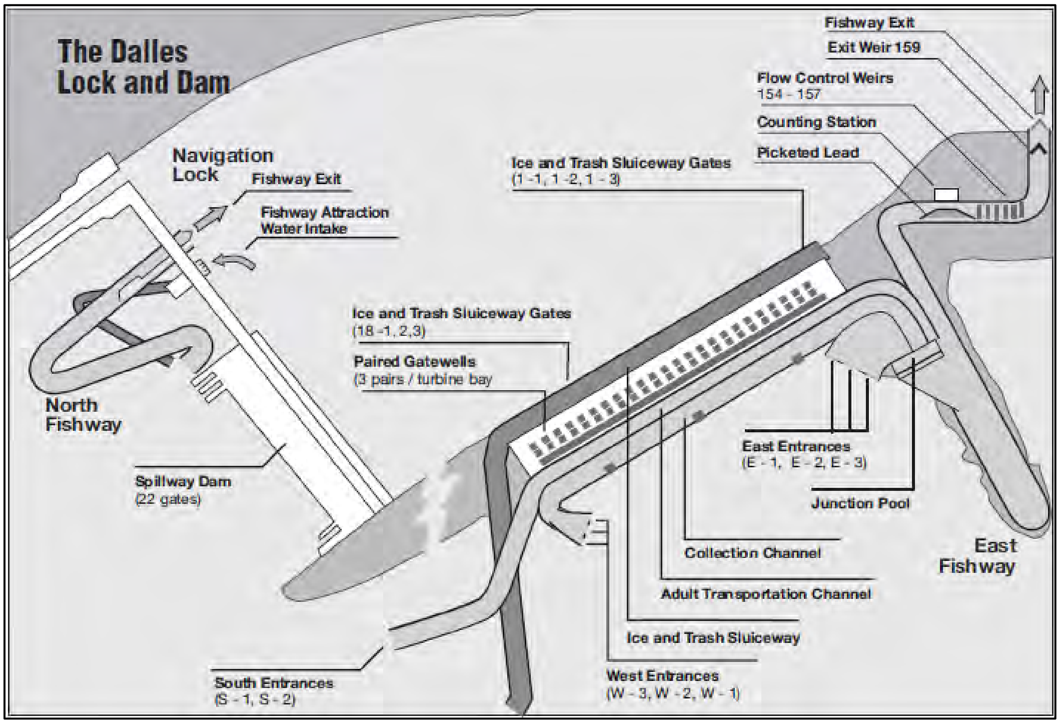

Figure 1-1. The Dalles Dam Fish Ladder System (USACE 2008)

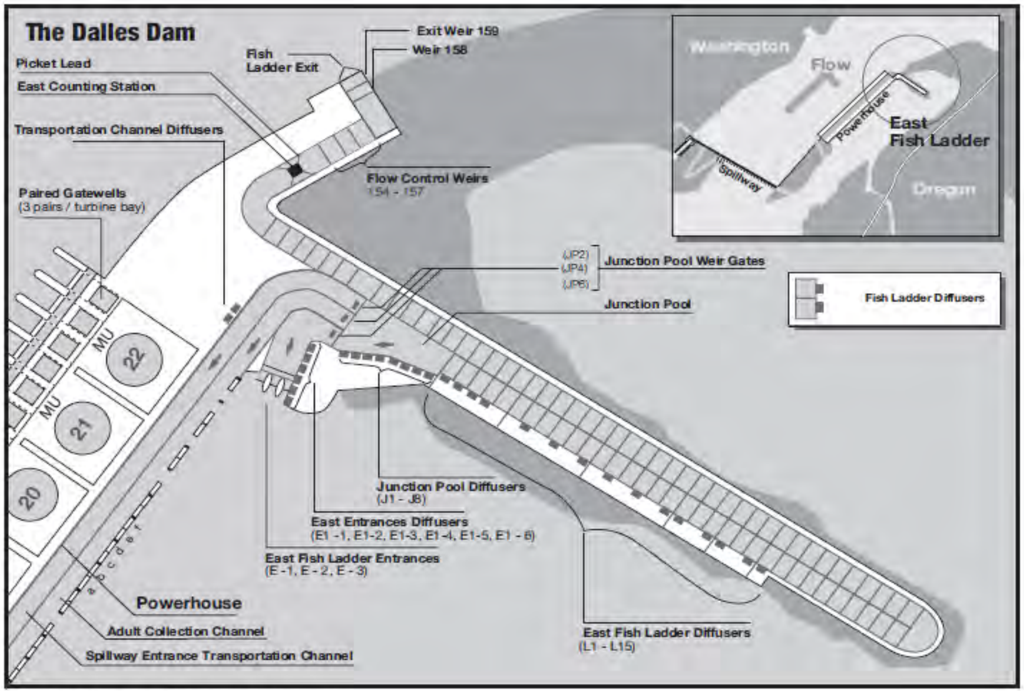

Figure 1-2. The Dalles Dam East Fish Ladder (USACE 2008)

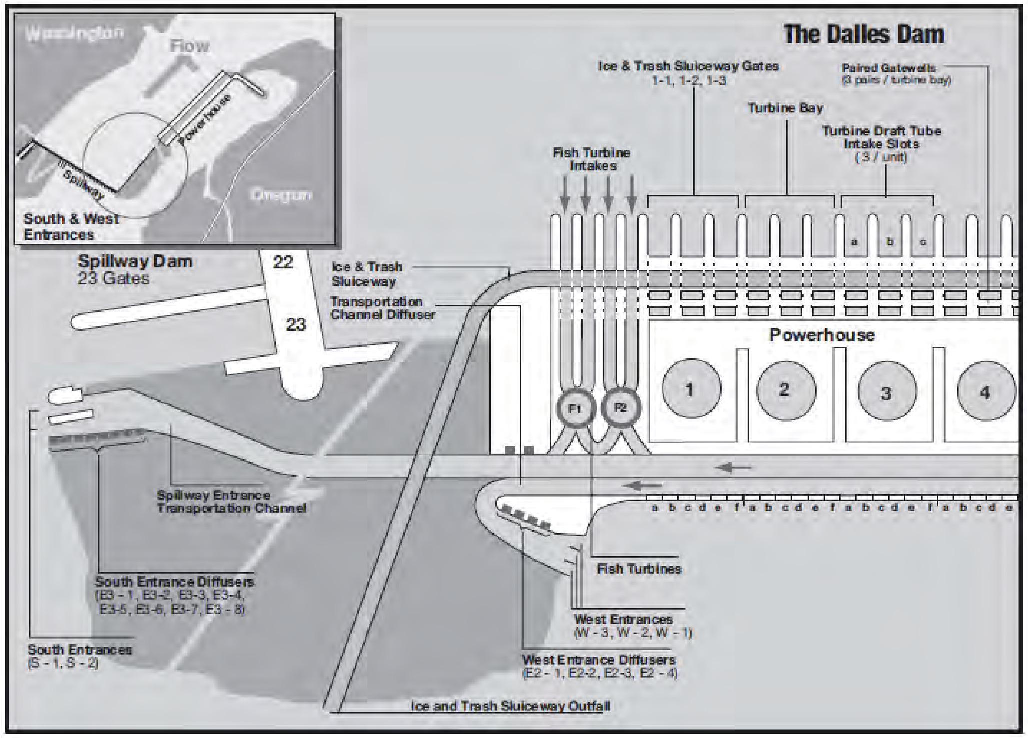

Figure 1-3. The Dalles Dam West and South Fish Ladders (USACE 2008)

1.7.2 Fish Turbine Units

The two fish turbine units, F1 and F2, are located at the west end of the powerhouse. The turbine units have a combined power capacity of 28,000 kilowatts (kW) and a maximum flow capacity of 2,500 cfs each. Water (5,000 cfs) is discharged from the fish turbine units into the AWC. Trash racks with 1-inch spacing are installed in the fish turbine unit intakes.

1.7.3 Auxiliary Water System

As shown on figures 1-3, the AWS consists of an AWC, a fish transport channel, fish collection channel, junction pool, weir gates, and a series of diffusers along the AWC that convey water to the junction pool and lower ladder diffusers. Water is supplied to the AWC from the two fish turbine units. This system is complex to operate, but is an integral part of the overall operation of the EFL system. Based on a numerical model provided by USACE, CENWP-EC-HD, the hydraulic head within the AWS conduit near the east entrance is approximately 5 feet greater than the pool elevation. This is consistent with a rough estimate based on the field data differentials to tailwater obtained at similar ladders (John Day, Little Goose, and Lower Granite). The original model was developed by Northwest Hydraulics, Inc. for USACE.

Prior to flowing through the EFL entrance, water is sent through a series of diffusers in the junction pool and lower ladder. The junction pool provides water to the fish transportation channel (FTC), which supplies the south fish entrance, and the fish collection channel (FCC), which supplies the west fish entrance. The AWS normally operates with a total flow of up to 5,000 cfs, but should be able to be operated in a temporary emergency capacity with a minimum discharge of 1,400 cfs with the south and west entrances closed.

1.8 AGENCY COORDINATION

This report was fully coordinated with the regional fisheries agencies and tribes through FFDRWG.

CHAPTER 2 – BIOLOGICAL DESIGN CONSIDERATIONS AND CRITERIA

2.1 GENERAL

Anadromous salmonid and lamprey passage criteria are described in this section, as these are the primary taxa of concern with respect to operation of the east fish ladder (EFL). The primary source of general criteria for adult and juvenile salmon passage is taken from the *Anadromous Salmonid Passage Facility Design* Report (NMFS 2011). Passage criteria specific to the EFL is provided in the 2013 *Fish Passage Plan* (USACE 2013). Lamprey criteria are under development by the scientific community concerned about lamprey passage.

The Dalles Dam has two primary fish ladders: the north and east fish ladders. The EFL has east, south, and west entrances for upstream migrating fish. The east entrance leads directly to the EFL. The south and west entrances direct fish into channels that pass along the downstream side of the powerhouse and join the EFL upstream of the east entrance at a junction pool.

Species of fish migrating past The Dalles Dam include Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), and sockeye (*Oncorhynchus nerka*) salmon, steelhead (*Oncorhynchus mykiss*), Pacific lamprey (*Entosphenus tridentatus*), white sturgeon (*Acipenser transmontanus*), and American shad (*Alosa sapidissima*). Bull trout (*Salvelinus confluentus*) have also been observed occasionally in the fish ladders. Upstream migrants are present at the dam year-round, whereas downstream migrating juvenile salmonids and shad are present primarily from April through November. No information has been collected to verify this, but it is likely that downstream migrating ammocoetes and juvenile Pacific lamprey are present during the winter.

2.2 REFERENCES

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2.3 ADULT PASSAGE PERIOD

Upstream migrating adult salmonids are present at The Dalles Dam throughout the year and adult passage facilities are operated year-round. Adult salmon, steelhead, lamprey, and shad are normally counted from April 1 through October 31. Counts are visual, and occur from 0500 to 2100 Pacific Daylight Time. Peak numbers of upstream migrating salmon and steelhead occur from April through October (figure 2-1). Adult Pacific lamprey also migrate past The Dalles Dam. Counts have ranged from almost 29,000 to fewer than 2,000 since 2002, with numbers generally decreasing in recent years. Count data can only serve as a relative index of adult passage because most adult lamprey pass at night when counting is not conducted, and numerous routes are available for lamprey to pass dams without being detected (Moser and Close 2003; Robinson and Bayer 2005). River discharge and temperature play important roles in migration timing, but in most years, passage occurs primarily between late June and early September (table 2-1).

Although numbers are far less than those of adult salmon or Pacific lamprey, limited upstream movement of white sturgeon occurs at The Dalles Dam. Upstream passage is generally highest during July and August. Sturgeon almost exclusively use the EFL for upstream passage (Parsley et al. 2007), although they may reside for periods of time in both the east and north fish ladders.

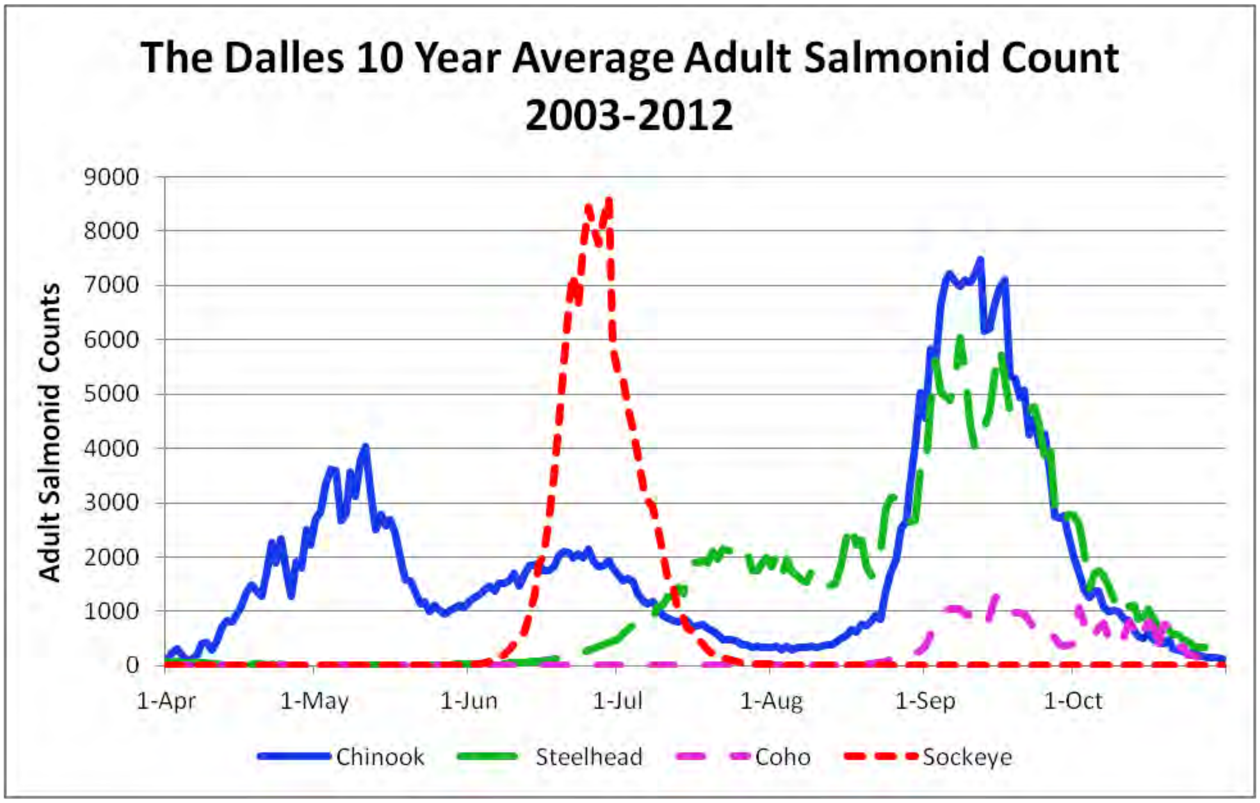


Figure 2-1. 10 Year Average (2003-2012) of Adult Migrating Salmonids at The Dalles Dam (Data Access in Real Time [DART] 2013)

2.4 ADULT SALMONID PASSAGE CRITERIA

The auxiliary water supply (AWS) backup system considered in this report allows for operation of the EFL in the event that the two fish turbine units are not operational. Per consultation with regional fish managers, the backup system considered will provide a design flow of 1,400 cubic feet per second (cfs), the discharge required to meet adult fish passage criteria for the east entrances of the EFL (HDR 2012, Appendix A). In the event of a double outage of the fish turbine units, the west and south entrances will be closed and the proposed backup system operated. USACE and regional fish managers have previously developed an emergency operation plan in the event of the loss of a *single* fish turbine unit (USACE 2013). The backup systems and proposed operations considered in this report are *not* intended to supplant the emergency operation plan for the loss of a single unit.

Table 2-1. Adult Pacific Lamprey Migration Dates for The Dalles Dam

Year	Cumulative Percent Passage		
	10%	50%	90%
2002	4-Jul	29-Jul	3-Sep
2003	3-Jul	23-Jul	27-Aug
2004	26-Jun	15-Jul	26-Aug
2005	26-Jun	12-Jul	12-Aug
2006	30-Jun	23-Jul	29-Aug
2007	8-Jul	17-Jul	15-Aug
2008	4-Jul	26-Jul	24-Aug
2009	23-Jun	19-Jul	21-Aug
2010	4-Jul	25-Jul	31-Aug
2011	19-Jul	8-Aug	3-Sep

2.4.1 Fish Passage Plan Criteria for Adult Fishways at The Dalles Dam

The adult fishway criteria discussed below should assume operation of the east entrances of the EFL only (in addition to normal operation of the north fish ladder). Per the 2013 *Fish Passage Plan* (USACE 2013), relevant criteria include:

- Depth over fish ladder weirs: 1.0 foot (± 0.1 foot). During the shad passage season (> 5,000 shad/count station/day at Bonneville Dam): 1.3 feet (± 0.1 foot). The 2013 *Fish Passage Plan* includes exceptions to these criteria:
    - East powerhouse entrance (east entrances): Operate entrance weirs E2 and E3 to maintain gate crest > 8 feet below tailwater, currently operated at 13 feet below tailwater. Weir E1 is to be closed at 81 feet mean sea level (msl), but will remain operational. At lower range of tailwater elevation, weir E1 may be operated manually at any depth to meet entrance differential criteria.
    - Operate EFL junction pool weir JP6 at the following minimum depths in relation to east entrances tailwater surface elevation: > 7 feet.
- Head on all entrances: 1 to 2 feet (1.5 feet optimum).
- Entrance weir depths: 8 feet or greater below tailwater. Maintain tailwater elevation greater than 70 feet msl to remain in entrance weir criteria operating range, which is regulated by the Reservoir Control Center (RCC).
- Velocity: A water velocity of 1.5 to 4 feet per second (fps) (2 fps optimum) shall be maintained for the full length of the powerhouse collection channel and lower

ends of the fish ladders that are below the tailwater. ***Note:*** *For the purposes of this report, it is assumed that these criteria will not apply to the powerhouse collection channel, as the west and south entrances will be closed. The water velocity criteria here will only apply to the lower ladder/junction pool area immediately upstream of the east entrances.*

- Diffuser velocities: AWS diffuser velocity must be < 1.0 fps for vertical diffusers and < 0.5 fps for horizontal diffusers, based on total diffuser panel area. Diffuser velocities should be nearly uniform. Energy dissipation on the upstream side of the diffuser screens will be provided, if needed, to meet this criterion.

- Debris removal: Remove debris as required to maintain head below 0.5 feet on attraction water intakes and trash racks at all ladder exits. Debris shall be removed when significant amounts accumulate.

Discharge from the two operating fish units will be adjusted to maintain criteria at all associated fishway entrances. Discharge volume will be dependent on criteria levels at entrances. ***Note:*** *The AWS system design in this report should provide discharge volume sufficient to maintain entrance criteria at the east entrances only.*

2.4.2 Adult Salmonid Passage Facility Design Criteria

Relevant criteria specified in the *Anadromous Salmonid Passage Facility Design* report (NMFS 2011) that is not already specified above from the 2013 *Fish Passage Plan*:

<u>AWS Diffusers</u>

- Velocity and orientation: The maximum AWS diffuser velocity must be < 1.0 fps for vertical diffusers and 0.5 fps for horizontal diffusers, based on total diffuser panel area. Vertical diffusers should only be used in appropriate orientation to assist in guiding fish within the fishway. Diffuser velocities should be nearly uniform.

- Debris removal: The AWS design must include access for debris for each diffuser, unless the AWS intake is equipped with a juvenile fish screen, as described in Section 11 (NMFS 2011) or if required by Section 4.3.4 (NMFS 2011).

- Edges: All flat bar diffuser edges and surfaces exposed to fish shall be rounded or grounded smooth to the touch, with all edges aligning in a single smooth plane to reduce potential for contact injury.

<u>AWS Fine Trash racks</u>

A fine trash rack must be provided at the AWS intake with clear space between the vertical flat bars of 7/8 inch or less, and the maximum velocity shall not exceed 1 fps, as calculated by the maximum flow divided by the entire fine trash rack area. The support structure for the fine trash rack must not interfere with cleaning requirements and must provide access for debris raking and removal. Fine trash racks must be installed at a 1:5 (horizontal:vertical) slope (or flatter) for ease of cleaning. ***Note:*** *The new AWS system design will include a new trash rack grating criteria of 0.75 inch clear opening to prevent debris from accumulating in the AWS diffuser system and exclude lamprey from the AWS.*

- Gages: Staff gages must be installed to indicate head differential across the AWS fine trash rack, and must be located to facilitate observation and in-season cleaning. Head difference across the AWS intake must not exceed 0.3 feet. ***Note****: Due to the potential depth of the AWS intake design, the staff gage criterion may have to be reconsidered or changed, in consultation with regional fish managers.*

- Structural integrity: The AWS intake fine trash racks must be of sufficient structural integrity to avoid permanent deformation associated with maximum occlusion.

Transport Channels:

- Dimensions: Transport channels should be a minimum of 5 feet deep.

- Velocity: A water velocity of 1.5 to 4 fps (2 fps optimum) shall be maintained in all channels and at the lower ends of the fish ladder that are below tailwater (already stated as 2013 *Fish Passage Plan* criteria).

Ladder Pools:

- Hydraulic drop: The maximum hydraulic drop between fishway pools is 1 foot or less. The maximum hydraulic drop between fishway pools is 1.3 feet during shad season.

- Pool dimensions: Pool dimensions should be a minimum of 5 feet deep.

- Pool volume: The fishway pools shall have a minimum water volume of:

$$V = \frac{\gamma Q i H o}{\left(4 \cdot \frac{ft}{s} \cdot \frac{lbs}{ft^3}\right)}$$

where:
V = Pool volume = depth x width x length (feet^3)
γ = Unit weight of water = 62.4 lbs/feet^3
Qi = Total inflow to pool (cfs)
Ho = Energy head of pool to pool flow (feet)

This pool volume must be provided under all expected design flow conditions, with the entire pool having active flow and contributing to energy dissipation.

2.5 ADULT PACIFIC LAMPREY CRITERIA

Most passage criteria developed for adult Pacific lamprey are not directly relevant to development of AWS backup system alternatives, as they generally address structural design (shape) of fish ladder features, such as overflow weirs. For the purposes of this report, it is assumed that maintaining the adult fish passage criteria described in the 2013 *Fish Passage Plan* (USACE 2013) and by NMFS (2011) will provide the hydraulic targets for the EFL in the event of the loss of both fish turbine units.

The primary concern relative to adult Pacific lamprey is infiltration of AWS backup system intakes, particularly those that are in close proximity to entrances (tailwater) or exits (forebay) of the EFL. Clear openings on AWS backup system intake trash racks shall be no greater than 0.75 inch clear opening to prevent lamprey infiltration.

2.5.1 Anadromous Fish Passage Structure Materials

Materials to be used for the construction of the AWS will be nontoxic stainless and carbon steel and should have no negative effect on adult salmonid and lamprey attraction and passage.

2.6 DESIGN IMPLICATIONS FOR ADULT FISH PASSAGE

It is imperative that the EFL have the appropriate attraction flow and entrance depth to effectively attract adult salmonids and lamprey. The AWS design specifications will be appropriate to provide the necessary EFL entrance conditions to eliminate delay and encourage adult salmonids and lamprey to enter. While the EFL AWS design is a fairly benign passage structure for adult fish, any construction project at a dam will have the potential to provide negative impacts on fish passage to some degree.

Adult salmonids migrating upriver and exiting the fishways of dams will occasionally pass back downstream via one of many potential routes, an event referred to as fallback. When exiting fishways and confronting the impounded water of a dam forebay, migrants may be attracted to water passing through spillways, sluiceways, and turbine intakes or may orient with the upstream face of the dam and enter these areas of downstream flow. Fallback rates at The Dalles Dam for adult salmonids have been higher than rates at other mainstem dams (Burke et al. 2005); however, fallback was lower for fish using the EFL (1.1 percent to 1.4 percent) than for those using the north fish ladder (1.8 percent to 5.0 percent). Similarly, fallback of adult Pacific lamprey was lower for those using the EFL (2.6 percent) than the north fish ladder (11.8 percent) (Claybough et al. 2011).

The design elevation and location of this AWS intake is sufficiently low in the water column with velocities low enough to minimize the potential for adult salmonid and lamprey attraction to the structure. Adult salmonids are more likely to remain surface and shoreline oriented as they move away from the fishway exit. Adult lamprey are at a slightly greater risk of interaction with the AWS intake because these fish tend to migrate deeper in the water column than salmonids. While adult fish interactions with the AWS intake structure are likely to be minimal, the entrainment and fallback of adult fish is not possible with this design. Fine trash rack spacing criteria will exclude adult salmonids and lamprey from physically entering the AWS intake. During tests at Bonneville Dam, no adult lamprey were able to pass through grating with ¾-inch spacing (Moser et al. 2007). Adult Pacific lamprey can achieve short-term burst speeds exceeding 12 fps (Moser et al. 2002); therefore, impingement on trash racks is not a concern.

Taking the possibility of adult attraction to the intake structure in the forebay into consideration, the possibility of a minor migration delay is offset by the benefit of having a reliable AWS. This AWS may be operating within hours in the event of the failure of both fish turbine units that currently supplement the EFL AWS entrance. Being operational in such short order will greatly reduce passage delay and ensure that adults will be attracted to the EFL entrance. Overall, the combination of sufficient fishway depth, entrance velocities, fine trash rack criteria on the intake, and the rare occasion that this AWS will be needed suggests that this design will provide a benefit to fish passage.

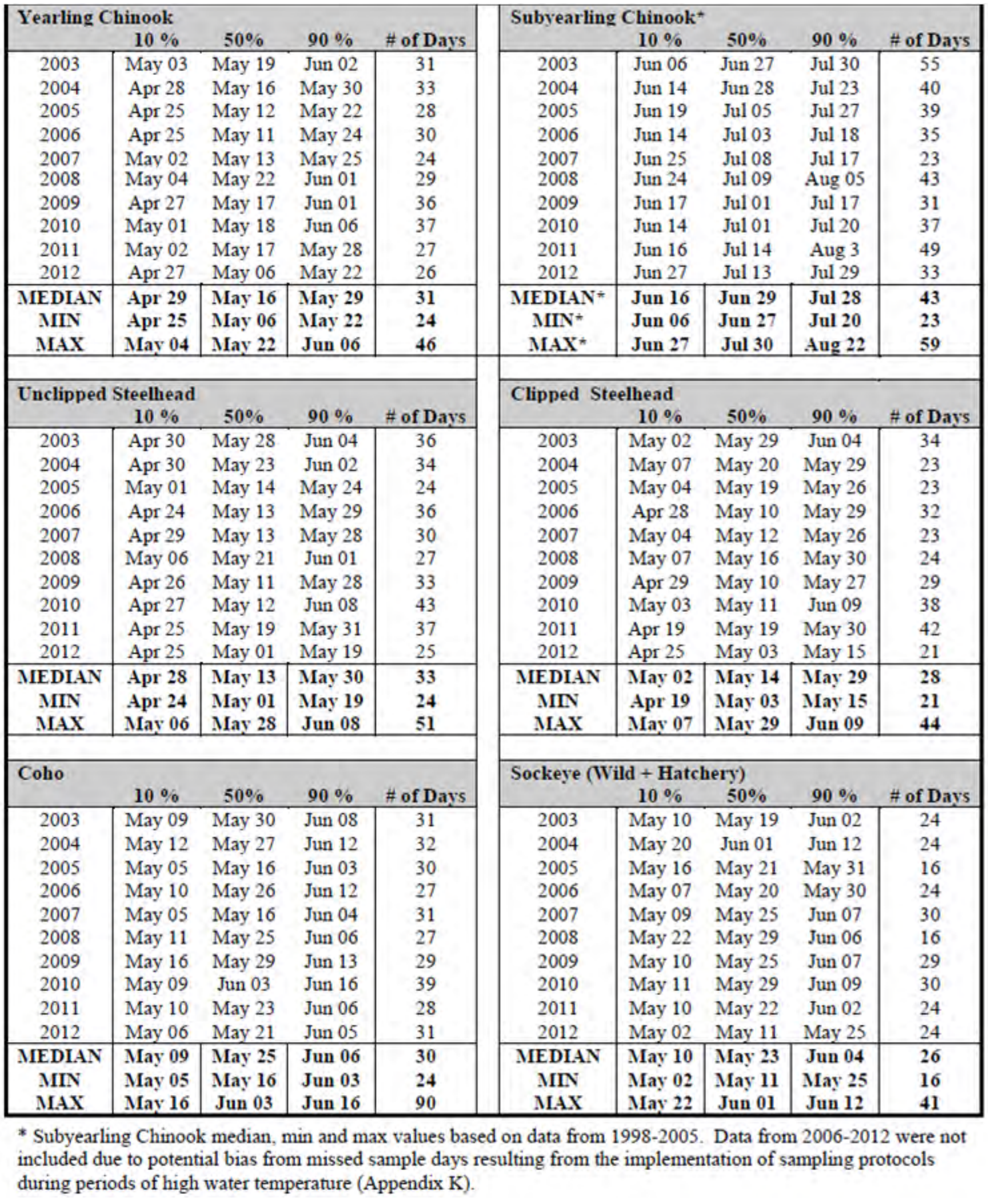
2.7 JUVENILE PASSAGE PERIOD

Turbine units at The Dalles Dam are not screened. Juvenile fish passage facilities consist of the spillway, the ice and trash sluiceway, and one 6-inch orifice in each gatewell. Gatewell orifices allow flow into the sluiceway, providing a potential means of passing fish from the gatewells into the sluiceway. However, it should be recognized that the 6-inch orifices are no longer being operated as part of the juvenile bypass system and are being closed as time and opportunity permit. When any of the sluiceway gates (located in the forebay side of the sluiceway) are opened, water and juvenile migrants are skimmed from the forebay into the sluiceway and deposited in the tailrace downstream of the dam. Approximately 80 percent of juvenile salmonids pass over the spillway (Johnson et al. 2007). Many others pass through the ice and trash sluiceway, with the remainder passing through turbines.

The primary juvenile salmonid passage period is April through November. Because juvenile monitoring is not performed at The Dalles Dam, refer to table 2-2 for John Day Dam (USACE 2013) and add approximately 1 day to the dates for each species to estimate the juvenile salmonid arrival dates at The Dalles Dam.

Although no sampling is conducted at The Dalles Dam, data from John Day Dam indicate that most juvenile lamprey are collected between early April and late June, with some fish collected into September (Fish Passage Center 2011). Many fish likely pass during winter when counting does not take place.

Table 2-2. Juvenile Salmonid Migration Dates for John Day Dam



Yearling Chinook	10 %	50%	90 %	# of Days
2003	May 03	May 19	Jun 02	31
2004	Apr 28	May 16	May 30	33
2005	Apr 25	May 12	May 22	28
2006	Apr 25	May 11	May 24	30
2007	May 02	May 13	May 25	24
2008	May 04	May 22	Jun 01	29
2009	Apr 27	May 17	Jun 01	36
2010	May 01	May 18	Jun 06	37
2011	May 02	May 17	May 28	27
2012	Apr 27	May 06	May 22	26
MEDIAN	**Apr 29**	**May 16**	**May 29**	**31**
MIN	**Apr 25**	**May 06**	**May 22**	**24**
MAX	**May 04**	**May 22**	**Jun 06**	**46**

Subyearling Chinook*	10 %	50%	90 %	# of Days
2003	Jun 06	Jun 27	Jul 30	55
2004	Jun 14	Jun 28	Jul 23	40
2005	Jun 19	Jul 05	Jul 27	39
2006	Jun 14	Jul 03	Jul 18	35
2007	Jun 25	Jul 08	Jul 17	23
2008	Jun 24	Jul 09	Aug 05	43
2009	Jun 17	Jul 01	Jul 17	31
2010	Jun 14	Jul 01	Jul 20	37
2011	Jun 16	Jul 14	Aug 3	49
2012	Jun 27	Jul 13	Jul 29	33
MEDIAN*	**Jun 16**	**Jun 29**	**Jul 28**	**43**
MIN*	**Jun 06**	**Jun 27**	**Jul 20**	**23**
MAX*	**Jun 27**	**Jul 30**	**Aug 22**	**59**

Unclipped Steelhead	10 %	50%	90 %	# of Days
2003	Apr 30	May 28	Jun 04	36
2004	Apr 30	May 23	Jun 02	34
2005	May 01	May 14	May 24	24
2006	Apr 24	May 13	May 29	36
2007	Apr 29	May 13	May 28	30
2008	May 06	May 21	Jun 01	27
2009	Apr 26	May 11	May 28	33
2010	Apr 27	May 12	Jun 08	43
2011	Apr 25	May 19	May 31	37
2012	Apr 25	May 01	May 19	25
MEDIAN	**Apr 28**	**May 13**	**May 30**	**33**
MIN	**Apr 24**	**May 01**	**May 19**	**24**
MAX	**May 06**	**May 28**	**Jun 08**	**51**

Clipped Steelhead	10 %	50%	90 %	# of Days
2003	May 02	May 29	Jun 04	34
2004	May 07	May 20	May 29	23
2005	May 04	May 19	May 26	23
2006	Apr 28	May 10	May 29	32
2007	May 04	May 12	May 26	23
2008	May 07	May 16	May 30	24
2009	Apr 29	May 10	May 27	29
2010	May 03	May 11	Jun 09	38
2011	Apr 19	May 19	May 30	42
2012	Apr 25	May 03	May 15	21
MEDIAN	**May 02**	**May 14**	**May 29**	**28**
MIN	**Apr 19**	**May 03**	**May 15**	**21**
MAX	**May 07**	**May 29**	**Jun 09**	**44**

Coho	10 %	50%	90 %	# of Days
2003	May 09	May 30	Jun 08	31
2004	May 12	May 27	Jun 12	32
2005	May 05	May 16	Jun 03	30
2006	May 10	May 26	Jun 12	27
2007	May 05	May 16	Jun 04	31
2008	May 11	May 25	Jun 06	27
2009	May 16	May 29	Jun 13	29
2010	May 09	Jun 03	Jun 16	39
2011	May 10	May 23	Jun 06	28
2012	May 06	May 21	Jun 05	31
MEDIAN	**May 09**	**May 25**	**Jun 06**	**30**
MIN	**May 05**	**May 16**	**Jun 03**	**24**
MAX	**May 16**	**Jun 03**	**Jun 16**	**90**

Sockeye (Wild + Hatchery)	10 %	50%	90 %	# of Days
2003	May 10	May 19	Jun 02	24
2004	May 20	Jun 01	Jun 12	24
2005	May 16	May 21	May 31	16
2006	May 07	May 20	May 30	24
2007	May 09	May 25	Jun 07	30
2008	May 22	May 29	Jun 06	16
2009	May 10	May 25	Jun 07	29
2010	May 11	May 29	Jun 09	30
2011	May 10	May 22	Jun 02	24
2012	May 02	May 11	May 25	24
MEDIAN	**May 10**	**May 23**	**Jun 04**	**26**
MIN	**May 02**	**May 11**	**May 25**	**16**
MAX	**May 22**	**Jun 01**	**Jun 12**	**41**

* Subyearling Chinook median, min and max values based on data from 1998-2005. Data from 2006-2012 were not included due to potential bias from missed sample days resulting from the implementation of sampling protocols during periods of high water temperature (Appendix K).

2.7.1 Juvenile Fish Passage Criteria

Although National Oceanic and Atmospheric Administration (NOAA) Fisheries typically requires screening on new intake structures, juvenile fish screening is not required for *forebay* intakes of alternatives described in this report due to the emergency-use only nature of the project, the limited duration of operation (up to 1 year), intake depth, and the anticipated construction, operation, and maintenance costs of juvenile fish screening (HDR 2012, Appendix J and Appendix K). The primary concern for juvenile salmon and juvenile lamprey with respect to the AWS backup system design discussed in this report is entrainment in the system via the forebay intake. With this in mind, the fine trash rack criteria as detailed above will likely provide exclusion of juvenile salmonids and lamprey to some degree; however, the assumptions regarding the operation of the AWS are as follows:

- 100 percent mortality is assumed for fish entering the AWS backup system. This is a reasonable assumption given potential velocities and pressures that may be experienced within the system. It is also assumed that the AWS backup system will be operated for up to 1 year, and outmigrating juvenile salmonids and lamprey will be exposed to the backup system for that period.
- Entrainment risk is influenced by a number of factors, including location, design discharge, and depth.

2.7.1.1 Juvenile Salmon and Steelhead

<u>Horizontal Distribution in Forebay</u>

Cash et al. (2005) observed a distinct divergence of juvenile salmonids as they approached The Dalles Dam. Juvenile salmonids approach at approximately mid-river and subsequently segregate – a portion of the fish move toward the powerhouse while the remaining fish move directly toward the spillway. Data on first detections within 328 feet (100 meters) of the dam indicate that acoustic-tagged yearling Chinook salmon and steelhead often approach from the east (upstream) end of the powerhouse, but move along the powerhouse toward the west (downstream) end before passing through turbines and the sluiceway (including F1 and F2). Conversely, subyearling Chinook salmon horizontal passage distribution is typically more evenly distributed across the powerhouse (Johnson et al. 2007, 2011). Overall, having the AWS intake located at the east end of the powerhouse will reduce the likelihood of juvenile salmonid entrainment into the system.

<u>Design Discharge</u>

Relative route use by outmigrating juvenile salmonids is influenced by the amount of water passing via various routes. This design will deliver 1,400 cfs, which was determined to be appropriate flow to maintain fishway entrance criteria (HDR 2012). This discharge is much less (72 percent less) than the 5,000 cfs supplied to the AWS via F1 and F2, and water velocities at the intake are limited by the fine trash rack at approximately 1.0 cfs. With this in consideration, juvenile salmonids should experience a very low risk of attraction, impingement, or entrainment potential from the AWS intake.

<u>Forebay Intake Depth</u>

Migration and passage depth varies by species, time of day, location, and structure encountered, but outmigrating juvenile salmonids generally occupy the upper 20 feet or less of the water column (Faber et al. 2005), which is well above the proposed intake depth of the AWS. Approximately 2 percent of outmigrating smolts may be migrating deep enough in the forebay to encounter the top of the AWS intake, and up to 1 percent may potentially be deep enough to approach the intake centerline (Faber et al. 2005). Therefore, locating the intake centerline at approximately 116 feet msl will submerge the structure approximately 43 feet below low forebay elevation at 155 feet msl. This will reduce the probability of juvenile salmonid entrainment as they approach the powerhouse.

2.7.1.2 Juvenile Pacific Lamprey

Horizontal Distribution in Forebay

The horizontal distribution is unknown for juvenile lamprey. Subyearling Chinook salmon can be used as surrogates for horizontal distribution, because both juvenile Pacific lamprey and subyearling Chinook salmon are relatively weak swimmers compared to larger yearling salmonids.

Design Discharge

Relative route use by outmigrating juvenile lamprey is influenced by the amount of water passing via various routes and the water velocities encountered at those routes. This design will deliver 1,400 cfs, which is much less than the 5,000 cfs supplied to the AWS via F1 and F2. Water velocities at the intake are designed to be approximately 1-2 fps. This is below the 2.6 fps mean burst swim speed, but within the range of the 1.3 fps sustained swimming speed of juvenile Pacific lamprey (Moursund et al. 2003). While some juvenile lamprey may be attracted to the intake as a potential downstream passage route, the reduced discharge is expected to reduce passage potential. With these considerations, the proposed AWS intake should result in a neutral impact on attraction and entrainment potential for juvenile lamprey.

Forebay Intake Depth

Migration depth of juvenile lamprey is poorly understood, but studies at various dams found that > 70 percent of juvenile lamprey passed below turbine intake screens of juvenile bypass systems (BioAnalysts Inc. 2000; Moursund et al. 2003; Monk et al. 2004; Moursund and Bleich, 2006). The proposed intake depth of the AWS backup system may increase entrainment risk for juvenile lamprey; however, it is expected that other factors such as design discharge and location will generally neutralize this risk.

2.8 DESIGN IMPLICATIONS FOR JUVENILE FISH PASSAGE

Juvenile salmonids and lamprey encounter The Dalles Dam during their downstream migration; therefore, flow through the intake pipes may result in some entrainment. Although approximately 80 percent of juvenile salmonids pass the dam via the spillway (Johnson et al. 2007), fish approaching the dam near the south shore of the Columbia River first pass along the powerhouse and will therefore be vulnerable to entrainment. However, the proposed intake depth and velocities of the AWS are such that entrainment of juvenile salmonids is not expected. Over 80 percent of all juvenile salmonids should be distributed within approximately 38 feet of the water surface (Faber et al. 2005), which is above the ceiling of the intake pipe, assuming a 10-foot-diameter intake pipe with the top of the structure approximately 43 feet deep at minimum operating pool.

Turbine and sluiceway passage of yearling Chinook salmon and steelhead is skewed to the west end of the powerhouse; therefore, location of the intake at the east end of the powerhouse will reduce risk of entrainment relative to the existing system. Horizontal distribution of subyearling Chinook salmon is more evenly distributed; therefore, location of the intake is not expected to provide a risk of entrainment to subyearling Chinook salmon.

Forebay distribution of outmigrating lamprey is unknown; however, they may distribute similarly to subyearling Chinook salmon, or travel slightly deeper, as some studies suggest (BioAnalysts Inc. 2000; Moursund et al. 2003; Monk et al. 2004; Moursund and Bleich. 2006). While juvenile lamprey may migrate deeper, it cannot be assumed that they prefer to migrate at depths below that of the juvenile bypass screen. It may be assumed that instinctual lamprey behavior may cue juveniles to dive below the intake screens when entering a turbine intake, potentially to avoid shallow water predators. Due to the unknowns of juvenile lamprey migration, the location of the AWS intake in the water column is not expected to provide a great risk of entrainment. Further, given the AWS fine trash rack criteria and low intake velocity, a low risk of entrainment is expected for juvenile lamprey.

While the AWS design imposes minor risks to juvenile salmonids and lamprey, the risks to juvenile fishes are outweighed by the benefit this system will provide to adult passage. The rare use of the system and potential to eliminate serious delays in adult salmonid migration for a duration that may extend to a year prove that this system design is acceptable for AWS backup system.

2.8.1 Predation

Structures added to the forebay will be limited to an intake pipe bulkhead and trash rack, which will provide little additional habitat for predators or change in conditions that may provide an advantage to predators. Piers will be constructed for bulkhead slots measuring 5 feet deep from pier nose to the dam face. These piers may provide velocity breaks and concealment on the downstream side of the structure where predators may hold. Once constructed, a backfill of concrete will be poured along each pier to eliminate the abrupt contour change along the structure and reduce the potential for predators to hold and ambush juveniles as they pass by.

2.9 CONSIDERATIONS FOR WHITE STURGEON

Position and depth of the intake should have a negligible effect on white sturgeon. Adult sturgeon will be precluded from entrainment by the trash racks. Young sturgeon are usually found near the bottom in reservoirs, preferring deep (approximately 30-125 feet), low velocity areas (Parsley et al. 1993; Parsley and Beckman 1994). During non-winter months, age-0 and juvenile white sturgeon tend to select areas of moderate to high depth (approximately 68 feet) with steep channel slopes (Hatten and Parsley 2009).

2.10 SUMMARY OF DESIGN IMPLICATIONS FOR FISH PASSAGE

The benefits this AWS will provide for adult passage makes the potential risk to juveniles insignificant. The fine trash rack criteria, intake depth, and low intake velocity will exclude fish from entering the system and eliminate any potential for entrainment or impingement for adults and minimize the potential for juveniles. The AWS bulkhead and trash rack installation in the forebay will also be designed to reduce predator habitat. The rare use of this system and expected minor risk to juvenile passage suggests this design will be acceptable to meet the requirements of the AWS with little impact to ESA listed fish.

2.11 IN-WATER WORK WINDOW

The in-water work window (IWWW) for annual maintenance of fish facilities is scheduled from December 1 through February 28 or 29. Work during this period minimizes impacts on both upstream and downstream migrating salmonids. During the in-water work period, one fish ladder (north or east fish ladder) is always operational. Coordination with Northern Wasco People’s Utility District (PUD) is needed prior to scheduling construction because they conduct routine maintenance each year when the north fish ladder is out of service.

CHAPTER 3 – GEOTECHNICAL DESIGN

3.1 GENERAL

This section describes the probable subsurface conditions and geotechnical design parameters and properties for The Dalles east fish ladder (EFL) auxiliary water supply (AWS).

3.2 REFERENCES

a. HDR Engineering, Inc. 2012. The Dalles East Fish Ladder Auxiliary Water Backup System Engineering Documentation Report. December. Report to U.S. Army Corps of Engineers, Portland District.

b. U.S. Army Corps of Engineers (USACE). Engineering Regulation (ER) 1110-2-1806, Earthquake Design and Evaluation for Civil Works Projects.

c. USACE Engineering Manual (EM) 1110-2-6053, Earthquake Design and Evaluation of Concrete Hydraulic Structures.

d. USACE. 1964. The Dalles Dam, Part IV, Foundation Report for the Closure and Non-overflow Dams. May. (not yet available)

e. U.S. Geological Survey (USGS) Seismic Hazard Curves and Uniform Hazard Response Spectra applet. http://earthquake.usgs.gov/hazards/designmaps/grdmotion.php

3.3 SUBSURFACE INFORMATION

3.3.1 Geology

The anticipated dominant subsurface material is a gravelly, sandy, SILT fill. The material was placed during construction of the east fish ladder. At depth, the anticipated material is Columbia River Basalt. The Dalles Dam design memo (USACE 1964) should detail the condition of the basalt (fractured, weathered, etc.). The original overburden is anticipated to have been removed during the original construction.

3.3.2 Geotechnical Design Parameter

Due to the uncertainty of the depth to basalt, the fill design parameters and properties are assumed, based on experience, and presented in table 3-1 below.

Table 3-1. Fill Design Parameters

FILL Assumed Design Properties & Parameters				
Property		**Value**	**Units**	
dry unit weight	γ_d	115	pounds per cubic foot	pcf
moisture	ω	10	percent	%
friction angle	ϕ	32	degrees	°
cohesion	c	100	pounds per square foot	psf

The basalt design parameters and properties are also assumed (HDR 2012) and are presented in table 3-2 below.

Table 3-2. Basalt Design Properties

BASALT Assumed Design Properties & Parameters				
Property		**Value**	**Units**	
unit weight	γ	140	pounds per cubic foot	pcf
rock quality designation	RQD	>90	percent	%
compressive strength	q_u	≈10,000	Pounds per square inch	psi

3.3.3 Groundwater

The river level is anticipated to strongly influence the groundwater elevation. It is possible for groundwater to be perched in the fill, but the quantity of water will be small.

3.3.4 Seismic Parameters

Earthquake ground motions for an event with a 50 percent probability of exceedence during the service life, known as the Operational Basis Earthquake (OBE), and an event with a 10 percent probability of exceedence during the service life, known as the Maximum Design Earthquake (MDE), are estimated to provide an economical design. After an OBE event, the project is expected to function with little or no damage; after the MDE, the project is not expected to experience catastrophic failure. If the structure is considered critical in accordance with ER 1110-2-1806, the Maximum Credible Earthquake (MCE) is determined as the greatest earthquake that can reasonably be expected to be generated and is used as the MDE.

The service life of the project is 100 years, resulting in a return period of 144 years for the OBE, and, for noncritical structures, the MDE return period is 950 years. For MCE events, there is no return period. Therefore, both the OBE and the MDE can be characterized by a probabilistic analysis; the MCE is determined by a deterministic analysis.

The seismic ground motion parameters in table 3-3 should be used in design. The ground motion for the MCE was estimated using a probabilistic analysis and a return period of 2,475 years. Additional work will be necessary to determine the MCE.

Table 3-3. Seismic Ground Motion Parameters

<table>
<tr><th colspan="4">Seismic Ground Motion Parameters (in % g)</th></tr>
<tr><td rowspan="3">Period</td><td></td><td colspan="2">Critical Structure</td></tr>
<tr><td colspan="2">Non-Critical Structure</td><td></td></tr>
<tr><td>MDE</td><td>OBE</td><td>MCE</td></tr>
<tr><td>Peak Ground Acceleration (PGA)</td><td>0.14</td><td>0.05</td><td>0.20</td></tr>
<tr><td>0.2 sec damping</td><td></td><td></td><td></td></tr>
<tr><td>1.0 sec damping</td><td></td><td></td><td></td></tr>
</table>

3.3.5 Anticipated Foundations

The new supply conduit will likely be placed on fill material and shallow foundations should be adequate. Depending on the stability of the existing fish lock approach channel (FAC), tie-backs may be required. If insufficient length is available to tie-back the FAC walls, then a dead-man anchorage will be developed, likely consisting of drilled shafts. Thrust blocks to restrain the change of momentum of the water in the new supply conduit will be resisted by passive earth pressures and sliding friction.

CHAPTER 4 –HYDRAULIC DESIGN

4.1 GENERAL

The selected alternative provides 1,400 cubic feet per second (cfs) of flow with a single conduit penetrating monolith 5 and discharging through an energy dissipation valve into the modified fish lock approach channel (FAC). Flow is then partially conveyed from the FAC to the auxiliary water supply chamber (AWSC) by two suspended flumes located at the FAC entrance.

4.2 REFERENCES

a. Beichley, C. L. and Peterka, A. J. 1961. Hydraulic Design of Hollow-Jet Valve Stilling Basins. Journal of the Hydraulics Division, ASCE, No. HY5.

b. Justin, J. D. and Creager, W. P. 1950. Hydroelectric Handbook.

c. King, H. W. and Brater, E. F. 1963. Handbook of Hydraulics, 5th Ed.

d. Miller, D. S. 1990. Internal Flow Systems, 2nd Ed.

e. Swamee, P. K. and Jain, A. K. 1976. Explicit equations for pipe-flow problems. Journal of the Hydraulics Division, American Society of Civil Engineers (ASCE), Vol. 102, No. HY5, pp. 657-664.

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h. USACE. 2006. Design Document Report #34, The Dalles Lock and Dam, Juvenile Behavioral Guidance System. May.

i. U.S. Dept. of the Interior Bureau of Reclamation (USBR). 1987. Design of Small Dams.

4.3 HYDRAULIC CRITERIA

Under a normal two turbine operating condition, the auxiliary water supply (AWS) operates with flows of up to 5,000 cfs. In an emergency operating scenario where there is a two fish turbine unit failure, the proposed backup AWS design discharge is 1,400 cfs (coordinated and approved by USACE and fisheries agencies; see table 4-1). Due to the reduced discharge available, the following operational changes will be made to the system.

- West and south fish entrance weirs will be closed.

- East fish entrance will operate with only two weirs; the third weir will be closed.

Table 4-1. Emergency AWS Discharge Requirements

Emergency AWS Discharge Requirements	
Design Discharge	1,400 cfs
Design Supply Head	90.0 feet

4.3.1 Water Surface Elevations

The design water surface elevations for forebay and tailwater are shown in table 4-2 below. These values were identified in the Juvenile Behavioral Guidance System report (USACE 2006). The AWSC water surface elevations were identified from the design tailwater elevation and the original east fish ladder (EFL) hydraulic design analysis. The exact water surface elevations used for the design of the alternative components are described in the appropriate sections of this report.

Table 4-2. Design Elevations

Design Elevations	
	Feet, msl
Maximum Forebay	160.0
Minimum Forebay	155.0
Maximum Tailwater	86.0
Minimum Tailwater	74.0
Maximum AWSC	90.0
Minimum AWSC	80.5

4.4 HYDRAULIC DESIGN

4.4.1 Inlet Design

The inlet of the supply conduit is set at elevation 116.5 feet, 38.5 feet below minimum forebay water surface elevation and approximately 20 feet off the river bottom, to avoid entrainment of juvenile salmonids and lamprey during operation. The current bathymetric survey indicates a river bottom of approximately 94 feet at the upstream sided of the penetration through the dam. The inlet is to be a bell-mouthed circular conduit inlet normal to the dam face with a rounded elliptical geometry of 1.5 feet for the secondary axis and 5 feet for the primary axis.

Trash racks for the intake are sized with a 3-feet-per-second (fps) approach velocity and a flow of 1,400 cfs. Velocity criterion was determined during the Engineering Documentation Report (EDR) phase of design and based off of EM 1110-2-1602. A through bar velocity of 5 fps is recommended by the Bureau of Reclamation *Design of Small Dams* (1987) publication. An assumed porosity of 70 percent for the trash rack results in a required gross area of 375 square feet; however, in order to meet the approach velocity a required gross area of trash rack is required to be 466 square feet.

Trash rack width is set at 22 feet and the height extends the full depth of the water column to the intake with an offset of 5 feet from the dam. This allows for uniform localized flow at the intake under clean conditions; as debris loads the trash rack, additional flow capacity is available above the intake elevation. Maximum debris loading design is 50 percent clogging of open area, resulting in a maximum loading of 42.08 pounds per square foot (psf).

An emergency closure gate slides down over the intake against the dam face to shut off flow in the event of failure at the cone valve or along the length of the 10-foot-diameter supply pipe. This gate will also act as the primary dewatering gate while the emergency auxiliary water supply system is not in operation and during inspection of the conduit and valve.

An air relief valve is located downstream of the emergency closure gate to supply air during typical dewatering of the conduit or emergency closure.

4.4.2 Main Supply Conduit

Conduit size selection and design were based on head loss, velocity constraints, cavitation potential, and alignment constraints.

Friction losses were based the Darcy-Weisbach friction formula (Equation 1) for a welded steel pipe,

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \quad \text{(Equation 1)}$$

where h_f is the head loss due to friction, f is the friction factor, L is the length of conduit, D is the conduit diameter, V is the fluid velocity in the pipe, and g is the acceleration due to gravity. The friction factor f was developed from the explicit friction factor equation listed below,

$$f = \frac{0.25}{log\left[\frac{k_S}{3.7D} + \frac{5.74}{Re^{0.9}}\right]^2} \quad \text{(Equation 2)}$$

where k_S is the equivalent sand grain roughness of the pipe, and Re is the Reynolds number for the fluid passing through the conduit. Equation 2 was developed in the ASCE *Journal of Hydraulics Division* article “Explicit equations for pipe-flow problems.”

Minor losses were based off of D.S. Miller’s *Internal Flow Systems* (1990) and consist of an entrance loss, an air relief valve and filling valve tee, two 90-degree bends, a 40-degree bend, one contraction, and the discharge valve. These are discussed in greater detail below.

The main supply conduit was sized to meet velocity limitations defined in the EDR of 18 fps. This resulted in a single conduit selection of 10 feet in diameter for 300 feet, the majority of the alignment, with a maximum velocity of 17.85 fps. Due to constraints of the energy dissipation valve to be later discussed, the conduit transitions to a 7-foot-diameter conduit at the valve, with a maximum velocity of 36.4 fps. Due to the proximity to the valve, the transition must be concentric in order to maintain uniform hydraulic loading on the valve. The contraction will help normalize any remaining turbulent flow patterns resulting from the 40-degree bend.

The conduit penetrates the dam with a centerline at 116.5 and angles downward to elevation 104.5 to achieve 2 feet of cover below the roadway and parking lot. It makes a 90-degree turn to parallel the dam toward the fish lock. The conduit enters the FAC in front of the fish lock and makes a second 90-degree turn to continue in line with the fish lock approach channel. The resulting forces at the first and second 90-degree turns are 437 kips (kilo pound) and 359 kips, respectively. The conduit makes a horizontal and vertical composite 40-degree bend, resulting in a required restraint force of 147 kips. Here, a contraction from a 10-foot-diameter to the 7-foot-diameter valve is installed at the valve support, as shown in appendix B. The resulting force from the contraction is 220 kips in the opposite direction of flow.

The total head loss through the conduit is 6.8 feet, leaving 45 to 50 feet of hydraulic energy to dissipate. Hydraulic transient analysis will be further developed to determine closure rate of the main operation valve and emergency closure gate.

4.4.3 Energy Dissipation

The EDR identified energy dissipation with the use of ported sleeve valves. Concerns for clogging within the valve or valve seizure due to intermittent use prompted investigation into alternative energy dissipation methods better suited for this use.

Excess energy is dissipated with the combination of a hollow-jet valve and stilling basin in the existing fish lock approach channel. A hollow-jet valve is a type of needle valve that forces water outward into a short containing sleeve to create a jet of water with an air void in the center of flow into which it can expand as it extends past the outlet of the valve.

A Howell-Bunger type hollow cone valve was selected from commercially available valves. In order to meet the required flow rate, an 84-inch valve with a maximum coefficient of discharge of 0.85 was selected. This results in a maximum discharge of 1,775 cfs at low reservoir and 1870 cfs at high reservoir with the design assumptions.

Due to concerns of entraining dissolved gasses into the water at the energy dissipation location, the valve will be submerged. This ensures that air is not forced into the FAC, supersaturating the water with dissolved gasses. This also reduces potential for spray from the valve ejecting out of the FAC and causing any maintenance or safety concerns.

The FAC acts as a stilling basin for the submerged valve, which has a Froude number of 2.4 at the design flow rate. Flow release from the valve was evaluated using guidance from EM 1110-2-1602 for adequate submergence of an equivalent sluice jet entrance, and using the U.S. Bureau of Reclamation (USBR) Design of Small Dams

(288-D-2428) method of developing stilling basin depth. The design water surface elevation of 102.5 feet exceeds the sequent depth requirement of both guidance sources for sluice way stilling basins, resulting in sufficient energy containment.

4.4.4 FAC Modifications

The FAC will be modified to contain the flow within the channel and prevent drainage into the cul-de-sac and fish ladder. This requires blocking off the cul-de-sac entrance to an elevation of 105.0 feet. The fish ladder entrance will be blocked off to 105.0 feet, with six culverts penetrating the new wall (see section 4.4.6).

The diffusers in the FAC from the existing AWS will have the diffuser baffles and the grating removed to increase flow capacity into the AWS culvert. The diffuser gates will be maintained to provide dewatering capability from the AWSC while the emergency system is under maintenance or not in use.

4.4.5 Existing AWS Subsurface Conduit

The EDR recommends passing all 1,400 cfs through the AWS fish lock conduit; however, further investigation shows that driving head required is insufficient at a high design pool in the AWSC. The EDR identifies the design maximum tailwater at 86.0-foot water surface elevation. Assuming 1 foot of attraction head differential at the junction pool to the EFL entrance, and a maximum of 2.2 feet of head differential from the AWSC to the junction pool through the diffuser from the EFL design calculations, the result water surface elevation required in the AWSC is 89.8 feet. The EDR assumes an AWS chamber water surface elevation of 85 feet in the calculations.

The velocity for the full 1,400 cfs through the 8-foot by 8-foot box culvert resulted in a velocity of 21.9 fps, which raised concerns for local scour/cavitation and complex upwelling in the AWSC.

The water surface elevation in the FAC is designed to 102.5 feet in order to provide adequate energy dissipation. The resulting minimum head differential available between the FAC and the AWSC is 12.5 feet; whereas in the EDR an assumption of raising the FAC walls and associated water surface to 109.0 feet will achieve a minimum head differential of 24 feet.

Further analysis of the AWS culvert with the removal of diffuser gates and other minor losses, and in conjunction with modifications noted in section 4.4.6, determined that the capacity of the AWS culvert was approximately 620 cfs at high tailrace conditions. Velocity through the AWS culvert is 9.7 fps, which will mobilize deposits out of the culvert from non-emergency AWS operations. Due to the extent of the modifications associated with the 8 by 8 culvert, dewatering of the FAC will become very difficult without also dewatering the AWSC.

Considering these factors, additional conveyance was deemed necessary to route flow from the FAC to the AWS chamber using the existing 8-foot by 8-foot box culvert and diffuser gates for system flexibility. With minimal modification to the diffusers, the 8 by 8 culvert can convey 300 cfs and still maintain dewatering capability of the FAC during operation of the AWS from the fish turbine units.

4.4.6 New FAC to AWSC Conduit

In order to convey the total flow from the fish lock approach channel to the auxiliary water supply chamber, six 6-foot diameter steel culverts will bridge across the fish ladder from the fish lock approach entrance. Due to entrance constraints into the AWSC, the culverts are stacked in pairs. The lower culvert operates flowing full while the upper culvert level operates under open channel conditions. This will alleviate potential for vortexing at the entrance of the culverts. The lower conduit has an invert elevation set at 92.0 feet, 2 feet above the AWSC maximum water surface, such that no flow will back feed into the FAC during normal AWS operation.

While utilizing the culverts to pass the full 1,400 cfs to the AWSC, the 8-foot by 8-foot culvert and diffuser manifold will remain as a backup conduit and isolation point for the dewatering of the FAC.

An analysis of the impact trajectory shows that the culvert outfalls reach the water surface within the AWSC before the opposite wall. An evaluation of each outfall will be further developed to ensure that the diffusers located below are not surcharged or can be shut off and distributed through other diffusers.

CHAPTER 5 – STRUCTURAL DESIGN

5.1 STRUCTURAL DESIGN FEATURES

- Guide slots for:
  - Emergency gate.
  - Trash rack.
  - Trash rack cleaning.
- Emergency gate:
  - Lifting beam will be designed at a later time, not part of this Design Documentation Report (DDR).
  - The bottom of the gate will have a slope to reduce hydraulic down-pull.
- Trash rack:

  Stainless steel bar grating with ¾-inch clear opening between bars will be used. The grating callout is W15 1-1/4x3/16. The trash rack frame will be 12 feet by 22 feet in overall size, made from stainless steel 4-foot 6-foot tubes. A guide pin will be required to align each rack vertically. The ends of the grating bars will be beveled to assist the trash rake between the trash racks in case of misalignment. The trash racks are sized at 12 feet tall for transport and unstacking. Stainless steel was chosen as material for reduced maintenance cost.
- Thrust block for 10-foot-diameter supply conduit.
- Penetration into fish lock approach channel (FAC) for 10-foot-diameter supply conduit.
- Thrust restraint in FAC for 10-foot-diameter supply conduit.
- Evaluation of removal and sizing of soil anchors for FAC side wall supports.
- Liner or scour protection in FAC and wall extension.
- Concrete infill in FAC. A 3-foot-thick wall will block the end of the FAC channel. The wall will act as a support for the pipes that will span over the fish lock.
- Pipe support over existing fish ladder. It has been determined that Wall E2, as shown on drawing sheet DDF-1-4-5/V10 (see appendix C), can support the increased load from the pipes that transport water from the FAC to the auxiliary water supply chamber (AWSC).

- Cul-de-sac fish chamber closure. Used precast concrete stoplogs will be grouted in place after installation. The contractor is to determine height of each stoplog based on their installation equipment, but a minimum height of 5 feet, 7 inches is required.
- 6-foot pipes between FAC and AWSC. A total of six 6-foot-diameter pipes will be used to transport water. The pipes will be stacked in groups of two high. The pipes will penetrate concrete Wall E2 between frames 16, 17, and 18.
- Protection for frame beams. A steel plate and beams will be installed around the existing concrete beams in frames 16 and 17 to protect them from scour and vibration from water coming through the 6-foot-diameter pipes.

5.2 GOVERNING DESIGN CODES

- Emergency gate and bulkheads:
    - Engineer Manual (EM) 1110-2-2105, Design of Hydraulic Steel Structures.
    - EM 1110-2-2701, Vertical Lift Gates.
- Steel Design – American Institute of Steel Construction (AISC) 360-05 Specification for Structural Steel Buildings – Steel Construction Manual 13th Ed.
- Concrete design:
    - American Concrete Institute (ACI) 318-08, Building Code Requirements for Structural Concrete.
    - EM 1110-2-2104 – Strength Design for Reinforced Concrete Hydraulic Structures – will use load factors from EM, will use ACI 318-08 for design equations.
- American Welding Society (AWS) D1.1-2008, American Welding Society, Structural Welding Code – Steel.
- AWS D1.5-2008, American Welding Society, Bridge Welding Code.
- American Society of Civil Engineers (ASCE)-7-05, American Society for Civil Engineers, Minimum Design Loads for Buildings and Other Structures.
- Stability Analysis of Concrete Structures, EM 1110-2-2100.
- American Water Works Association (AWWA) M11, Steel Water Pipe: A Guide for Design and Installation.

5.3 MATERIAL PROPERTIES

- Existing concrete 28-day compressive strength: f’c = 3,000 psi.
- New concrete 28-day compressive strength: f’c = 4,000 psi.
- Precast concrete 28-day compressive strength: f’c = 6,000 psi.
- Existing reinforcing steel: Grade 40 fy = 40,000 psi.
- New reinforcing steel: American Society for Testing and Materials (ASTM) A615, Grade 60 fy = 60,000 psi.
- Existing structural steel: ASTM A36, fy = 36,000 psi or ASTM A572, fy = 50,000 psi.
- New structural steel:
  - W shapes: ASTM A992, fy = 50,000 psi.
  - M, S, C, MC, and L shapes: ASTM A36, fy = 36,000 psi.
  - Hollow structural sections (HSS):
    - Round – ASTM A500 Grade B, fy = 42,000 psi.
    - Rectangular and Square – ASTM A500 Grade B, fy = 46,000 psi.
  - Pipe: ASTM A53 Grade B, fy = 35,000 psi.
  - HP shapes: ASTM A572 Grade 50, fy = 50,000 psi.
  - Plates and Bars: ASTM A36, fy = 36,000 psi.
  - Plates and Bars for HSS: ASTM A 709 Grade 50, fy = 50,000 psi.
  - Conventional Structural Bolts: ASTM A325.
  - Nuts: ASTM A563.
  - Washers: ASTM F436.
  - Anchor Rods: ASTM F1554 Grade 36, fy = 36,000 psi, Grade 55, fy = 55,000 psi.
  - All-Thread Bar: ASTM A722 fy = 150,000 psi.
  - All-Thread Bar Couplings: ASTM A29, Grade C1045.

CHAPTER 6 – MECHANICAL DESIGN

6.1 GENERAL

This section describes the design of mechanical features and systems as part of The Dalles East Fish Backup Auxiliary Water Supply.

6.2 MECHANICAL FEATURES

6.2.1 Trash Rake

The components for the intake structure, from upstream to downstream will be first the trash rake, then the trash rack, then the emergency gate. The trash rake will be designed to clear the trash rack from incidental debris that may accumulate as a result of flow through the pipeline. The trash rake will be designed to push debris downward from the rack surface in order to clear the passageway. The assumed operational procedure for raking trash will be to suspend flow with the downstream isolation valve, then lower the trash rake to clear debris. It is anticipated that this operation would be very infrequent and require less than one hour to complete. As a result, it is assumed that a no flow type of operation is acceptable.

The trash rack is approximately 22 feet wide and will extend from just below the pipeline entrance up to the water surface. The rack width is required to maintain the required water velocity through the bars in order to reduce risk of impinging debris and adult fish. The trash rake will be sized to match that width. The height of the trash rake is approximately 7 feet tall. This height is intended to provide a reasonable aspect ratio that is unlikely to rack in its slots. It is also required to develop sufficient weight to push debris downward off the rack. The initial concept for the rake geometry weighs in at approximately 7,000 pounds. The rake geometry is essentially 4 wide flange beams spanning the width of the rack. The beams are tied together at each end by a pair of vertically mounted channels. The raking surface of the rake is formed by bar grating on the back side of the wide flange beams. The bar grating will be welded to the beams. The grating design will consist of ¼ inch bars two inches deep tied together by pins run through the bars at their centerlines. The tines will be spaced to provide ¾ inches of clear space in order to accommodate the trash rack, with the tines centered between the rack grating.

This interaction will require some careful consideration. With the trash rack bars space at ¾ of an inch and the rake tines centered between those bars, there will only be ¼ inch of space between the rake tines and the rack bars. As a result, the rake system will be very sensitive to binding if it is not lowered evenly. A 1/16th-inch difference in the elevation between either end of the rake would cause it to bind. This condition could be mitigated by ensuring tight clearances between the gate and the guide; however, that would require less than ¼ inch of play between the rake and guides over the full travel of the rack. For this reason, UHMW aligning shoes are located on the sides of the rake. This issue will also require tight tolerances in the fit-up between trash rack panels. If the bars of one panel do not line up well with those of the panel below or above it, that out-of-line bar could bind on the rake tine. For this reason, the rack will provide tapered alignment pins between each panel. The exposed ends of each bar will also be tapered so that there is more room for the rake tines to pass by interface between the bars of two rack panels.

While it is assumed that there will be a no-flow condition when the rake is lowered, the initial concept provides for the ability to rake under flow. The beams are sized to take the drag of the water flowing through the tines and the wheels are provided to allow for the gate to roll under flow. The leading edge of the rake will form a ramp away from the rack surface, so that the as the rake encounters debris it will lift debris off the rack surface and force it downward.

The rake will typically be dogged off above the water surface. If it is determined that trash has built up on the racks, a mobile crane will be required to lift the rake off the dogs and lower it to clear debris.

6.2.2 Emergency Gate

The dam safety criteria for the emergency gate have one requirement in particular that pertains to mechanical design. That requirement is that the gate be deployable under flow. This suggests some kind of gate end roller to eliminate or mitigate the amount of sliding friction between the gate structure and the gate guides while the gate is moving through flowing water.

6.2.3 Gate Wheels

The emergency gate is approximately 14.5 feet square in order to cover the 10-foot-diameter pipe. This area would have a 50-foot water head applied to it, resulting in a total normal force of approximately 650,000 pounds. This is the load that would need to be carried by the end rollers. It was initially assumed that the gate would have self-lubricating, self-aligning, spherical track rollers similar to the closure gate wheel on the John Day top spillway weir (TSW). However, this type of roller is essentially a sliding roller, where an internal ball slides on an external race separated by a self lubricating liner. This type of roller can lower the frictional sliding at the interface but not remove it entirely. Under the given load, the force required to move the gate with this type of wheel would be approximately 42,000 pounds. This is almost double the gate weight of approximately 20,000 pounds. As a result, the gate would not be able to close under its own weight. Rather, it would require some type of closing actuator. This would add expense and complexity to the system.

As a result of this analysis, three alternative end rolling systems were evaluated. The first was the spherical plain roller described above, the second was a roller chain system similar to that on powerhouse head gates, and the third was a spherical roller bearing based wheel similar to the spillway lift gates at McNary Dam.

The roller chain is essentially a chain that encircles either end of the gate. The idea is that the load is transferred from the gate structure through the rollers and into the guides. As the gate is lowered under load, it rolls along these rollers. As the gate lowers the roller chain rolls around the end of the gate as new rollers at the bottom are brought in to take up bearing and rollers at the top are removed from bearing.

A spherical roller is similar to the spherical plane bearing except that spherical element does not slide, but rather rolls on a series of rollers arranged in a circle around the spherical element. It is essentially a roller chain that encircles each gate axle instead of the entire gate end.

A list of pros and cons were developed for each option to facilitate the selection of the most appropriate roller type.

The benefits of the spherical plane bearing are as follows. First, there are very few moving parts, only the outer race that rotates around a solid ball. Because the bearing is self lubricating, there is no potential for grease to enter the river. While a gate operator would be required to force the gate downward, that operator could be configured for push button operation, eliminating the need to bring in a crane to lower the gate. Finally, the spherical geometry of the bearings allows the gate to deflect while maintaining good contact between the wheel and guide. However, there are several negative aspects to this type of bearing. Primary among them is that a gate operator would be required. This adds cost and complexity to the system. The operator would likely consist of a hydraulic system, which would require additional maintenance and introduce a potential for oil entering into the river. The presence of a standalone operator would require a dedicated electrical system to be installed in the area, again adding cost to the project. Another detriment to a wheel on axel type roller is that it imposes a point load on the guide structure.

The benefits of a roller chain system are included below. First is that the gate could be deployed by crane without the need for a standalone operator. The roller chain system is not lubricated so there is no potential for grease to enter the river. Finally, due to the large number or rollers, the load on the gate is spread out more evenly onto the guide structure. However, there are several drawbacks to this system. There are a large number of moving parts; each roller consists of a roller, axle, and link bar. A failure of any one of those parts could cripple the system. Typically, to allow these items to roll freely without worry of seizure due to corrosion, the chains are made from stainless steel. This large volume of stainless steel contacting the carbon steel gate would result in the need to have a cathodic protection system, most likely sacrificial anodes. The chains themselves are heavy and unwieldy. And finally, the chains do not compensate well for gate deflection.

The third system under consideration is the spherical roller bearing. Its analysis is included herein. The benefits of this system are that with this system the gate could be lowered under flow without the need of a dedicated operator. The roller bearings have several moving parts, however they are contained and protected within the wheel structure. The spherical geometry allows the wheel to compensate for gate deflection while still maintaining good contact between the wheel and the guide. There are however a few drawbacks to this system. The spherical roller bearing is a grease packed bearing, and as such there is potential for grease to enter the river. This also would require additional maintenance to periodically monitor and re-pack the bearings. And, finally, the individual wheel imposes a point load on the guide structure.

The selected roller system is the spherical roller bearing system. The primary concern is to simplify the system, and the need to have a dedicated gate operator would create an overly complex system. The maintenance and grease potential were strikes against this system; however, the maintenance requirement is infrequent and the grease is thick and behind seals, so the likely hood of grease escaping is minimal. This type of system has been operating on the McNary spillway lift gates for 50 years without much of a problem. These gate are currently being rehabilitated and the majority of these wheels are still in good shape.

The gate geometry provided for ten wheels, five on either side. The wheels have an approximately 10-inch spherical element diameter and a 16-inch-diameter tread. The wheel axle is about 6 inches in diameter to accommodate the bending generated by cantilevering out from the end of the gate. The wheel tread and axle will be fabricated from 17-4 PH stainless steel. The amount of stainless steel in contact with the carbon steel gate is low and as such will not require a galvanic protection system beyond the paint coating on the gate.

6.2.4 Operating Gate Hydraulic Operators

The original concept called for the emergency gate to be supported against flow using wheels mounted on plain spherical bearings. As discussed above this would not completely eliminate the sliding friction as the gate was lowered into place. The remaining friction could not be overcome by the weight of the gate itself, as a result some means to push the gate closed would be required.

The original concept called for this to be accomplished through the use of hydraulic cylinders pushing downward on the gate. The gate closure system was to be designed to keep the hydraulic components above the water surface. A frame was to be installed above the gate to transfer the force from the hydraulic cylinders to the gate. The frame could be pin coupled to the gate and act as both a closure device and lifting beam to lift the gate out of the slot. A means would also have been required to pin the upper parts of the hydraulic system to the intake structure to react the force applied by the hydraulics.

A portable hydraulic power unit was also to be provided to supply pressure to the hydraulic cylinders. This system would have been skid mounted so that it could be trucked into place on the rare occasions that gate operation was required. This hydraulic unit would have required electrical power, and as such the design would need to be coordinated with electrical design. It is assumed that the time required to deploy this portable system would be acceptable.

However, by selecting a spherical roller bearing system to support the gate, the excess friction is eliminated. As a result, the gate can close under its own weight and a separate operator is not required. This part of the mechanical scope has been eliminated.

6.2.5 Downstream Isolation Valve

For the 30 percent DDR concept, a butterfly valve downstream of the dam was included to serve as another means to isolate flow. This valve was to be located immediately downstream of the dam, and tied into the dam structure by means of anchors and concrete. This would provide a stable isolation point that would move with the dam in case of a seismic event. With this valve in place, it was assumed to be more likely that damage to the pipeline would occur downstream of the dam in the buried portion of the pipe. If this were to happen, the butterfly valve could be closed to stop flow through the dam. The butterfly valve would have been motor operated, and as such its design would require coordination with electrical design.

This was intended to be a secondary isolation location so that if a seismic event occurred that damaged the pipeline downstream of the dam, the butterfly valve could have been used to isolate flow. Since the 30 percent DDR, there were discussions that took place with Dam Safety that suggested this isolation point was not required. As a result of these discussions, this isolation point has been eliminated and removed from the mechanical scope.

6.2.6 Energy Dissipation Valve

The primary means of dissipating energy in the water stream is an 84-inch cone valve similar to a Howell Bunger valve. The function of this valve is described in the hydraulics section of this DDR. This valve would be specified by mechanical design. This valve also requires an electrical actuation system. This valve actuator would be mounted on a platform above the valve. The actuator itself would be a multi-turn valve actuator similar to a Limitorque actuator. The actuator would be coupled to the valve via an extension stem. As this presents an electrical load, the design of this system will require coordination with electrical design.

Operationally, this valve would be the first place to start up or shut down the system. For startup, the initial condition would be with the emergency gate closed and the cone valve partially opened to make sure that the pipeline stays drained. If in this condition the emergency gate were opened there would be jet of water entering and pressurizing a large volume of air. This pressurized air could potentially cause problems in this system. In order to mitigate this effect, provisions have been included to slowly flood this air cavity. For this purpose, a smaller 8-inch tap will be taken from the 42-inch line in the valve room and routed to a location just downstream of where the pipe exits the downstream face of the dam. This line would be valve controlled. This would add water to the cavity, however there would also need to be a place to vent the air. The entrance to the pipeline at the upstream face of the dam is the high point in the system and as such is likely the best place to locate a vent. A vent would be routed from this point, up the face of the dam and terminate in a “candy cane” type vent.

With these lines in place at startup the backfill line could be used to flood the air cavity between the emergency gate and the cone valve. With that space flooded, the pressure on either side of the emergency gate would be equalized. With the cone valve closed, the emergency gate could be raised without adding air to the system. The cone valve

For the shutdown case, the cone valve could be closed to suspend flow. Then the emergency gate would be closed. Finally, the cone valve would be opened to drain the pipeline.

6.2.7 Pipeline

The pipeline itself will be a 10-foot diameter, ½-inch wall, welded steel pipe. Connections to valves and specialty fittings will be done using flanged joints. In order to accommodate relative motion between the ground and structure resulting from seismic conditions, at least two restrained dresser style mechanical couplings will be place in the run of the pipe. One connection will be located immediately downstream of the butterfly valve and the other just upstream of the penetration through the approach channel wall. The pipe will be epoxy lined and coated to protect it against corrosion.

6.2.8 Expansion Joints

Another dam safety requirement for this system is that the pipeline will have expansion joints to accommodate thermal expansion. It is currently unclear whether or not thermal expansion joints are required in a buried pipe system, as temperature fluctuations will likely be small and buried pipe is partially anchored due to soil friction with its bedding. If expansion joints are required, there are a couple of methods that could be used to accommodate this growth. If expansion lengths are short, perhaps ½ inch or less, it may be possible to take up the expansion in the dresser couplings used to provide seismic flexibility. If expansion joints are longer, a dedicated expansion joint may be required in the long run of pipe. An additional benefit to providing expansion joints in the pipeline is that they will act as seismic isolators, allowing sections of the pipeline to move independently from each other. In any case, the joints will required some form of vault to allow for inspection, maintenance, and replacement of the joint. As such, the design of this system will require coordination with structural and geotechnical design. This vault would also make a good location for an inspection hatch into the pipeline.

6.2.9 Valve Room

In this design, the entirety of the attraction flow will come from the 10-foot-diameter pipe through the dam. As a result of this, the valve room will be left alone, with the exception of a small tap that will back fill the void between the emergency gate and the isolation valve. This tap will be controlled via a gate valve in the valve room. Since the 30 percent DDR there have been some discussions as to whether not scope should be added to rehabilitate some of the valve in the valve room. Part of this discussion stems from a desire to allow a 200 cfs flow from the pipes in the valve room, through the approach channel. This could provide a benefit of providing only a small amount of flow without starting up the full AWS system, or potentially augmenting the AWS flow if more water were required. New or rehabilitated valves would provide more reliable control over this augmentation water.

However, over the course of our discussion it was determined that the cone valve could provide more flow than the 1400 cfs required, and that a small 200 cfs flow was not required. As a result it was decided not to include any rehabilitation in the mechanical scope.

6.2.10 Demolition of Approach Channel Gates

There are currently several gates in the approach channel and fish lock, and most of these have hoist works above them. The new system will provide for the demolition of these gates and the hoist works that support them. In place of the gates, the channel will be confined by new concreted permanent bulkheads.

6.3 DESIGN CODE REFERENCES

The design will conform to the following pertinent mechanical criteria and applicable standards and codes.

6.3.1 General Standards

- American Society of Mechanical Engineers, 2004. ASME B31.1, Power Piping.
- American Welding Society, 2008. AWS D1.1, Structural Welding Code – Steel.
- American Welding Society, 1999. AWS D1.6, Structural Welding Code – Stainless Steel.
- International Code Council, 2012. International Plumbing Code.

6.3.2 Water Control Gates

- Maximum effort on crank or handwheel: 40 pounds.
- Centerline height of crank or handwheel: 36 inches.
- Stem covers: Clear butyrate plastic with Mylar open/close indicator. Maximum allowable leakage rate: 0.1 gallons per minute (gpm) per foot of seat perimeter.

6.3.3 Piping

- AWWA C200, Standard for Steel Water Pipe: 6 inches (150 mm) and larger.
- AWWA C206, Standard for Field Welding of Steel Water Pipe.

- AWWA C207, Standard for Steel Pipe Flanges for Waterworks Service – Sizes 4-inch through 144-inch.

- AWWA C208, Standard for Dimensions for Fabricated Steel Water Pipe Fittings.

- AWWA C210, Standard for Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines.

- AWWA M11, Steel Water Pipe: A Guide for Design and Installation.

6.3.4 Valves

- AWWA C515, Standards for Reduced-Wall, Resilient-Seated Gate Valves for Water.

6.3.5 Supply Service

- AWWA C504, Rubber Seated Butterfly Valves.

- AWWA C540, Standard for Power-Actuating Devices for Valves and Slide Gates.

- AWWA C550, Standard for Protective Epoxy Interior Coatings for Valves and Hydrants.

CHAPTER 7 – ELECTRICAL DESIGN

7.1 GENERAL

7.1.1 Electrical Power

There is no reserved electrical electric valve actuators power capacity at any of the existing motor control centers to provide power to the new equipment as part of this alternative. New connected loads, and demolished gate actuators need to be evaluated to determine the size of the new separately fed motor control center.

The following are expected electrical loads for this project:

- The total connected electrical load is estimated to be 35 kilovolt-ampere (kVA).
- The largest expected load is the portable hydraulic power unit (forebay emergency gate on intake deck).
- The cone-jet valve actuator with associated (motor) controllers.
- Instrumentation for alarm annunciation (minor 120 volt [V]).
- Adding local maintenance lighting and receptacles.

Motor voltages will be 460-V, 3-phase (PH) for motors 0.5 horsepower (hp) up to 200 hp, and 120V, single-phase for motors < 0.5 hp.

Evaluate the loads of demolished approached channel gates and fish lock entrance gate circuits for use by the new cone-jet valve actuator.

7.1.2 Control

There are no automatic or remote controls associated with the operation of this equipment. When this system is required, the equipment will be manually operated.

The electric valve actuator motor control will be manually switched.

7.1.3 Instrumentation and Annunciation

Instrumentation for announcing alarm conditions should be considered, as well as providing three ultrasonic water level sensors on the fish lock approach channel. These water level sensors will detect cone-jet overflow conditions in the channel. Overflow conditions will be annunciated in the powerhouse control room and the fish biologist's office.

7.1.4 Relocate Existing Conduit, Devices, and Equipment

- Survey existing drawings and locate existing conduit, devices, and equipment impacted by construction.

- Conduct a site survey to locate existing conduit, devices, and equipment impacted by construction.

- Determine electrical items needing relocation.

- Develop plan for relocating electrical items located in the construction area.

7.1.5 Demolish Electrical Equipment (see sheets MD-901 and MD-902 in appendix G)

- Disconnect and remove gate valve actuators.

- Determine electrical circuit to be reused and protect from damage.

- Label and update as-built drawings to abandoned and reused circuits.

7.2 EMERGENCY GATE OPERATOR, HYDRAULIC

The forebay emergency gate needs to be operable under flow, as a means to push the gate into the flow. Typically, this is accomplished through the use of hydraulic cylinder pushing downward on the gate. Control of the emergency gate is assumed to be hand lever hydraulic valves.

A portable hydraulic power unit will be provided to supply pressure to the hydraulic cylinders. This system will be skid mounted so that it could be trucked into place on the rare occasions that gate operation is required. This hydraulic unit will require electrical power.

7.2.1 Portable Hydraulic Power Unit

A manufacturer supplied control panel will be included with the hydraulic power unit. This panel will include the motor controls as needed to operate the system. In automatic mode, the unit will be controlled by pressure switches or transmitters located on the hydraulic power unit. The panel will include the following operator control devices:

- HAND/OFF/AUTO selector switch.

- EMERGENCY STOP push button (maintained contact).

- RUNNING indicator light.

- FAULT indicator lights.

Electrical design work is needed to determine if the portable hydraulic power unit can be fed from an existing 480V/3PH weld receptacle, or whether a dedicated power circuit needs to be designed and installed. Preliminary estimated size for the hydraulic unit is 10 horsepower.

7.3 ELECTRIC VALVE ACTUATORS

The mechanical valves will be positioned with electric valve actuators. The valve actuators include an electric motor, gear box, adjustable limit switches, manual lock, and (possibly) electric break. Each valve actuator requires an electrical power circuit and (reversible) motor controller. The valve actuators will be controlled by hand switches on or near the valve (motor) controller cabinet close to the valves. It is assumed the valves and gates will include motors in the range of 1 to 5 hp. Valves and gates will include a local control station with LOCAL/OFF selector switch and push-buttons for OPEN, CLOSE, and STOP operation.

7.3.1 Energy Dissipation Valve

The primary means of dissipating energy in the water stream is a 7-foot ring cone-jet valve. This valve will require an electric valve actuator, an associated motor controller, and control switches.

7.4 INSTRUMENTATION AND ANNUNCIATION

Discussion is needed to determine if instrumentation is required. As an example, additional or relocated water level sensors should be considered to annunciate the channel overflowing. Instrumentation in concert with annunciation should be considered to alarm dangerous conditions.

7.5 CONTROL

In general, most electrical control will be local hand switch control operating NEMA 3 motor controllers. NO REMOTE OR AUTOMATIC CONTROL IS EXPECTED.

7.5.1 Cone-Jet Valve Control

The valves will include local control stations located near each valve. Because these valves are to be rarely operated, the local operator controls (push buttons) are to be installed in a secured enclosure. The local control station will include the following operator control devices:

- OPEN push button (momentary contact).
- STOP push button (momentary contact).
- CLOSE push button (momentary contact).
- FULLY OPEN indicator light.

- FULLY CLOSED indicator light.
- Gate position (percent open) will be by mechanical dial.

7.6 MAINTENANCE LIGHTING AND RECEPTACLES

Design work should include maintenance lighting and receptacles in the project area. This will involve providing a lighting panel and circuit.

7.7 VALVE ROOM

It is assumed only incidental electrical work will be needed in the valve room. The backfill valve for the 10-foot pipe will be manually operated, not requiring electrical power. The incidental electrical work will be to relocate or reconfigure electrical equipment impacted by changes associated with this project.

In this design, the all of the attraction flow will come from the 10-foot-diameter pipe through the dam. As a result of this, the valve room will be left alone, with the exception of a small tap that will back fill the void between the emergency gate and the cone-jet valve. This tap will be controlled via a gate valve in the valve room. This gate valve is assumed to be operated mechanically by hand.

7.8 DEMOLITION OF FISH LOCK APPROACH CHANNEL GATE HOISTS

There are currently five gates in the fish lock approach channel with hoist works above them. This project will modify these gates and remove the hoist works that support them. These hoists will need their electric power and controllers disconnected and removed. See MD901 and MD902 in appendix G.

7.9 DEMOLITION OF GATE HOISTS ON TOP OF FISH LOCK

There are three gates on top of the fish lock with hoist works above them. This project will modify these gates and remove the hoist works that support them. These hoists will need their electric power and controllers disconnected and removed. See MD902 in appendix G.

7.10 DEMOLITION OF FISH LOCK MISCELLANEOUS ELECTRICAL EQUIPMENT

There is existing electrical equipment and electrical conduits near the fish lock entrance (see photo in appendix D) that will need to be relocated. This equipment is in the proposed path of the new low level intake pipes. This equipment includes a control panel associated with security and a disconnect switch for the vehicle gate operator.

7.11 DESIGN CODE REFERENCES

The designs of alternatives will conform to the following pertinent electrical criteria and applicable standards and codes:

National Codes

National Fire Protection Association (NFPA) 70 – National Electrical Code

NFPA 79 – Electrical Standard for Industrial Control

American National Standards Institute (ANSI) C2 2012 – National Electric Safety Code

U.S. Army Corp of Engineers

Unified Facilities Criteria (UFC) 3-501-01 – Electrical Engineering

Valve Actuators, Electrical

International Society of Automation (ISA) 96.02.01-2007 – Guidelines for the Specification of Electric Valve Actuators

CHAPTER 8 – ENVIRONMENTAL AND CULTURAL RESOURCES

8.1 GENERAL

This section outlines the environmental and cultural resources and permitting requirements as they may apply to providing a backup auxiliary water system for The Dalles EFL. During development of the Design Documentation Report (DDR), the recommended alternative will be further refined with additional development of the major facility components. The design refinement will continue throughout the development of the plans and specifications. Typically, it is during this phase that environmental clearance documents are prepared to satisfy the various environmental laws and regulations that U.S. Army Corps of Engineers (USACE) must comply with prior to constructing the facilities or modifying operations to improve the adult fish facilities operation. USACE is required to comply with numerous Federal laws, rules, and regulations as well as potential additional requirements under state and/or local jurisdictions.

All Federal actions that are funded, constructed, or permitted must comply with the National Environmental Policy Act (NEPA). The District Commander is the USACE NEPA official responsible for compliance with NEPA for actions within District boundaries. Typically, under NEPA, the District will prepare a Categorical Exclusion for O&M activities, or an Environmental Assessment (EA) for larger construction projects. An EA is a brief document that provides sufficient information to the District Commander on potential environmental effects of the proposed action, if appropriate, and its alternatives. The EA review also determines whether an Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI) needs to be prepared. In the case where project impacts are known to be major, USACE may decide to proceed to an EIS without conducting the EA/FONSI.

Consultation with appropriate Federal, State, and tribal agencies regarding potential environmental effects is coordinated by CENWP-PM-E. Compliance and consultation includes all permitting activities associated with the Clean Water Act (CWA) including Sections 401, 402, and 404. Under Section 401 of the CWA, water quality certification will be requested from the State of Oregon. Cultural resource clearance will be required for construction sites, other areas disturbed to facilitate construction (access roads, staging areas, etc.), or otherwise affected by operational changes. Endangered Species Act (ESA) compliance will include interagency consultation with the National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) on all threatened, endangered, and proposed species and/or designated critical habitat, including terrestrial and aquatic plants and animals.

The consultation process may also encompass sections of the Fish and Wildlife Coordination Act; Magnuson-Stevens Act (Essential Fish Habitat); Bald and Golden Eagle Protection Act; several cultural resource laws including the National Historic Preservation Act; Archaeological Resources Protection Act; Native American Grave Protection and Repatriation Act; Antiquities Act; Archaeological and Historic Preservation Act; Executive Order 11988, Flood Plain Management; Executive Order

11990, Protection of Wetlands; Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance; Comprehensive Environmental Response, Compensation, and Liability Act; Resource Conservation and Recovery Act; Toxic Substances Control Act; Federal Insecticide, Fungicide, and Rodenticide Act; and Migratory Bird Treaty Act.

CHAPTER 9 – CONSTRUCTION

9.1 CONSTRUCTABILITY

The recommended low level intake through The Dalles Dam will require boring or mining for one 120-inch-diameter steel pipe through the east non-overflow structure. The boring will be angled such that the forebay inlet will meet design elevation and will exit low enough to allow for a minimum of 2 feet of ground cover. The mining through the dam will require some form of cofferdam on the forebay face of the dam to allow access to the pipe inlet. The cofferdam will be left in place throughout the entire construction process. This will eliminate the need for divers throughout the construction process and alleviate in-water work window restrictions. Following completion of the inlet, bulkhead, and trash rack, the cofferdam can be filled with water and removed. Installation and removal of the cofferdam will require the use of divers, a barge, and a crane from the surface deck of the dam.

9.2 CONSTRUCTION SEQUENCE AND SCHEDULE

Construction of the east fish ladder (EFL) auxiliary water supply (AWS) will require work to be performed during and after the regulated in-water work window (IWWW) which typically runs from December 15th to March 31st annually. The following synopsis is a theoretical estimate of what is believed to be the most efficient construction sequence. If the project is awarded to allow sufficient time for pre-construction, the duration of construction should not exceed 5 months.

The two items that will require installation during the IWWW are the cofferdam and bridge flume. The cofferdam is a large steel structure that will be attached to the forebay side of the dam with the use of cranes and divers. The use of impact equipment and welders in the water will be required for installation of this piece. The bridge flume will require demolition of concrete over the EFL and into a water storage area that cannot be drained. Proper protection methods will also need to be installed to ensure contamination of the water is limited.

Following installation of the cofferdam and bridge flume, all other operations can occur. By installing a large enough cofferdam, the contractor will have the ability to perform the boring through the dam and installation of all equipment (i.e. piping, bulkhead, trash rack) without the use of divers. All other work is performed in the dam’s parking lot and old fish lock channel. Work in these areas will have to be coordinated with the dam so it does not impact daily dam operations.

Construction sequencing and schedule is estimated as follows:

1. Mobilization to the site – 1 week.
2. Excavation and setup of launch pad for mining – 2-3 weeks.
3. Boring operations – 4 weeks.

4. Fabrication and installation of cofferdam – 3-4 weeks. Performed concurrently with work items 2 and 3.

5. Excavation from boring to channel – 2 weeks.

6. Installation of bulkhead and trash rack – 1-2 weeks.

7. Modification of fish approach channel (FAC) – 5 weeks.

8. Fabrication and installation of 10-foot-diameter supply conduit – 4-6 weeks.

9. Installation of two 72-inch-diameter pipes to auxiliary water supply conduit (AWSC) – 2 weeks.

10. Punch list and testing – 1-2 weeks.

11. Removal of cofferdam – 1 week.

12. Demobilization – 1 week.

Total Duration: 20 to 29 weeks onsite

CHAPTER 10 – OPERATIONS AND MAINTENANCE

To be developed.

CHAPTER 11 – COST ESTIMATES

11.1 COST EVALUATION

Construction of the recommended alternative will require mining or boring of up to a 144-inch-diameter hole to accommodate a 120-inch-diameter pipe, and fabrication and installation of a cofferdam, bulkhead, and trash rack system. Following installation of the cofferdam, it is assumed divers will not be needed until the cofferdam needs to be removed. Total cost estimate to be determined at a later date. See appendix F.

The Dalles East Fish Ladder Auxiliary Water Backup System

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APPENDIX A

USACE Memorandum for Estimated Minimum Discharge

CENWP-EC-HD 21 January 2011

MEMORANDUM FOR Randy Lee, CENWP-EC-HD

SUBJECT: The Dalles East Fish Ladder Emergency Backup for the Auxiliary Water Supply System–Minimum Discharge

Objective:

1. This memo will present the rationale for choosing 1400 cfs as the minimum discharge target for emergency backup flow to the Auxiliary Water System (AWS) at The Dalles East Fish Ladder (TDEFL) for the purpose of initial alternatives brainstorming by HDR and USACE Portland District (NWP).

Background:

2. The AWS at TDEFL supplies water to the east, west, and south fish ladder entrances, the fish ladder itself, as well as the transportation and collection channels in order to attract and transport upstream migrating adult fish. Water is currently supplied to the AWS by two fish unit turbines located on the west end of the powerhouse. The AWS normally operates with a total flow of up to 5,000 cfs (2,500 cfs per turbine unit). If both turbines were to fail at the same time, water supplied to the AWS would be severely limited or eliminated.

3. Previous studies have been undertaken to find alternatives to provide a backup supply of water to the AWS for a one-year duration in the event that both fish units fail. For these studies, alternatives have been evaluated assuming that at least 3400 cfs is required to allow the ladder system (including east, west and south entrances) to meet fisheries criteria. Estimated costs for the alternatives that were deemed most promising turned out to be very expensive and consequently impractical.

4. A special Fish Facilities Design Review Work Group (FFDRWG) meeting was held on 2 November 2010 in part for the purpose of discussing the possible reduction of operational constraints for a one-year emergency situation where both fish turbine units were unavailable. Based on discussions at this meeting, it was agreed that the minimum acceptable one-year emergency operation would be to use TDEFL east entrance exclusively.

5. The relative importance of various design criteria was also discussed at the FFDRWG meeting and is shown below in relative order of priority:
   a. Maintain 1.5 ft. of head differential over the entrance weir(s).
   b. Assume operation of two of the three weirs (however, there was additional interest in considering a variable width vertical entrance structure instead with the goal of improved downstream attraction flow properties).
   c. Maintain at least 8 ft. depth at entrance weir(s) (depth from tailwater elevation to top of the weir)

Other operational criterion that were not discussed but need to be considered include:

d. Water velocity of 1.5 to 4 fps (2 fps optimum) maintained for the full length of the lower end of the fish ladder that is affected by tailwater elevation.

e. Water depth over fish ladder weirs: 1.0 ft. +/- 0.1 ft. and 1.3 ft, +/- 0.1 ft, during shad season.

f. Maximum diffuser velocity = 0.5 ft/s

Discussion:

6. Calculations of a single weir discharge at the TDEFL east entrance were made for a range of tailwater elevations with the following equations, criteria, assumptions and constants:
   - Villamonte Equation for Submergence:
     - Q = (1 – (H2/H1)^1.5)^0.385*CwLH1^1.5
     - H1 = depth from water surface elevation (WSE) to top of weir;
     - H2 = depth from tailwater elevation (TW) to top of weir
   - Rehbock Equation for Weir Coefficient:
     - Cw = 3.22 + 0.44 H/P
     - H = H1; P = weir height
   - Entrance weir head (WSE – TW) at entrance weir(s) of 1.5 ft.
   - Depth of weir (H2) minimum of 8 ft.
   - Entrance weir width of 8.67 ft.
   - Invert elevation at entrance of 60 ft.
   - Entrance channel width just upstream of weir of 34 ft.
   - No pier or contraction losses were used to allow for a more conservative discharge (ie: higher acceptable minimum emergency flow).

7. Tailwater (TW) elevation used in the above equations can markedly influence the estimated minimum flow. Therefore it was necessary to choose a reasonable range for this analysis. Both stage and flow duration curves for the period of record (1974-1999) were used to compile a range of tailwater elevations of note at The Dalles Dam (Table 1). As seen in the table, the forebay of Bonneville Dam can influence the tailrace elevation of The Dalles Dam such that there is a range of possible tailwater levels for any given total river flow. A range of probable flow operations within the fish passage season would be banded by the higher flows in May/June and the lower flows in September/October. For the upper tailwater limit in May/June the 5% exceedance TW elevation range is 85.4 to 86.6 ft. Additionally, within the range of high flows, there is a peak where river flow conditions are such that adult fish will hold rather than travel upstream. Until a more defined estimate can be identified using existing fish passage data, it is estimated that this river discharge is around 400 to 450 kcfs, The corresponding TW elevation range (based on Bonneville forebay) for this condition is 84.7-88.6 ft. or an average of 86.6 ft which coincides with the 5% exceedance for June. Therefore, 86.6 ft. was chosen as the upper TW elevation limit for this analysis. Focusing on lower TW levels, the range of 95% exceedance for September and October is 74.0 to 74.2 ft. These values fall within the TW elevation range for the minimum powerhouse flow of 50,000 cfs (72.6 to 77.6 ft.). Therefore the 95% exceedance TW elevation for October (74.0 ft.) was chosen for the lower TW elevation limit for this analysis.

8. Using the criteria deemed most critical for an emergency operation (the ability to maintain 1.5 ft. entrance weir differential head and a minimum of 8 ft. weir depth) through the range of TW elevations 74.0 to 86.6 ft. results in design flows of 1200 cfs and 1000 cfs respectively. However, if minimum channel velocities are to be maintained at the downstream end of the east entrance, more flow would be needed at the higher TW elevation limit of 86.6 ft. If 1.5 fps (minimum channel velocity criteria) is required at the entrance then the flow would need to be 1400 cfs. For the purposes of this analysis, the upper flow of 1400 cfs has been chosen for the minimum allowable emergency flow for TDEFL east entrance-only condition. When the inflow from the upper ladder flow control section (80-120 cfs) is subtracted, the actual total AWS flow required would be 1320 to 1280 cfs. However, for this level of analysis a conservative AWS discharge of 1400 cfs has been chosen.

9. Considerations that could help maintain and/or reduce the minimum allowable emergency flow required for TDEFL include the potential for reduction of the forebay elevation at Bonneville dam during the higher TW period of an emergency operation. Also, further analyses should include the development of an operational logic for the full range of design TW elevations (ie: prescribing weir depth as a function of TW) as the weir height is pivotal to keeping within the minimum discharge needed for emergency operations.

Conclusions:

10. For this initial analysis, 1400 cfs is determined to be a minimum allowable emergency backup flow for TDEFL based on meeting ladder entrance head and 8 feet of passage depth over 2 of the 3 East entrance weirs. A range of TW elevation conditions were defined and flows approximated given certain fisheries criteria. Ultimately, for future alternative analyses, the hydraulics throughout the ladder system will need to be analyzed to ensure that all internal hydraulic criteria are met in order to maximize fish passage success. Also, as studies progress to a recommended design solution, the impact of system operations (such as the elevation of the Bonneville forebay) on an emergency ladder operation should be discussed and possible emergency operations to improve adult movement should be defined.

Recommendations:

11. For this phase of the comparison of alternatives for supplying emergency backup water to the Auxiliary Water Supply System for The Dalles East Fish Ladder in the case where both fish units are unable to function, we recommend using 1400 cfs.

Karen Kuhn
Hydraulic Engineer

REVIEW PROCESS:

HD – Steve Schlenker

CF:
CENWP-EC-HD - Randy Lee
CENWP-EC-HD – Kyle McCune
CENWP-PM-E – Sean Tackley

Table 1 - Range of Significant River Discharge and Tailwater Conditions for The Dalles Dam*

Condition	Discharge	Approximate Tailwater Range at Powerhouse by Flow **		TW at Powerhouse by Exceedance***
	kcfs	ft	ft	ft
100 year event	680	95.6	97.0	
Maximum Tailwater				92.2
5% Exceedance June***				**86.6**
Max Q for Adult Movement****	400-450	84.7	88.6	
5 % Exceedance May***				85.4
Max Ph w/ 40% spill	430	85.3	88.0	
Max Ph	270	77.8	81.3	
Discharge 100kcfs (92% Flow Exceedance)	100	73.5	78.2	
Min Ph w/40% Spill	85	73.3	78.0	
Min Ph	50	72.6	77.6	
95% Exceedance Sept***				74.2
95% Exceedance Oct***				***74.0***
Minimum Operating Tailwater*****				70.0

*Data Source: Stage exceedance, stage/discharge relationships, and tailwater ranges for the period of record (1974-1999) developed by CENWP-EC-HY October 2000.
**Tailwater range based on forebay fluctuations at Bonneville Dam from 71.5-76.5 ft. Tailwater elevations were adjusted from RM 188.95 to location at TDEFL powerhouse (RM 192.43) using relationships developed in Oct. 2000 study.
***Based on hourly readings at Powerhouse gage.
****Estimate to be verified with fish passage data.
*****From Fish Passage Plan 2010

Note: Highlighted values used in final selection of minimum emergency flow analysis.

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APPENDIX B

Hydraulic

Project Title: Dalles EFL Emergency AWS Trashrack Calculations	6/1/2013	By: Logan Negherbon Check by: Ryan Laughery

Units definition

$\text{cfs} := \text{ft}^3 \cdot \text{s}^{-1}$ cubic feet per second

$\text{fps} := \text{ft} \cdot \text{s}^{-1}$ feet per second

Hydraulic Properties

$\rho := 1000 \dfrac{\text{kg}}{\text{m}^3}$ Fluid density

Assumed temperature deg. F

$T_f := 50$ $T_c := (T_f - 32) \cdot \dfrac{5}{9}$ $T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + \left(0.0337 \cdot T_c + 0.000221 \cdot T_c^{\,2}\right)} \cdot \frac{\text{m}^2}{\text{s}}$$

$\nu = 1.319 \times 10^{-6} \cdot \dfrac{\text{m}^2}{\text{s}}$ Kinematic viscosity of water from temp. relationship

Project Title: Dalles EFL Emergency AWS
Trashrack Calculations
6/1/2013
By: Logan Negherbon
Check by: Ryan Laughery

Design Parameters

$Q := 1400\text{cfs}$ Design flow rate

$V := 3\text{fps}$ Velocity limitation for trashrack approach velocity - EM 1110-2-1602

$V_{thr} := 5\text{fps}$ Recommended thru velocity maximum for cleaning accessible trashracks from Bureau of Reclamation - Design of Small Dams

$A_{req} := \frac{Q}{V}$ $A_{req} = 466.667\ \text{ft}^2$ Area required to meet trashrack approach velocity limitation

$h_t = K_t \cdot \frac{v_n^2}{2 \cdot g}$ $K_t = 1.45 - 0.45 \cdot \frac{a_n}{a_g} - \left(\frac{a_n}{a_g}\right)^2$ Equation 11, Design of Small Dams - BoR

$a_n := 0.75\text{in}$ Design bar spacing per EDR

$a_g := \frac{5}{16}\text{in} + a_n$ Assummed unit thickness for bar and space

$\frac{a_n}{a_g} = 0.706$ Resultant porosity

$K_t := 1.45 - 0.45 \cdot \frac{a_n}{a_g} - \left(\frac{a_n}{a_g}\right)^2$ $K_t = 0.634$ Resultant loss coefficient

$v_n := V_{thr}$ Thru velocity for head loss differential

$h_t := K_t \cdot \frac{v_n^2}{2 \cdot g}$ $h_t = 0.246\ \text{ft}$ Resultant head differential

$A_{req} := \frac{Q}{v_n} \cdot \frac{a_g}{a_n}$ $A_{req} = 396.667\ \text{ft}^2$ Based on thru velocity limitations $\boxed{A_{req} := 466\text{ft}^2}$ Area required based on approach velocity limitations - Controlling

Required trashrack height based on 15 foot width

$H := \frac{A_{req}}{15\text{ft}}$ $H = 31.067\ \text{ft}$

Required trashrack height based on 20 foot width

$H := \frac{A_{req}}{20\text{ft}}$ $H = 23.3\ \text{ft}$

Trashracks for the intake are sized with a 3 fps approach velocity and a flow of 1400 cfs. Velocity criterion was determined during the EDR phase of design and based off of EM 1110-2-1602. A through bar velocity of 5 fps is recommended by the Bureau of Reclamation *Design of Small Dams* publication. An assumed porosity of 70 percent for the trashrack results in a required gross area of 350 square feet; however, in order to meet the approach velocity a required gross area of trashrack is required to be 466 square feet.

$A_{req} = 466\,ft^2$

$R_h := 160ft$ $R_l := 155ft$ $CL := 116.5ft$ $p_t := h_t \cdot \rho \cdot g$ $p_t = 0.107\,psi$

$P_1 := (R_h - CL) \cdot g \cdot \rho$ $P_1 = 18.858\,psi$ $p_1 := R_h - CL$

$P_2 := P_1 - h_t \cdot g \cdot \rho$ $P_2 = 18.752\,psi$ $p_2 := p_1 - h_t$

$\beta := 100\%$ Debris blockage factor (% open area)

$V_1 := V = 3\,\frac{ft}{s}$ $V_2 := \dfrac{Q}{\beta A_{req} \cdot \dfrac{a_n}{a_g}} = 4.256\,\frac{ft}{s}$

$F_r := (P_1 - P_2) \cdot A_{req} \cdot \left(1 - \beta \dfrac{a_n}{a_g}\right) + \rho \cdot Q \cdot (V_2 - V_1)$ Equation for force imparted by momentum and pressure differential

$F_r = 5.52 \cdot kip$ Resultant force from momentum and pressure differential

$\dfrac{F_r}{A_{req}} = 11.845 \cdot psf$ Resultant pressure resistance from momentum and pressure differential

$V_{thr} := \dfrac{Q}{A_{req}} \cdot \dfrac{a_g}{a_n}$

$V_{thr} = 4.256\,\frac{ft}{s}$

$\beta := 50\%$ Debris blockage factor (% open area)

$V_1 := V = 3\,\frac{ft}{s}$ $V_2 := \dfrac{Q}{\beta A_{req}\cdot\frac{a_n}{a_g}} = 8.512\,\frac{ft}{s}$

$$F_r := (P_1 - P_2)\cdot A_{req}\cdot\left(1 - \beta\frac{a_n}{a_g}\right) + \rho\cdot Q\cdot(V_2 - V_1)$$

Equation for force imparted by momentum and pressure differential

$F_r = 19.611\cdot kip$ Resultant force from momentum and pressure differential

$\dfrac{F_r}{A_{req}} = 42.083\cdot psf$ Resultant pressure resistance from momentum and pressure differential

$$V_{thr} := \frac{Q}{A_{req}}\cdot\frac{a_g}{a_n}$$

$V_{thr} = 4.256\,\frac{ft}{s}$

Sensitivities

- 10% increase minor losses
- 10% decrease minor losses
- 10x increase in relative roughness
- 0.1x decrease in relative roughness

$\alpha_k := 0.9$ minor loss sensitivity coeff.

$\alpha_f := 0.1$ friction loss sensitivity coeff.

10 degree temperature increase/decrease makes negligible changes and is not varried in sensitivity matrix

Factors of 1.0 indicate assumed losses

Custom Units Definition

$\text{fps} := \text{ft}\cdot\text{s}^{-1}$ feet per second

$\text{cfs} := \text{ft}^2\cdot\text{fps}$ cubic feet per second

Fluid Properties

$\rho := 1000\,\frac{\text{kg}}{\text{m}^3}$ $\gamma := 62.41\,\frac{\text{lbf}}{\text{ft}^3}$

Assumed temperature deg. F

$T_f := 50$ $T_c := \left(T_f - 32\right)\cdot\frac{5}{9}$ $T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792\cdot10^{-6}}{1.0 + \left(0.0337\cdot T_c + 0.000221\cdot T_c^{\,2}\right)}\cdot\frac{\text{m}^2}{\text{s}}$$

$\nu = 1.319\times10^{-6}\cdot\frac{\text{m}^2}{\text{s}}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function

$A(d) := \frac{\pi\,d^2}{4}$

Reynolds number

$Re(Q,d) := \frac{Q\cdot d}{A(d)\cdot\nu}$

Average velocity

$V(Q,d) := \frac{Q}{A(d)}$

Jain's equation for friction factor

$$f\left(Q,d,k_s\right) := \frac{0.25}{\log\left(\frac{k_s}{3.7\cdot d} + \frac{5.74}{Re(Q,d)^{0.9}}\right)^2}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Design Parameters

$Q := 1400\text{cfs}$ Design flow rate

	Diameter	Length	Roughness - Assumed epoxy coating	
Pipe 1	$D_1 := 10\text{ft}$	$L_1 := 300\text{ft}$	$k := \alpha_f \cdot 0.025\text{mm}$	Through new pipe (Miller Table 8.1 - Plastic)
Pipe 2 - contraction	$D_2 := 7\text{ft}$	$L_2 := 7\text{ft}$	$k_{sr} := 0.025\text{mm}$	Rough (Miller Table 8.1- no lining)
Final diameter before valve	$D_3 := 7\text{ft}$		$k_{ss} := 0\text{mm}$	Fully smooth

Pipe 1 Losses

Trash rack - See Trashrack Calculations.xcmd

Entrance loss

17 deg bend loss 1 & 2

90 deg bend loss 1 & 2

Minor bend - 40 deg

Contraction

Friction Losses

$\text{Re}(Q, D_1) = 1.256 \times 10^7$ Reynolds number

Trash rack loss from other worksheet $K_t := 0.634$ ---> $h_t := 0.246\text{ft}$

Entrance loss $K_e := 0.16$ Assumed loss based on guidance from EM 1110-2-1602 (Section 3-7)

17 deg bend loss

$\frac{r}{d} = 1$

$k'_b := 0.03$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1.0$ No outlet, Miller Fig. 9.4

$C_f := \frac{f(Q, D_1, k_{sr})}{f(Q, D_1, k_{ss})}$ $C_f = 1.111$ From Miller Eq. 9.3

$K_{b17} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b17} = 0.033$ From Miller Eq. 9.4

90 deg bend loss

90 deg bend made up of three 30 deg mitered bends

$\frac{r}{d} = 2$

$k'_b := 0.275$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1.0$ No outlet, Miller Fig. 9.4

$C_f := \frac{f(Q, D_1, k_{sr})}{f(Q, D_1, k_{ss})}$ $C_f = 1.111$ From Miller Eq. 9.3

$K_{b90} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b90} = 0.306$ From Miller Eq. 9.4

40 deg bend loss

triple-mitered bend

$\frac{r}{d} = 2$

$k'_b := 0.22$ From Miller Fig. 9.9, conservatively based on single miter

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 0.5$ No outlet, Miller Fig. 9.4

$C_f := \frac{f(Q, D_2, k_{sr})}{f(Q, D_2, k_{ss})}$ $C_f = 1.179$ From Miller Eq. 9.3

$K_{b40} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b40} = 0.13$ Miller Eq. 9.4

Contraction loss

Length of contraction over contracted radius

$A(D_1) = 78.54\,\text{ft}^2$

$A(D_2) = 38.485\,\text{ft}^2$

$\frac{A(D_1)}{A(D_2)} = 2.041$

$\frac{N}{R} = 2$ $N = 7\text{ft}$ $K_{c1} := 0.05$ From Miller Fig. 14.14(1)

Friction loss

$f_1 := f(Q, D_1, k)$ $f_1 = 7.998 \times 10^{-3}$

$f_2 := f(Q, D_2, k)$ $f_2 = 7.707 \times 10^{-3}$

Total losses

Velocity head $H_{v1} := \frac{V(Q,D_1)^2}{2g}$ $H_{v1} = 4.938\,\text{ft}$ $V(Q,D_1) = 17.825 \cdot \text{fps}$

$H_{v2} := \frac{V(Q,D_2)^2}{2g}$ $H_{v2} = 20.566\,\text{ft}$ $V(Q,D_2) = 36.378 \cdot \text{fps}$

$H_{v3} := \frac{V(Q,D_3)^2}{2g}$ $H_{v3} = 20.566\,\text{ft}$ $V(Q,D_3) = 36.378 \cdot \text{fps}$

$$H_{p1} := \left[f_1 \cdot \frac{L_1}{D_1} + \alpha_k \cdot \left(K_e + 2 \cdot K_{b17} + 2 \cdot K_{b90} + K_{b40}\right)\right] H_{v1}$$ $L_1 = 300\,\text{ft}$

$H_{p1} = 5.485\,\text{ft}$ Head loss through 10-ft diameter conduit

$$H_{p2} := \left[f_2 \cdot \frac{L_2}{D_2} + \alpha_k \cdot \left(K_{c1}\right)\right] H_{v2}$$ $L_2 = 7\,\text{ft}$

$H_{p2} = 1.084\,\text{ft}$ Head loss through 7-ft diameter conduit

Maximum Operating Forebay

$R_h := 160\text{ft}$ $FL_h := R_h - h_t - H_{p1} - H_{p2}$ $FL_h = 153.185\,\text{ft}$

Miniumum Operating Forebay

$R_l := 155\text{ft}$ $FL_l := R_l - h_t - H_{p1} - H_{p2}$ $FL_l = 148.185\,\text{ft}$

$WSE_{fl} := 102.5\text{ft}$ Water surface in FLAC

$H_{vH} := FL_h - WSE_{fl}$ $\boxed{H_{vH} = 50.685\,\text{ft}}$ Energy to dissipate at high pool

$H_{vL} := FL_l - WSE_{fl}$ $\boxed{H_{vL} = 45.685\,\text{ft}}$ Energy to dissipate at low pool

Thrust force calculations for new bypass - First 90 degree bend

$V(Q,D_1) = 17.825\,\frac{ft}{s}$ Thrust velocity

$V_1 := V(Q,D_1)$ $V_{1x} := V_1\cdot\cos(0)$ $V_{1x} = 17.825\,\frac{ft}{s}$

$V_{1y} := V_1\cdot\sin(0)$ $V_{1y} = 0\,\frac{ft}{s}$

$V_2 := V(Q,D_1)$ $V_{2x} := V_2\cdot\cos\left(\frac{\pi}{2}\right)$ $V_{2x} = 1.091\times 10^{-15}\,\frac{ft}{s}$

$V_{2y} := V_2\cdot\sin\left(\frac{\pi}{2}\right)$ $V_{2y} = 17.825\,\frac{ft}{s}$

$z := 104.5ft$ Approximated center of pipe elevation

$R_1 := 160ft$

$$H_z := R_1 - h_t - \left(f_1\cdot\frac{50ft}{D_1} + K_e + 2\cdot K_{b17}\right)H_{v1}$$

$H_z = 158.437\,ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z)\cdot\rho\cdot g$ $p = 23.383\,psi$

$A_1 := A(D_1) = 78.54\,ft^2$

$A_2 := A(D_1) = 78.54\,ft^2$

Cavitation check

$h_u := p$ $h_v := 0.18psi$

$$\sigma_b := \frac{h_u - h_v}{\gamma\cdot\frac{V(Q,D_1)^2}{2\cdot g}}$$

$\sigma_b = 10.842$

Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} := 2.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1

$p_1 := p$ $\quad p_{1x} := p_1 \cdot \cos(0)$ $\quad p_{1x} = 23.383\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0)$ $\quad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{b90} \cdot H_{v1} \cdot \rho \cdot g$ $\quad p_{2x} := p_2 \cdot \cos\left(-\frac{\pi}{2}\right)$ $\quad p_{2x} = 1.392 \times 10^{-15}\,\text{psi}$

$p_{2y} := p_2 \cdot \sin\left(\frac{-\pi}{2}\right)$ $\quad p_{2y} = -22.729\,\text{psi}$

$$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$$0 = F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

Thrust Restraint Force

$$F_{rx} := p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$F_{rx} = 312.88 \cdot \text{kip}$ Force in the plane of the bend acting towards the dam

$$F_{ry} := -\left[p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)\right]$$

$F_{ry} = 305.482 \cdot \text{kip}$ Force in the plane of the bend acting in line with the downstream flow $\quad \sqrt{F_{rx}^{\;2} + F_{ry}^{\;2}} = 437.28 \cdot \text{kip}$

Project Title: Dalles EFL Emergency AWS - 10-ft Conduit Calcs	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Thrust force calculations for new bypass - Second 90 degree bend

$V(Q, D_1) = 17.825\,\frac{ft}{s}$ Thrust velocity

$V_1 := V(Q, D_1)$ $V_{1x} := V_1 \cdot \cos(0)$ $V_{1x} = 17.825\,\frac{ft}{s}$

$V_{1y} := V_1 \cdot \sin(0)$ $V_{1y} = 0\,\frac{ft}{s}$

$V_2 := V(Q, D_1)$ $V_{2x} := V_2 \cdot \cos\left(\frac{-\pi}{2}\right)$ $V_{2x} = 1.091 \times 10^{-15}\,\frac{ft}{s}$

$V_{2y} := V_2 \cdot \sin\left(\frac{-\pi}{2}\right)$ $V_{2y} = -17.825\,\frac{ft}{s}$

$z := 104.5ft$ Approximated center of pipe elevation

$R_1 := 160ft$

$$H_z := R_1 - h_t - \left(f_1 \cdot \frac{220ft}{D_1} + K_e + 2 \cdot K_{b17} + K_{b90}\right) H_{v1}$$

$H_z = 156.257\ ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z) \cdot \rho \cdot g$ $p = 22.438\,psi$

$A_1 := A(D_1) = 78.54\ ft^2$

$A_2 := A(D_1) = 78.54\ ft^2$

$h_u := p$ $h_v := 0.18psi$

$$\sigma_b := \frac{h_u - h_v}{\gamma \cdot \frac{V(Q, D_1)^2}{2 \cdot g}}$$ $\sigma_b = 10.401$

Cavitation parameter is greater than incipient choking for r/d = 1

$\sigma_{bi} := 2.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1

$p_1 := p \qquad p_{1x} := p_1 \cdot \cos(0) \qquad p_{1x} = 22.438\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0) \qquad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{b90} \cdot H_{v1} \cdot \rho \cdot g \qquad p_{2x} := p_2 \cdot \cos\left(\frac{\pi}{2}\right) \qquad p_{2x} = 1.334 \times 10^{-15}\,\text{psi}$

$p_{2y} := p_2 \cdot \sin\left(\frac{\pi}{2}\right) \qquad p_{2y} = 21.784\,\text{psi}$

$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$

$0 = -F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$

Thrust Restraint Force

$F_{rx} := p_{1x} \cdot A_1 + p_{2x} \cdot A_2 + \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$

$F_{rx} = 205.347 \cdot \text{kip}$ Force in the plane of the bend acting away from the dam

$F_{ry} := p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$

$F_{ry} = 294.792 \cdot \text{kip}$ Force in the plane of the bend acting against with the upstream flow $\sqrt{F_{rx}^{2} + F_{ry}^{2}} = 359.263 \cdot \text{kip}$

Thrust force calculations for 40 degree bend

$V_1 := V(Q, D_2)$ $V_{1x} := V_1 \cdot \cos(0)$ $V_{1x} = 36.378 \frac{ft}{s}$

$V_{1y} := V_1 \cdot \sin(0)$ $V_{1y} = 0 \frac{ft}{s}$

$V_2 := V(Q, D_2)$ $V_{2x} := V_2 \cdot \cos(-40deg)$ $V_{2x} = 27.867 \frac{ft}{s}$

$V_{2y} := V_2 \cdot \sin(-40deg)$ $V_{2y} = -23.384 \frac{ft}{s}$

$z := 104.5 ft$ Approximated center of pipe elevation

$R_1 := 160 ft$

$$H_z := R_1 - h_t - \left(f_1 \cdot \frac{230ft}{D_1} + K_e + 2K_{b90} + K_{c1}\right)H_{v1} - f_2 \cdot 20 \frac{ft}{D_2} \cdot H_{v2}$$

$H_z = 154.338 ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z) \cdot \rho \cdot g$ $p = 21.606 psi$

$A_1 := A(D_2) = 38.485 ft^2$

$A_2 := A(D_2) = 38.485 ft^2$

$h_u := p$ $h_v := 0.18psi$

$$\sigma_b := \frac{h_u - h_v}{\gamma \cdot \frac{V(Q, D_2)^2}{2 \cdot g}}$$ $\sigma_b = 2.404$

$\sigma_{bi} := 0.75$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 2

Cavitation parameter is greater than incipient cavitation for r/d = 2 with a 8 ft conduit -> ok

$p_1 := p \qquad p_{1x} := p_1 \cdot \cos(0) \qquad p_{1x} = 21.606\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0) \qquad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{b40} \cdot H_{v2} \cdot \rho \cdot g \qquad p_{2x} := p_2 \cdot \cos(140\text{deg}) \qquad p_{2x} = -15.665\,\text{psi}$

$p_{2y} := p_2 \cdot \sin(140\text{deg}) \qquad p_{2y} = 13.145\,\text{psi}$

$$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$$0 = -F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

Thrust Restraint Force

$$F_{rx} := \left[p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)\right]$$

$F_{rx} = 56.043 \cdot \text{kip}$ Force in the plane of the bend acting towards the dam

$$F_{ry} := p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

$F_{ry} = 136.365 \cdot \text{kip}$ Force in the plane of the bend acting perpendicular with the upstream flow $\sqrt{F_{rx}^2 + F_{ry}^2} = 147.432 \cdot \text{kip}$

Thrust force calculations for contraction

$V(Q, D_1) = 17.825 \frac{ft}{s}$ Thrust velocity

$V_1 := V(Q, D_1)$ $V_{1x} := V_1 \cdot \cos(0)$ $V_{1x} = 17.825 \frac{ft}{s}$

$V_{1y} := V_1 \cdot \sin(0)$ $V_{1y} = 0 \frac{ft}{s}$

$V_2 := V(Q, D_2)$ $V_{2x} := V_2 \cdot \cos(0)$ $V_{2x} = 36.378 \frac{ft}{s}$

$V_{2y} := V_2 \cdot \sin(0)$ $V_{2y} = 0 \frac{ft}{s}$

$z := 88.25 ft$ Approximated center of pipe elevation

$R_1 := 160 ft$

$$H_z := R_1 - h_t - \left(f_1 \cdot \frac{230 ft}{D_1} + K_e + 2K_{b90} \right) H_{v1}$$

$H_z = 155.038 \, ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z) \cdot \rho \cdot g$ $p = 28.954 \, psi$

$A_1 := A(D_1) = 78.54 \, ft^2$

$A_2 := A(D_2) = 38.485 \, ft^2$

$p_1 := p$ $\quad p_{1x} := p_1 \cdot \cos(0)$ $\quad p_{1x} = 28.954\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0)$ $\quad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{c1} \cdot H_{v2} \cdot \rho \cdot g$ $\quad p_{2x} := p_2 \cdot \cos(\pi)$ $\quad p_{2x} = -28.509\,\text{psi}$

$p_{2y} := p_2 \cdot \sin(\pi)$ $\quad p_{2y} = 3.491 \times 10^{-15}\,\text{psi}$

$$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$$0 = F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A - \blacksquare + \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

Thrust Restraint Force

$$F_{rx} := p_{1x} \cdot A_1 + p_{2x} \cdot A_2 + \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$F_{rx} = 219.876 \cdot \text{kip}$ Force in the plane of the bend acting towards the dam

$$F_{ry} := p_{1y} \cdot A_1 + p_{2y} \cdot A_2 + \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

$F_{ry} = 1.935 \times 10^{-14} \cdot \text{kip}$ Force in the plane of the bend acting opposite the direction of flow $\quad \sqrt{F_{rx}^{\,2} + F_{ry}^{\,2}} = 219.876 \cdot \text{kip}$

Project Title: Dalles EFL Emergency AWS - 10-ft Transient Calcs	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Preliminary Hydraulic Transient Analysis for Valve Closure

Reference	EM 1110-3-173 Pumping System Design Hydroelectric Handbook by Creager and Justin Fundamentals of Hydraulic Engineering by Prasuhn Handbook of Hydraulics by King and Brater

Custom Units Definition

$\text{fps} := \text{ft}\cdot\text{s}^{-1}$ feet per second

$\text{cfs} := \text{ft}^2\cdot\text{fps}$ cubic feet per second

Fluid Properties

$\rho := 1000\frac{\text{kg}}{\text{m}^3}$

$\gamma := 62.41\frac{\text{lbf}}{\text{ft}^3}$

Assumed temperature deg. F

$T_f := 50$

$T_c := (T_f - 32)\cdot\frac{5}{9}$

$T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792\cdot 10^{-6}}{1.0 + \left(0.0337\cdot T_c + 0.000221\cdot T_c^{\,2}\right)}\cdot\frac{\text{m}^2}{\text{s}}$$

$\nu = 1.319 \times 10^{-6}\cdot\frac{\text{m}^2}{\text{s}}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function

$A(d) := \frac{\pi d^2}{4}$

Reynolds number

$Re(Q,d) := \frac{Q\cdot d}{A(d)\cdot\nu}$

Average velocity

$V(Q,d) := \frac{Q}{A(d)}$

Design Parameters

$Q := 1400\text{cfs}$ Design flow rate

	Diameter	Length
Pipe 1	$D_1 := 10\text{ft}$	$L_1 := 300\text{ft}$
Pipe 2 - contraction	$D_2 := 7\text{ft}$	$L_2 := 7\text{ft}$

EM 1110-3-173 Pumping System Design (Water Hammer Guidance)

$a_{min} := 2700\text{fps}$ Minimum wave speed for steel pipe

$a_{max} := 3900\text{fps}$ Maximum wave speed for steel pipe

$T_c := \dfrac{2\cdot(L_1 + L_2)}{a_{min}}$ $T_c = 0.227\,\text{s}$ Maximum time of closure

$T_c := \dfrac{2\cdot(L_1 + L_2)}{a_{max}}$ $T_c = 0.157\,\text{s}$ Minimum time of closure

$h_w := \dfrac{a_{min}\cdot V(Q, D_1)}{g}$ $h_w = 1496\,\text{ft}$ Theoretical surge in head due to instantaneous closure (using min. wave speed for steel pipe)

$h_w := \dfrac{a_{max}\cdot V(Q, D_1)}{g}$ $h_w = 2161\,\text{ft}$ Maximum theoretical surge in head due to instantaneous closure (using max. wave speed for steel pipe)

$t = FS\,\dfrac{L\cdot V}{g\cdot H_{av}}$ Time of closure for specified head surge

$t := 20\text{s}$ Trial time of closure

$FS := 4$ Factor of safety (typical range of FS from 1 to 4)

$H(t) := FS\,\dfrac{L_1\cdot V(Q, D_1)}{g\cdot t}$ Reorganized to solve for head with respect to time

$H(t) = 33.242\,\text{ft}$ $H(t)\cdot\gamma = 14.407\,\text{psi}$ Head/pressure increase due to closure at specified time.

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6/1/2013
By: Logan Negherbon
Checked By: Ryan Laughery

Hydroelectric Handbook (Chapter 34)

$\mu = \frac{2 \cdot L}{a}$ Critical time - Eq 1

$h = \frac{a \cdot \Delta v}{g}$ Head increase - Eq 2

$a = \frac{4675}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e}\right)}} \text{fps}$ Pressure wave speed - Eq 3

For simple burried section of 10-ft diameter pipe

$d := 10\text{ft}$ Diameter

$e_{min} := 0.5\text{in}$ Potential minimum thickness of pipe $e_{max} := 1.5\text{in}$ Potential maximum thickness of pipe

$k := 294000 \frac{\text{lbf}}{\text{in}^2}$ Voluminal modulus of elasticity of water in compression

$E := 29400000 \frac{\text{lbf}}{\text{in}^2}$ Modulus of elasticity of the sidewall material (steel)

$a := \frac{4675\text{fps}}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e_{min}}\right)}}$ $a = 2535 \cdot \text{fps}$ $a := \frac{4675\text{fps}}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e_{max}}\right)}}$ $a = 3485 \cdot \text{fps}$

For section of 10-ft diameter pipe encased in concrete/grout thru dam

$d := 10\text{ft}$ Diameter

$\frac{k \cdot d}{E \cdot e} = 0$ For a pipe in solid concrete, this fraction becomes infintesimal and the limiting value of 4675 is reached for *a*, this being the velocity of sound in water.

$a_c := 4675\text{fps}$ Max potential wave speed due to concrete encasement

Project Title: Dalles EFL Emergency AWS - 10-ft Transient Calcs	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Fundamentals of Hydraulic Engineering - Prasuhn

$\rho = 1.94 \cdot \frac{slug}{ft^3}$ $\rho = 62.428 \frac{lb}{ft^3}$ $\gamma = 62.41 \cdot \frac{lbf}{ft^3}$ $L := L_1 = 300\,ft$

$K := 294000 \frac{lbf}{in^2}$ Voluminal modulus of elasticity of water in compression

$E := 29400000 \frac{lbf}{in^2}$ Modulus of elasticity of the sidewall material (steel)

$D := d = 10\,ft$ Diameter

$t := 0.5in$ Thickness

$C_o := 1$ Eq 6-41c (Assuming pipe is anchored against axial movement throughout its length, but provided with expansion joints at regular intervals)

$c := \frac{\sqrt{\frac{K}{\rho}}}{\sqrt{1 + \frac{K}{E} \cdot \frac{D}{t} \cdot C_o}}$ Eq 6-45 Wave speed calculation $c = 2533.254 \cdot fps$

$H = \frac{c \cdot V_o}{g} + \frac{f}{\sqrt{2}} \cdot \frac{L}{D} \cdot \frac{V_o^{\,2}}{2g} = \frac{V_o^{\,2}}{2g} \cdot \left(\frac{2 \cdot c}{V_o} + \frac{f \cdot L}{\sqrt{2 \cdot D}} \right)$ Eq 6-47 Maximum increase in head at valve due to water hammer including friction

$H_f = \frac{h_l}{\sqrt{2}}$ Eq 6-46 Approximation of reduced friction loss seen at the valve at closure

$\Delta p = \left(\rho \cdot c \cdot V_o \right) \cdot \frac{2 \cdot \frac{L}{c}}{t_c} = \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$ Eq 6-48 Pressure rise do to time of closure

$V_o := V(Q, d)$ $V_o = 17.825 \frac{ft}{s}$ Velocity in 10-ft pipe $T_c := \frac{2 \cdot L}{c}$ $T_c = 0.237\,s$

$\Delta p_{max} := \left(\rho \cdot c \cdot V_o \right)$ $\Delta p_{max} = 608.454\,psi$ Maximum pressure increase using wave speed derived from Prasuhn method

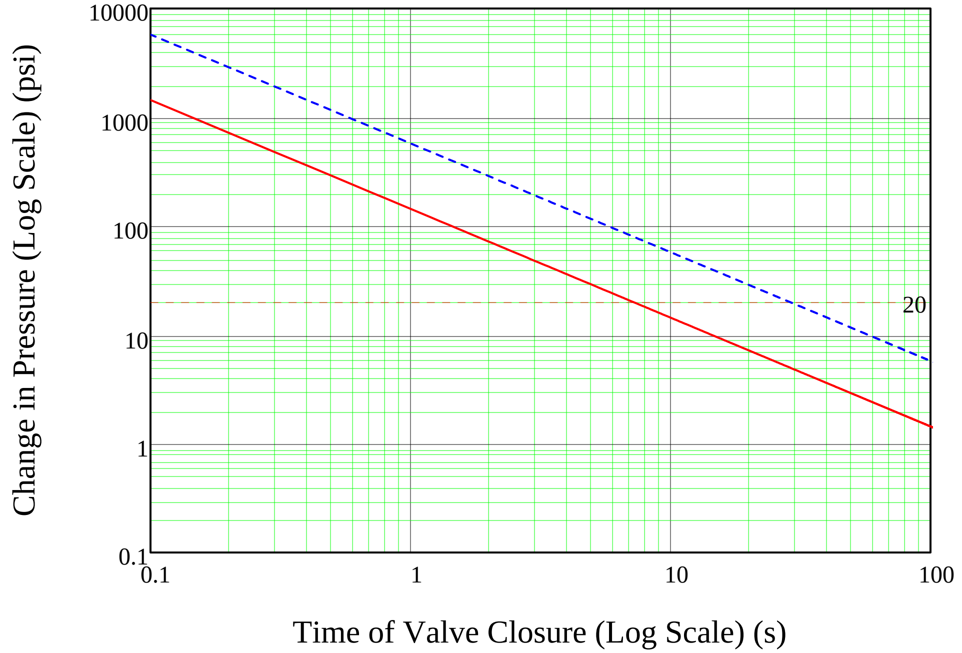
$\Delta p_{max} := \left(\rho \cdot a_c \cdot V_o \right)$ $\Delta p_{max} = 1122.873\,psi$ Maximum pressure increase using wave speed derived from Hydroelectric Handbook

$h_l := \frac{\gamma \cdot 15ft}{\sqrt{2}} = 4.597\,psi$ Losses through the 10-ft conduit due to friction that will be not be present when velocity equals 0 for rapid closure cases.

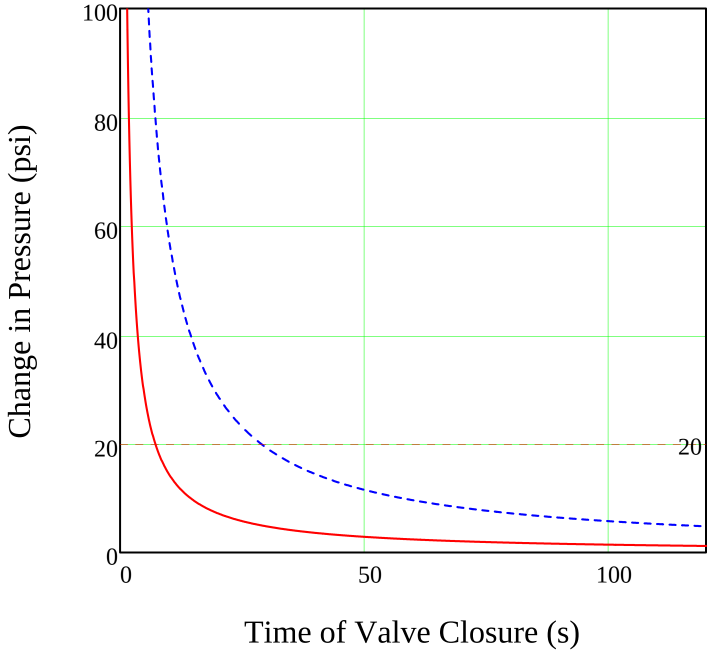
$\Delta p(t_c) := \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$ $t_c := 0.1s, 0.2s .. 120s$ $\boxed{\Delta p(20s) = 7.206 \cdot psi}$ Pressure increase due to 20s valve closure time

$FS\Delta p(t_c) := FS \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$ Applied factor of safety noted above from EM 1110-3-173 $FS = 4$ $\boxed{FS\Delta p(20s) = 28.822\,psi}$ Pressure increase due to 20s valve closure time with FS

Hydraulic Transient Magnitude vs Time of Closure



Expanded



Further analysis will be completed upon defining valve actuation limitations and valve manufacture recommendations.

It is noted that the conduit will be partially encased in concrete causing the waves speed to be accelerated to the speed of sound traveling through water. However, the wave speed is not accounted for in time of closure calculations and does not affect out operating limitations. EM 1110-3-175 will be used as primary design guidance; however, approximations with other methods will be used to assess the applied factor of safety.

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Custom Units Definition

$fps := ft \cdot s^{-1}$ feet per second

$cfs := ft^2 \cdot fps$ cubic feet per second

Fluid Properties

$\rho := 1000 \dfrac{kg}{m^3}$ Assumed density

Assumed temperature deg. F

$T_f := 50$ $T_c := (T_f - 32) \cdot \dfrac{5}{9}$ $T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + \left(0.0337 \cdot T_c + 0.000221 \cdot T_c^{2}\right)} \cdot \frac{m^2}{s}$$

$\nu = 1.319 \times 10^{-6} \cdot \dfrac{m^2}{s}$ Kinematic viscosity of water from temp. relationship

Area function

$A(d) := \dfrac{\pi d^2}{4}$

Reynolds number

$Re(Q, d) := \dfrac{Q \cdot d}{A(d) \cdot \nu}$

Average velocity

$V(Q, d) := \dfrac{Q}{A(d)}$

Jain's equation for friction factor

$$f(Q, d, k_s) := \frac{0.25}{\log\left(\frac{k_s}{3.7 \cdot d} + \frac{5.72}{Re(Q, d)^{0.9}}\right)^2}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Design Parameters

$Q := 1400\text{cfs}$ Design flow rate

$d := 7\text{ft}$ Trial Diameter

$R_h := 160\text{ft}$ Maximum forebay operating range

$R_l := 155\text{ft}$ Minimum forebay operating range

$TW := 102.5\text{ft}$ Design tailwater for stilling basin

$H_h := R_h - TW$ $H_h = 57.5\,\text{ft}$ Maximum driving head

$H_l := R_l - TW$ $H_l = 52.5\,\text{ft}$ Minimum driving head

$H := 45.6\text{ft}$ Minium head at valve with friction losses from 2 - 10 ft Supply.xmcd

Basin design sizing and valve selection

$C := 0.7$ Typical hollow-jet valve discharge coefficient

$A := \dfrac{Q}{C\cdot\sqrt{2g\cdot(H)}}$ $A = 36.922\,\text{ft}^2$ Required area

$d := \sqrt{\dfrac{4A}{\pi}}$ $d = 6.856\,\text{ft}$ $d_o := d$ Recommended diameter

$d := 7\text{ft}$ Selected diameter

$$\text{Check\_d} := \begin{cases} \text{"ok"} & \text{if } d_o \le d \\ \text{"fix d"} & \text{otherwise} \end{cases}$$

$\text{Check\_d} = \text{"ok"}$ Diameter selection check

$A := \pi\cdot\dfrac{d^2}{4}$ Cross sectional valve area

$C := \frac{Q}{A\cdot\sqrt{2g\cdot(H)}}$ $C = 0.672$ Coefficient of discharge needed

Note: 7-foot Howell Bunger valve provides more efficient C value of 0.87 at max opening, it should be capable of achieving design discharge

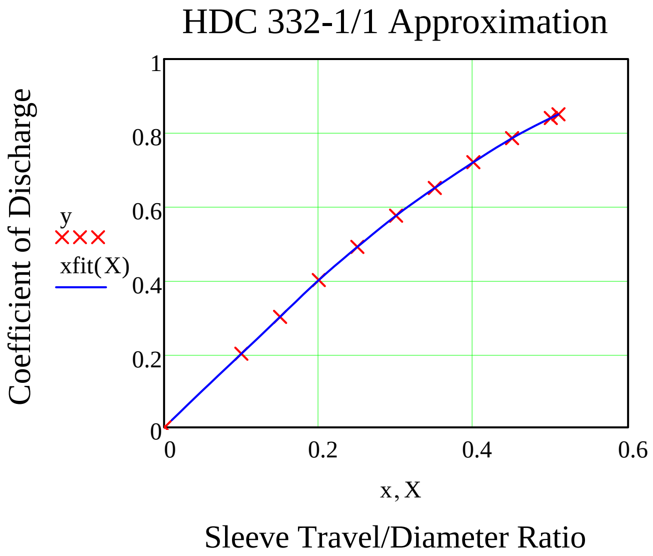
$Q_{max} := 0.85\cdot\left[A\cdot\sqrt{2g\cdot(H)}\right]$ $Q_{max} = 1772\cdot cfs$ Maximum available flow given low pool

HDC 332-1/1 Discharge Coefficients for sleeve travel/diameter ratios on a six-vanes howell-bunger valve

$$data := \begin{pmatrix} 0.001 & 0.001 \\ 0.1 & 0.2 \\ 0.15 & 0.3 \\ 0.2 & 0.4 \\ 0.25 & 0.49 \\ 0.3 & 0.575 \\ 0.35 & 0.65 \\ 0.4 & 0.72 \\ 0.45 & 0.785 \\ 0.5 & 0.84 \\ 0.51 & 0.85 \end{pmatrix}$$

$Data := csort(data, 0)$ $x := Data^{\langle 0 \rangle}$ $y := Data^{\langle 1 \rangle}$

$splinefit := cspline(x, y)$ $X := 0.01, 0.02 .. 0.51$ $xfit(X) := interp(splinefit, x, y, X)$



$0.4\cdot d = 2.8\,ft$

$xfit(0.34) = 0.636$

$V_c := \frac{Q}{A}$ $\qquad$ $V_c = 36.378\,\frac{ft}{s}$

From the USACE HDC 332-1, a four- and six-vane Howell-Bunger (HB) valve produces discharge valve coefficients at 100% open of 0.82 and 0.87, respectively.

Using the provided charts, the operating opening for a six-vane HB valve under the stated assumptions is 70% open or 0.34 times the valve diameter in sleeve travel.

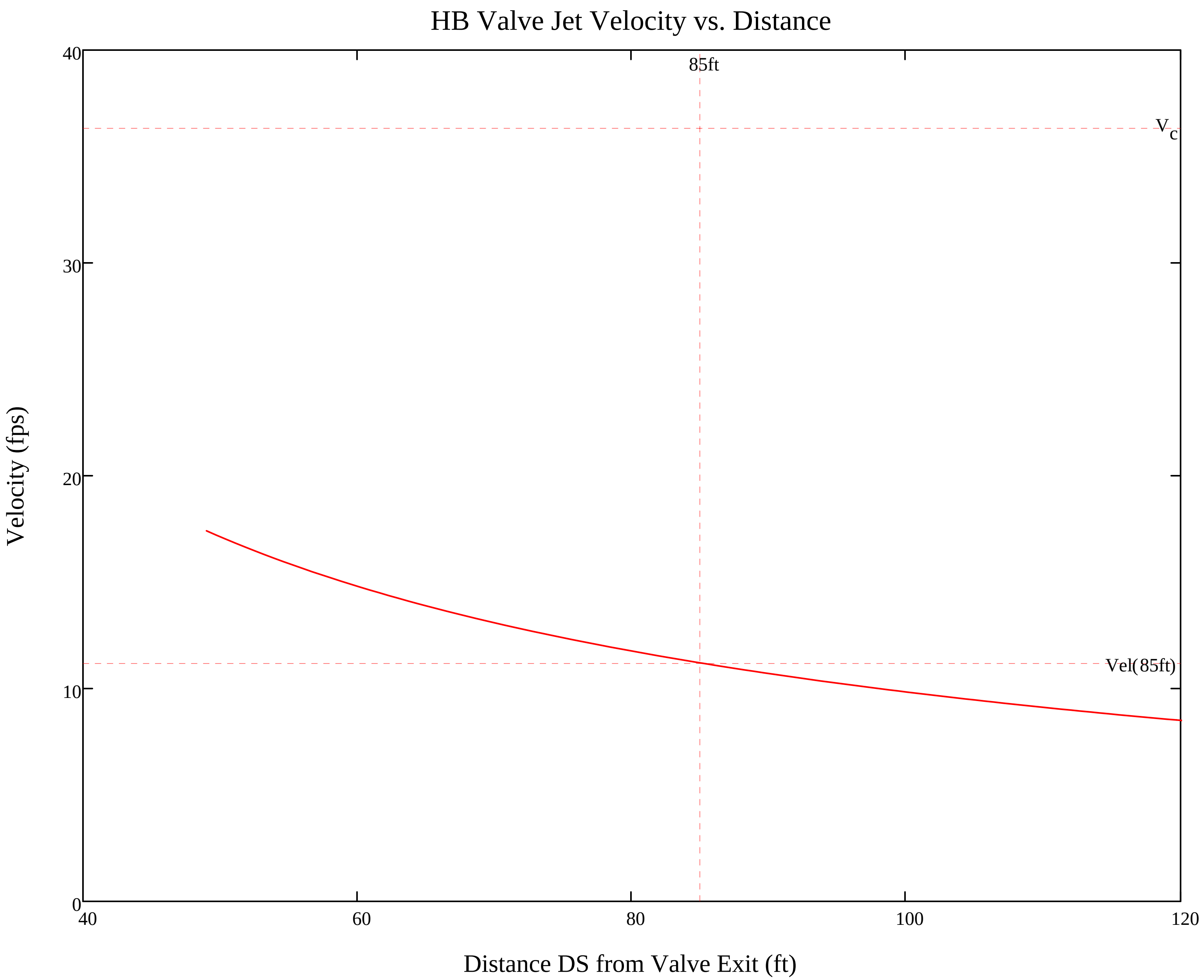
The design elevation for the valve is set to be submerged during emergency auxiliary water supply to the east fishladder entrance at half the channel depth.

$El_{valve} := 88.25ft$

$Submergence := TW - El_{valve}$ $\qquad$ $Submergence = 14.25\,ft$

$Vel(dist) := V_c \cdot 2.27 \cdot \left(\frac{dist}{d}\right)^{-0.80}$ $\qquad$ $Vel(85ft) = 11.205\,\frac{ft}{s}$ $\qquad$ Longitudinal velocity profile based on USBR publication PAP-560

$dist := 7 \cdot d, 7.1d .. 25d$


HB Valve Jet Velocity vs. Distance
Velocity (fps)
40
30
20
10
0
40
60
80
100
120
Distance DS from Valve Exit (ft)
85ft
V_c
Vel(85ft)

Stilling basin assessment

Assuming that the valve acts like a 7-ft by 7-ft sluice gate opening,
BoR Design of Small Dams was used to estimate required sequent depth
for the stilling basin.

$Q = 1400 \cdot \text{cfs}$

$w := 7\text{ft}$

$q := \dfrac{Q}{w}$ $\qquad q = 200 \cdot \dfrac{\text{cfs}}{\text{ft}}$

$H_t := 160\text{ft} - 102.5\text{ft}$

$H_t = 57.5\,\text{ft}$ Maximum energy

$H_t := 155\text{ft} - 102.5\text{ft}$

$H_t = 52.5\,\text{ft}$ Minimum energy

For the maximum energy potential, a sequent depth of 29 ft is required for a 7 ft wide continuous channel, the FAC has 30 ft of depth at the valve discharge and increases depth downstream in the channel with a continuous width of 20 ft. The extimated 29 ft is a conservative value

DESIGN OF SMALL DAMS

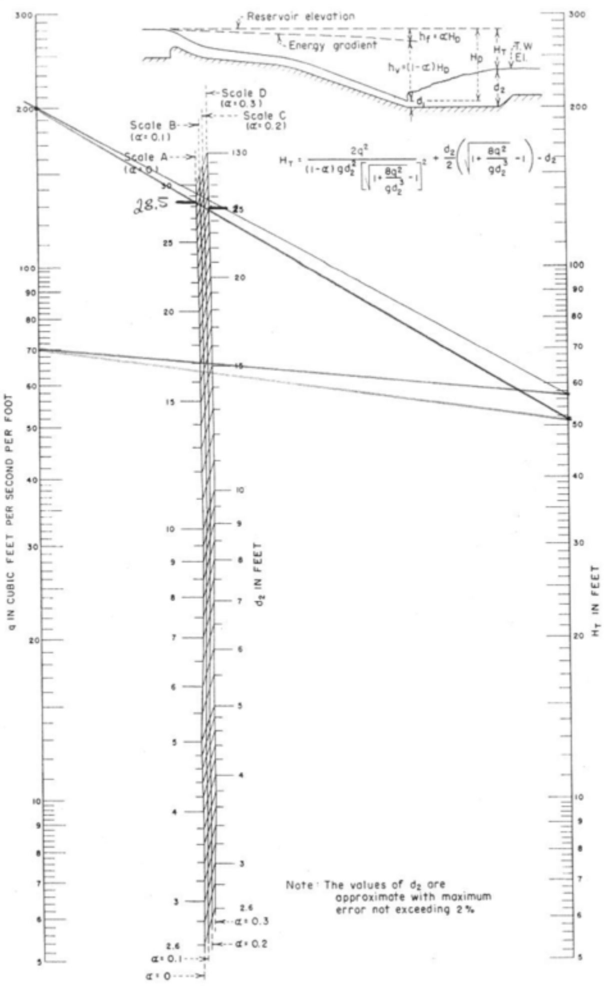


Figure 9-43.—Stilling basin depths versus hydraulic heads for various channel losses. 288-D-2428.

EM 1110-2-1602 Basin Guidance

Still assuming 7-ft diameter valve behaves as 7-ft by 7-ft square jet.

e. Elevation fo Stilling Basin Floor

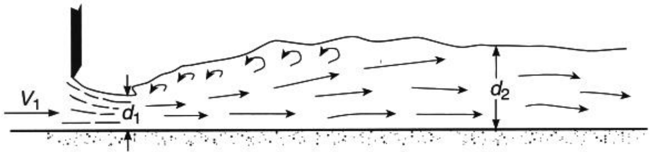
$V_c = 36.378\,\frac{ft}{s}$ Exit velocity of 1400 cfs thru 7 ft valve.

$d_1 := 7ft$

$Fr := \frac{V_c}{\sqrt{g \cdot d_1}}$ $Fr = 2.424$ Froude is less than 2.5, considered prejump stage (Sturm - Open Channel Hydraulics image below)

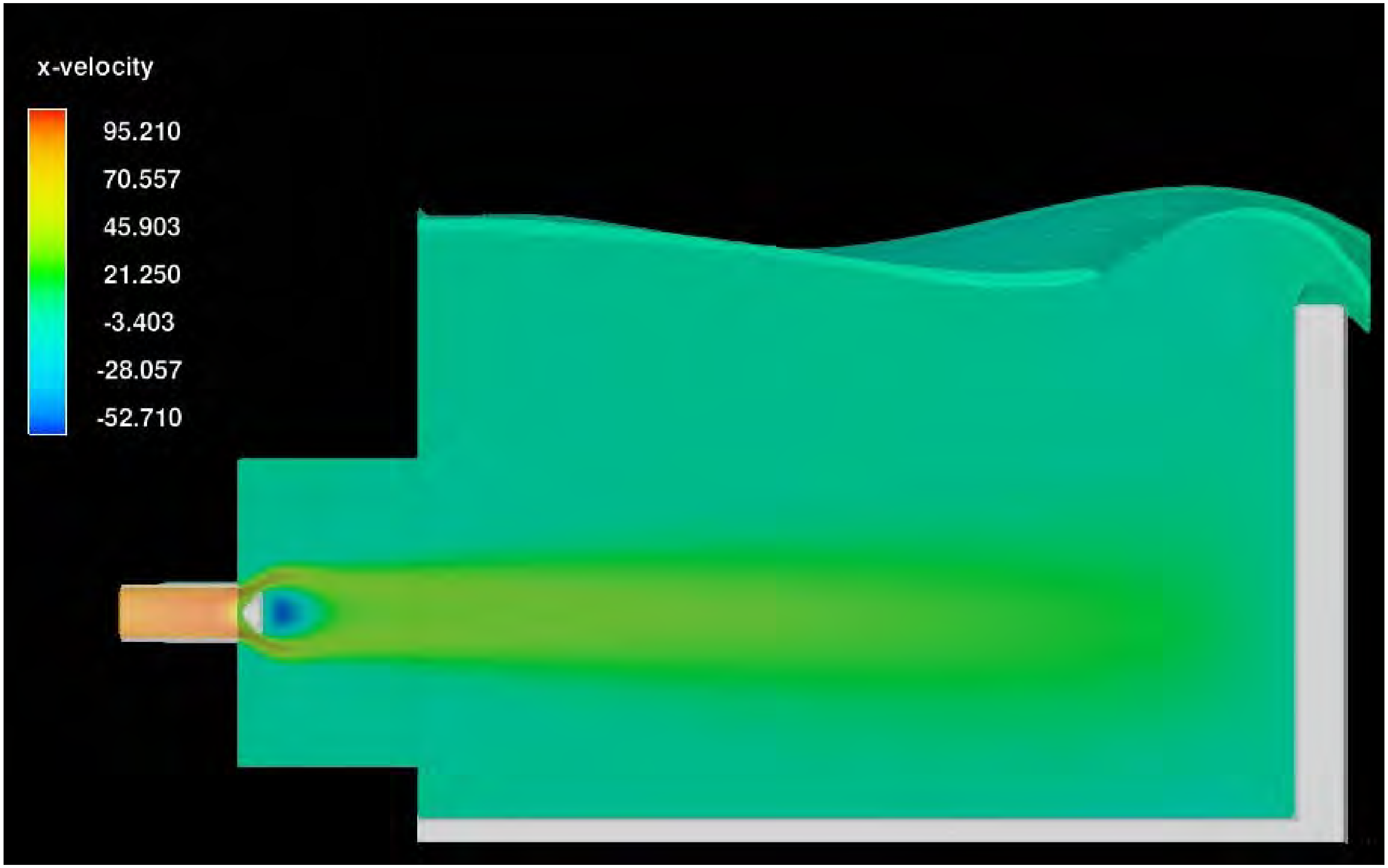
$d_2 := d_1\left(0.5 \cdot \sqrt{1 + 8 \cdot Fr^2} - 1\right)$ Eq 5-4 EM 1110-2-1602

$d_2 = 17.251\,ft$ Required sequent depth for 7-ft by 7-ft square sluice jet



F_1 Between 1.7 and 2.5
Form A—Prejump stage

Rodney Hunt, a commercial manufacturer of hollow jet cone valves, supplied this graphic of the CFD modeling depicting submerged flow pattern of a Howell-Bunger type hollow jet cone valve with similar conditions to the intended application (exact conditions not disclosed by supplier).



Project Title: Dalles EFL Emergency AWS
FLAC to AWS Chamber Additional 6-ft Dia
6/1/2013
By: Logan Negherbon
Checked By: Ryan Laughery

Units Definition $cfs := ft^{3} \cdot s^{-1}$ Units Coefficient $C_u := 1.486 \sqrt[3]{ft} \cdot s^{-1}$ Energy Coefficient $\alpha := 1$

Culvert Computations **Circular Culvert (Clean)** **Input** **Output**

Data Input

Pipe Diameter $D := 6ft = 72 \cdot in$

Pipe Manning's n $n := 0.01$

Pipe Slope $S_o := 0.000001$ Flow Rate $Q := 350cfs$ Per culvert

FHWA Table 9 Coefficients

$K := 0.0045$	$M := 2.0$	$c := 0.0317$	$Y := 0.69$	Circular, concrete groove end projecting
$K := 0.0018$	$M := 2.0$	$c := 0.0292$	$Y := 0.74$	Circular, concrete groove end with headwall entrance
$K := 0.0098$	$M := 2.0$	$c := 0.0398$	$Y := 0.67$	Circular, concrete with square edge headwall entrance

Culvert Length $L := 50ft$

Outlet Invert Ele. $OInv_{el} := 92ft$ TW Elevation $TW_{el} := 90.5ft$

Inlet Invert Ele. $InInv_{el} := OInv_{el} + S_o \cdot L$ $InInv_{el} = 92\,ft$

Loss Coefficients, Sturm pg 226

$k_e := 0.5$ Entrance loss $k_o := 1.0$ Exit loss

Hydraulic Geometry

Angle Functions $\theta(y) := 2 \cdot acos\left(1 - 2 \cdot \frac{y}{D}\right)$ $A_f := \frac{\pi \cdot D^2}{4}$

Area Functions $A(\theta) := \frac{D^2}{8} \cdot (\theta - \sin(\theta))$

Perimeter Functions $P(\theta) := \frac{D}{2} \cdot (\theta)$

Hydraulic Radius $R_H(\theta) := A(\theta) \cdot P(\theta)^{-1}$

Top Width $T(\theta) := D \cdot \sin\left(\frac{\theta}{2}\right)$

Full Pipe Condition

$y_f := 0.90D$ $y_f = 5.4\,ft$ $\theta_f := 2 \cdot acos\left(1 - 2\frac{y_f}{D}\right)$ $\theta_f = 4.996$

Inlet Control Computations

Critical Depth Computations

$N_f = \frac{V}{\sqrt{\alpha \cdot g \cdot D}}$ $Z_c := \frac{Q^2}{g \cdot \alpha}$ $Z_c = 3.807 \times 10^3\, ft^5$ Critical Section Factor

$\theta := 1.5\pi$ Trial value

Given Solve block for critical depth angle

$\frac{A(\theta)^3}{T(\theta)} = Z_c$ $\theta_c := \text{Find}(\theta)$ $\theta_c = 4.664$ $\theta_c := \begin{cases} (2\cdot\pi) & \text{if } \theta_c > 2\cdot\pi \\ \theta_c & \text{otherwise} \end{cases}$ $\theta_c = 4.664$

$y_c := \begin{cases} D & \text{if } \theta_c > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_c}{2}\right)\right) & \text{otherwise} \end{cases}$ $y_c = 5.069\, ft$ Critical Depth

Hydraulic Radius $R_H(\theta_c) = 1.821\, ft$

Percent Full $Per_{full}(y) := \frac{y}{D}$ $Per_{full}(y_c) = 84.481\cdot\%$

Velocity $V_c := Q\cdot A(\theta_c)^{-1}$ $V_c = 13.736\, \frac{ft}{s}$ Critical Velocity

Top Width $T(\theta_c) = 4.345\, ft$

Critical Slope $S_c := \frac{Q^2\cdot n^2}{C_u^{\,2}\cdot A(\theta_c)^2\cdot \sqrt[3]{R_H(\theta_c)^4}}$ $S_c = 0.384\cdot\%$

Inlet Condition Factor $N := \frac{Q\cdot cfs^{-1}}{A_f\cdot ft^{-2}\cdot\sqrt{D\cdot ft^{-1}}}$ $N = 5.054$

Specific Head at Critical Depth

$H_c := y_c + \frac{V_c^{\,2}}{2\cdot g}$ $H_c = 8.001\, ft$

Calculate Headwater For Inlet Control, feet above culvert invert at the inlet:

$HW_{inlet} := \begin{cases} \left[H_c + D\cdot\left(K\cdot N^M - 0.5\cdot S_o\right)\right] & \text{if } N < 3.5 \\ \left[D\cdot\left(c\cdot N^2 + Y - 0.5\cdot S_o\right)\right] & \text{otherwise} \end{cases}$ $HW_{inlet} = 10.119\, ft$ $\frac{HW_{inlet}}{D} = 1.686$

Outlet Control Computations

Normal Depth Computation

Trial depth angle $\theta := 2.5\pi$

Given $Q = \frac{C_u}{n} \cdot A(\theta) \cdot R_H(\theta)^{\frac{2}{3}} \cdot \sqrt{S_o}$ $\theta_n := \text{Find}(\theta)$ $\theta_n = 399.151$

$$\theta_n := \begin{vmatrix} (2\cdot\pi) & \text{if } \theta_n > 2\cdot\pi \\ \theta_n & \text{otherwise} \end{vmatrix}$$ $\theta_n = 6.283$

Normal Depth Critical Depth

$$y_n := \begin{vmatrix} D & \text{if } \theta_n > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_n}{2}\right)\right) & \text{otherwise} \end{vmatrix}$$ $y_n = 6\ \text{ft}$ $y_c = 5.069\ \text{ft}$

Flow Area $A(\theta_n) = 28.274\ \text{ft}^2$

Hydraulic Radius $R_H(\theta_n) = 1.5\ \text{ft}$

Percent Full $\text{Per}_{\text{full}}(y_n) = 100\cdot\%$

Velocity $V_n := Q\cdot A(\theta_n)^{-1}$ $V_n = 12.379\ \frac{\text{ft}}{\text{s}}$

Top Width $T(\theta_n) = 0\ \text{ft}$

Hydraulic Depth $D_{hn} := \frac{A(\theta_n)}{T(\theta_n)}$ $D_{hn} = 3.848 \times 10^{16}\ \text{ft}$

Calculate Headwater For Outlet Control, feet above culvert invert at the inlet:

$k_f := \frac{2\cdot g\cdot n^2\cdot L}{C_u^{\,2}\cdot\sqrt[3]{R_H(\theta_f)^4}}$ Friction loss based on full pipe $k_f = 0.067$

$TW := TW_{el} - OInv_{el}$ $TW = -1.5\ \text{ft}$ Tailwater depth $\frac{TW}{D} = -0.25$

$$\text{PipeCondition} := \begin{vmatrix} \text{"pipe full"} & \text{if } TW > D \\ \text{"part-full pipe"} & \text{otherwise} \end{vmatrix}$$ PipeCondition = "part-full pipe"

Calculation of Energy Loss

$H := (k_e + k_o + k_f)\cdot\frac{V_n^{\,2}}{2\cdot g}$ $H = 3.732\ \text{ft}$

Outlet Head

$$h_o := \begin{cases} TW & \text{if } TW > \dfrac{y_c + D}{2} \\ \dfrac{y_c + D}{2} & \end{cases} \qquad h_o = 5.534\ \text{ft}$$

$$HW_{out} := h_o - S_o \cdot L + H \qquad HW_{out} = 9.266\ \text{ft}$$

Control and Headwater

$$HW\_Condition := \begin{cases} \text{"Inlet"} & \text{if } HW_{inlet} > HW_{out} \\ \text{"Outlet"} & \text{otherwise} \end{cases} \qquad HW := \begin{cases} HW_{inlet} & \text{if } HW_{inlet} > HW_{out} \\ HW_{out} & \text{otherwise} \end{cases}$$

$HW_{inlet} = 10.119\ \text{ft}$

$HW_{out} = 9.266\ \text{ft}$

$HW\_Condition = \text{"Inlet"}$ $\qquad HW = 10.119\ \text{ft}$

Design Summary - (Project)

$D = 6\ \text{ft}$	Culvert Diameter	$L = 50\ \text{ft}$	Culvert Length
$S_o = 1 \times 10^{-6}$	Invert Slope	$n = 0.01$	Manning's n for pipe
$Q = 350 \cdot \text{cfs}$	Discharge		
$y_c = 5.069\ \text{ft}$	Critical Depth		
$y_n = 6\ \text{ft}$	Normal Depth		

$HW\_Condition = \text{"Inlet"}$ Headwater Condition

$HW = 10.119\ \text{ft}$ Headwater Depth

$WSE_{inlet} := HW + InInv_{el}$

$WSE_{inlet} = 102.119\ \text{ft}$ Water surface elevation in FLAC

$$V_o := \frac{Q}{A_f} \qquad V_o = 12.379\ \frac{\text{ft}}{\text{s}}$$ Exit velocity

Exit Trajectory Analysis

$EL_{imp\_min} := 80.5ft$ Minimum Depth in AWSC

$EL_{imp\_max} := 90.0ft$ Maximum Depth in AWSC

$OInv_{el} = 92\,ft$ Invert Elevation of Culvert Outlet

$Ocl_{el} := OInv_{el} + \frac{y_c}{2}$ Centerline Elevation of Culver Outlet

$Ocl_{el} = 94.534\,ft$

$y_{imp\_max} := Ocl_{el} - EL_{imp\_min}$ Maximum fall distance from centerline

$y_{imp\_max} = 14.034\,ft$

$y_{imp\_min} := Ocl_{el} - EL_{imp\_max}$ Minimum fall distance from centerline

$y_{imp\_min} = 4.534\,ft$

$$t_{max} := \sqrt{\frac{y_{imp\_max} \cdot 2}{g}}$$

$t_{max} = 0.934\,s$

$$t_{min} := \sqrt{\frac{y_{imp\_min} \cdot 2}{g}}$$

$t_{min} = 0.531\,s$

$x(t) := V_o \cdot t$ $\qquad x(t_{max}) = 11.562\,ft$

$y(t) := -g \cdot \frac{t^2}{2}$ $\qquad x(t_{min}) = 6.572\,ft$

$v_y(t) := -g \cdot t$ $\qquad v_y(t_{max}) = -30.051\,\frac{ft}{s}$ $\qquad v_y(t_{min}) = -17.082\,\frac{ft}{s}$

$v_x := V_o$

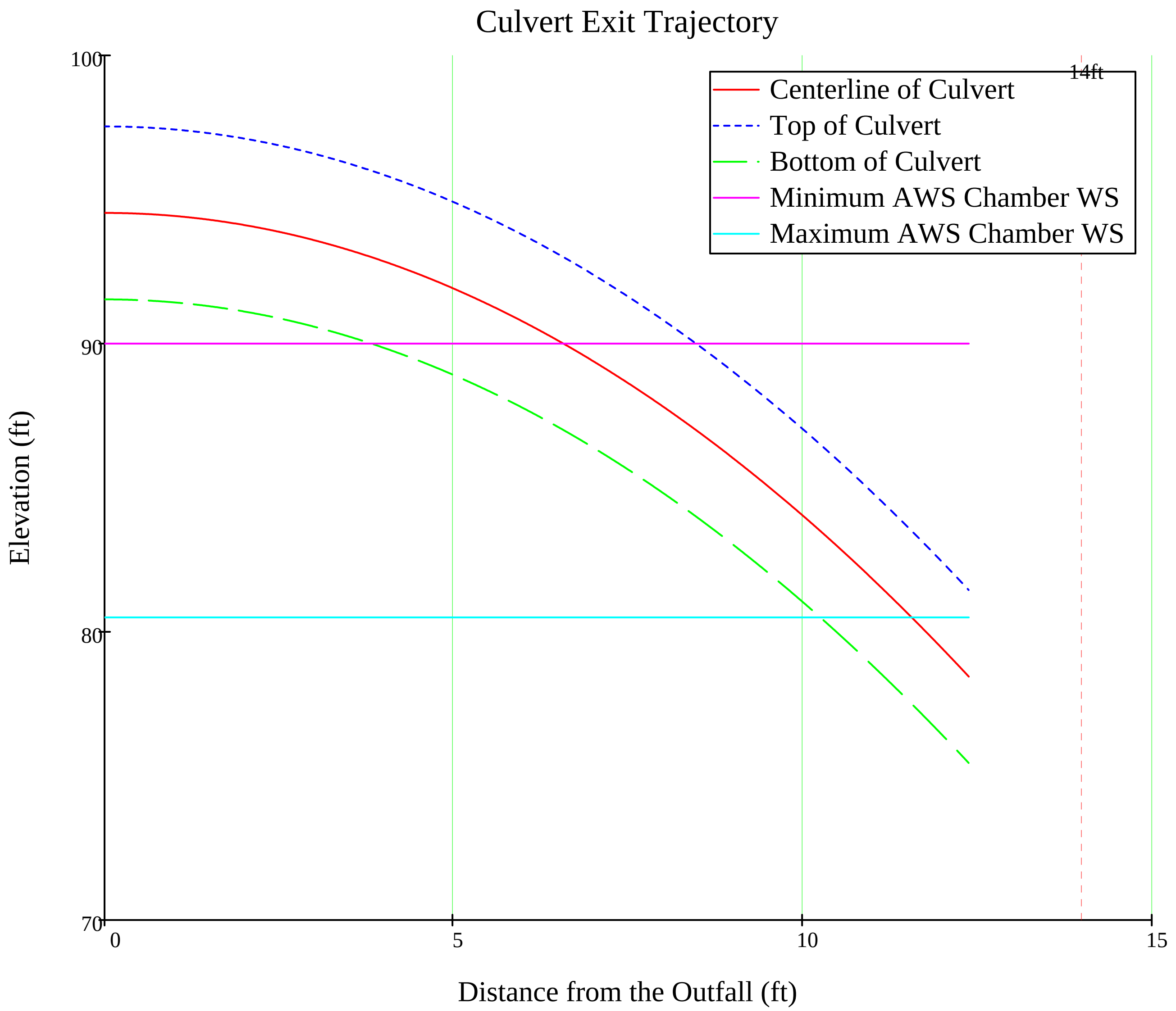
$\theta_{imp\_min} := atan\left(\frac{v_y(t_{min})}{v_x}\right)$ $\qquad \theta_{imp\_min} = -54.07 \cdot deg$

$\theta_{imp\_max} := atan\left(\frac{v_y(t_{max})}{v_x}\right)$ $\qquad \theta_{imp\_max} = -67.612 \cdot deg$

$v_{max} := \sqrt{v_y(t_{max})^2 + v_x^2}$ $\qquad v_{max} = 32.501\,\frac{ft}{s}$

$v_{min} := \sqrt{v_y(t_{min})^2 + v_x^2}$ $\qquad v_{min} = 21.095\,\frac{ft}{s}$

$t := 0s, 0.001s .. 1s$


Culvert Exit Trajectory
100
90
80
70
0
5
10
15
14ft
Centerline of Culvert
Top of Culvert
Bottom of Culvert
Minimum AWS Chamber WS
Maximum AWS Chamber WS
Elevation (ft)
Distance from the Outfall (ft)

Project Title: Dalles EFL Emergency AWS FLAC to AWS Chamer Additional Upper 6-ft	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

WSP Computations **Circular channel** **Input** **Output**

Data Input

Bed slope $S_o := 0.000001$ Diameter $D := 6\text{ft}$ Channel discharge $Q := 200\text{cfs}$

Manning's n $n := 0.01$ Channel Length $L := 50\text{ft}$

No. of steps $N := 300$

Hydraulic Geometry

$$A(\theta) := \frac{D^2}{8}\cdot(\theta - \sin(\theta)) \qquad T(\theta) := D\cdot\sin\left(\frac{\theta}{2}\right) \qquad y_f := 0.9\cdot D$$

$$R(\theta) := \frac{D}{4}\cdot\left(1 - \frac{\sin(\theta)}{\theta}\right) \qquad P(\theta) := \frac{D}{2}\cdot\theta \qquad \theta(y) := 2\cdot\text{acos}\left[1 - 2\cdot\frac{(y)}{D}\right]$$

$$\theta_f := 2\cdot\text{acos}\left(1 - 2\frac{y_f}{D}\right) \qquad \theta_f = 4.996$$

Critical Depth Computations

$$Z_c := \frac{Q^2}{g\cdot\alpha} \qquad Z_c = 1.243\times 10^3\,\text{ft}^5$$ Critical section factor $\theta_t := 1.5\cdot\pi$ Trial value

Given Solve block for critical depth angle

$$\frac{A(\theta_t)^3}{T(\theta_t)} = Z_c \qquad \theta_c := \text{Find}(\theta_t) \qquad \theta_c = 3.727$$

Critical Depth Angle Critical Depth

$$\theta_c := \begin{cases} (2\cdot\pi) & \text{if } \theta_c > 2\pi \\ \theta_c & \text{otherwise} \end{cases} \qquad \theta_c = 3.727 \qquad y_c := \begin{cases} D & \text{if } \theta_c > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_c}{2}\right)\right) & \text{otherwise} \end{cases} \qquad y_c = 3.866\text{ ft}$$

$$V_c := \frac{Q}{A(\theta_c)} \qquad V_c = 10.385\,\frac{\text{ft}}{\text{s}}$$

Normal Depth Computation

Trial depth angle $\theta_t = 4.712$

Solve block for normal depth angle

$$\text{Given} \quad Q = \left(\frac{C_u}{n}\cdot A(\theta_t)\cdot R(\theta_t)^{\frac{2}{3}}\cdot\sqrt{S_o}\right) \qquad \theta_n := \text{Find}(\theta_t) \qquad \theta_n = 228.92$$

Normal Depth Angle Normal Depth

$$\theta_n := \begin{cases} (2\cdot\pi) & \text{if } \theta_n > 2\pi \\ \theta_n & \text{otherwise} \end{cases} \qquad \theta_n = 6.283 \qquad y_n := \begin{cases} D & \text{if } \theta_n > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_n}{2}\right)\right) & \text{otherwise} \end{cases} \qquad y_n = 6\text{ ft}$$

Profile Identification and Step Selection

$tw := y_c$

Control Depth

$y_o := -1\mathrm{ft}$

Mild sloped with downstream control

Control depth definition

```
$y_1 :=$
    $tw$   if  $y_o = -1\mathrm{ft}$
    $y_o$  otherwise
```

$y_1 = 3.866 \cdot \mathrm{ft}$

Profile Type and Definition

$ORIGIN := 1$

```
$Type :=$
    if  $y_c > y_n$
        $type \leftarrow$ "S1"   if  $y_1 > y_c$
        $type \leftarrow$ "S2"   if  $y_n < y_1 \le y_c$
        $type \leftarrow$ "S3"   otherwise
    if  $y_c < y_n$
        $type \leftarrow$ "M1"   if  $y_n < y_1$
        $type \leftarrow$ "M2"   if  $y_c \le y_1 < y_n$
        $type \leftarrow$ "M3"   otherwise
    otherwise
        $type \leftarrow$ "This profile is not steep or mild"
        return  $type$
```

$Type =$ "M2"

$y_1 = 3.866\ \mathrm{ft}$ $\quad y_n = 6\ \mathrm{ft}$ $\quad y_c = 3.866\ \mathrm{ft}$

Define Computational Step

```
$\Delta y :=$
    if  $y_n < y_c$
        $\Delta y \leftarrow y_c - 0.99 y_1$   if  $Type =$ "S1"
        $\Delta y \leftarrow 1.01 y_n - y_1$   if  $Type =$ "S2"
        $\Delta y \leftarrow 0.99 y_n - y_1$   if  $Type =$ "S3"
    if  $y_c < y_n$
        $\Delta y \leftarrow 1.01 y_n - y_1$   if  $Type =$ "M1"
        $\Delta y \leftarrow 0.99 y_n - y_1$   if  $Type =$ "M2"
        $\Delta y \leftarrow y_c - y_1$   if  $Type =$ "M3"
    return  $\Delta y$
```

$\Delta y = 2.074 \cdot \mathrm{ft}$

$y_1 := y_1$

Profile Computations

Direct Step Program

```
$AProfile(y) :=$
    $x_1 \leftarrow 0.0ft$
    $dy \leftarrow \Delta y \cdot N^{-1}$
    $E_1 \leftarrow y_1 + \frac{\alpha \cdot Q^2}{2 \cdot g \cdot A(\theta(y_1))^2}$
    $R_1 \leftarrow A(\theta(y_1)) \cdot P(\theta(y_1))^{-1}$
    $Sf_1 \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_1)) \cdot \sqrt[3]{(R_1)^2}}\right]^2$
    for $i \in 2..N$
        $y_i \leftarrow y_{i-1} + dy$
        $E_i \leftarrow y_i + \alpha \cdot Q^2 \cdot \left(2 \cdot g \cdot A(\theta(y_i))^2\right)^{-1}$
        $R_i \leftarrow A(\theta(y_i)) \cdot P(\theta(y_i))^{-1}$
        $Sf_i \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_i)) \cdot \sqrt[3]{(R_i)^2}}\right]^2$
        $S_f \leftarrow (Sf_i + Sf_{i-1}) \cdot 0.5$
        $\Delta x \leftarrow \frac{E_{i-1} - E_i}{S_f - S_o}$
        $x_i \leftarrow x_{i-1} + \Delta x$
        $WSP_{1,1} \leftarrow x_1$
        $WSP_{2,1} \leftarrow y_1$
        $WSP_{1,i} \leftarrow x_i$
        $WSP_{2,i} \leftarrow y_i$
    $WSP$
```

Numerical Integration Program

```
$BProfile(y) :=$
    $x_1 \leftarrow 0ft$
    $dy \leftarrow \frac{\Delta y}{N} \cdot 0.999$
    $R_1 \leftarrow \frac{A(\theta(y_1))}{P(\theta(y_1))}$
    $Sf_1 \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_1)) \cdot \sqrt[3]{(R_1)^2}}\right]^2$
    $V_1 \leftarrow \frac{Q}{A(\theta(y_1))}$
    $D_{h_1} \leftarrow \frac{A(\theta(y_1))}{T(\theta(y_1))}$
    $NF_1 \leftarrow \frac{V_1}{\sqrt{g \cdot D_{h_1}}}$
    $Gy_1 \leftarrow \frac{1 - (NF_1)^2}{S_o - Sf_1}$
    for $i \in 2..N$
        $y_i \leftarrow y_{i-1} + dy$
        $R_i \leftarrow \frac{A(\theta(y_i))}{P(\theta(y_i))}$
        $Sf_i \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_i)) \cdot \sqrt[3]{(R_i)^2}}\right]^2$
        $V_i \leftarrow \frac{Q}{A(\theta(y_i))}$
        $D_{h_i} \leftarrow \frac{A(\theta(y_i))}{T(\theta(y_i))}$
        $NF_i \leftarrow \frac{V_i}{\sqrt{g \cdot D_{h_i}}}$
        $Gy_i \leftarrow \frac{1 - (NF_i)^2}{S_o - Sf_i}$
```

```
    $\Delta x \leftarrow \left(y_i - y_{i-1}\right)\cdot\frac{Gy_{i-1} + Gy_i}{2}$
    $x_i \leftarrow x_{i-1} + \Delta x$
    $WSP_{1,1} \leftarrow x_1$
    $WSP_{2,1} \leftarrow y_1$
    $WSP_{1,i} \leftarrow x_i$
    $WSP_{2,i} \leftarrow y_i$
$WSP$
```

$i := 1..N$

Direct Step Computation Results

$y_n = 6 \cdot ft$ $y_c = 3.866 \cdot ft$ $x_1 := AProfile(y)_{1,1}$ $x_1 = 0\ ft$ $y_1 := AProfile(y)_{2,1}$ $y_1 = 3.866\ ft$

$Adepth_i := AProfile(y)_{2,i}$ $Adistance_i := AProfile(y)_{1,i}$

$AY_{final} := AProfile(y)_{2,N}$ $AY_{final} = 5.933\ ft$

$AX_{final} := AProfile(y)_{1,N}$ $AX_{final} = -911.715\ ft$

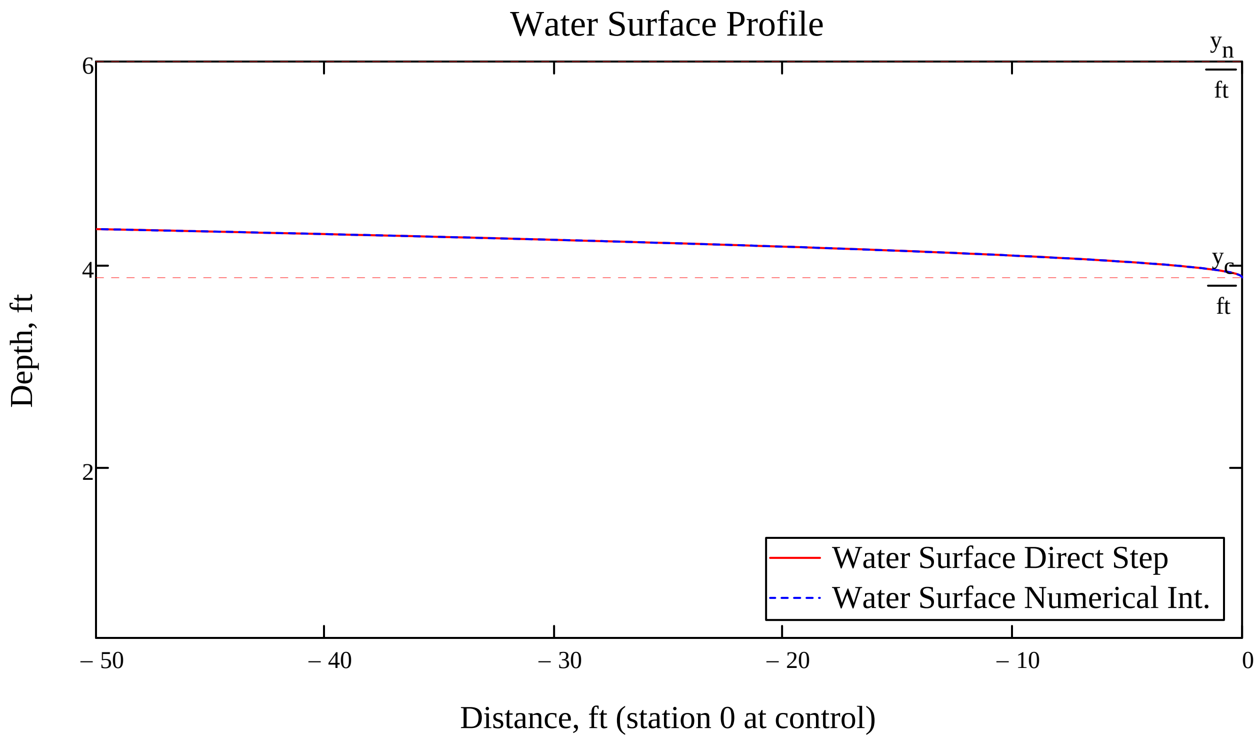
Numerical Integration Computation Results

$y_n = 6 \cdot ft$ $y_c = 3.866 \cdot ft$ $x_1 := BProfile(y)_{1,1}$ $x_1 = 0\ ft$ $y_1 := BProfile(y)_{2,1}$ $y_1 = 3.866\ ft$

$Bdepth_i := BProfile(y)_{2,i}$ $Bdistance_i := BProfile(y)_{1,i}$

$BY_{final} := BProfile(y)_{2,N}$ $BY_{final} = 5.931\ ft$

$BX_{final} := BProfile(y)_{1,N}$ $BX_{final} = -910.128\ ft$



Type = "M2" Hydraulic_condition := $\begin{cases} \text{"Short"} & \text{if } |AX_{final}| > L \\ \text{"Long"} & \text{otherwise} \end{cases}$ Hydraulic_condition = "Short"

$\mathrm{AProfile}(y)^{T} =$ ft

	1	2
1	0	3.866
2	-0.01	3.873
3	-0.04	3.879
4	-0.091	3.886
5	-0.162	3.893
6	-0.253	3.9
7	-0.365	3.907
8	-0.497	3.914
9	-0.65	3.921
10	-0.823	3.928
11	-1.017	3.935
12	-1.231	3.942
13	-1.466	3.949
14	-1.722	3.956
15	-1.998	3.962
16	-2.295	...

8 ft by 8 ft Culvert and Header Computations

Custom Units Definition

$fps := ft \cdot s^{-1}$ feet per second

$cfs := ft^{2} \cdot fps$ cubic feet per second

Fluid Properties

$\rho := 999.7 \frac{kg}{m^{3}}$ fluid density

Assumed temperature deg. F

$T_f := 50$ $T_c := \left(T_f - 32\right) \cdot \frac{5}{9}$ $T_c = 10$ Temp. deg. C

$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + \left(0.0337 \cdot T_c + 0.000221 \cdot T_c^{2}\right)} \cdot \frac{m^{2}}{s}$ $\nu = 1.319 \times 10^{-6} \cdot \frac{m^{2}}{s}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function: $A(h,w) := h \cdot w$

Equivalent diameter for rectangular conduit: $D'(h,w) := \frac{4 \cdot A(h,w)}{2 \cdot h + 2 \cdot w}$

Reynolds number: $Re(Q,h,w) := \frac{Q \cdot D'(h,w)}{A(h,w) \cdot \nu}$

Average velocity: $V(Q,h,w) := \frac{Q}{A(h,w)}$

Jain's equation for friction factor

$$f\left(Q,h,w,k_s\right) := \frac{0.25}{\log\left(\frac{k_s}{3.7 \cdot D'(h,w)} + \frac{5.74}{Re(Q,h,w)^{0.9}}\right)^{2}}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Assumed concrete equivalent sand grain roughness

$\alpha_f := 1.0$ friction loss sensitivity coefficient

$\alpha_k := 1.0$ minor loss sensitivity coefficient

$k_s := \alpha_f \cdot 0.25mm$ assumed roughness

$k_{sr} := 2.0mm$ extremely rough

$k_{ss} := 0.025mm$ smooth roughness

Roughness values taked from Miller Table 8.1

Driving head characteristics

$Tailrace_{max} := 86.0ft$ $Tailrace := 86ft$ $Tailrace_{min} := 76.4ft$

$Diffuser_{head} := 2.2ft$ $Attraction_{head} := 1.0ft$

$TW := Tailrace + Attraction_{head} + Diffuser_{head}$

WSE in FLAC WSE in AWS chamber

$HW := 101.65ft$ $TW = 89.2\ ft$ $Available := HW - TW$ $Available = 12.45\ ft$

▾

For the header losses through modified diffusers

Pipe 1 Floor diffuser 1 (node 1 to node 7)

$Q_{1'} := 300\text{cfs}$ Trial flow rate for loss coefficient estimation

$D_{h1} := 6.5\text{ft}$ Conduit height

$D_{w1.1} := 6.0\text{ft}$ Initial conduit width

$D_{w1.2} := 5.2\text{ft}$ Final conduit width

$L_1 := 5\text{ft}$ Estimation of conduit length

Entrance loss

$K_{1e} := 0.5$ Miller Fig. 14.11

Bend loss 45 deg

$k'_b := 0.3$ From Miller Fig. 9.9

$\text{Re}\left(Q_{1'}, D_{h1}, D_{w1.1}\right) = 3.382 \times 10^6$ Reynolds number at entrance

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{1'}, D_{h1}, D_{w1.1}, k_{sr}\right)}{f\left(Q_{1'}, D_{h1}, D_{w1.1}, k_{ss}\right)}$ $C_f = 1.962$ From Miller Eq. 9.3

$K_{1b45} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{1b45} = 0.589$ From Miller Eq. 9.4

Contraction loss

$$\frac{A\left(D_{h1}, D_{w1.2}\right)}{A\left(D_{h1}, D_{w1.1}\right)} = 0.867$$

$K_{1c} := 0.08$ Miller Fig. 14.14

Combining tee loss

$K_{t17} := 0.4$ Miller Fig 13.10

Friction loss

Contracted section assumed negligible for friction due to short section

$$f_1(Q) := f\left(Q, D_{h1}, D_{w1.1}, k_s\right) \cdot \frac{L_1}{D'\left(D_{h1}, D_{w1.1}\right)}$$

Pipe 1 summation of losses

$$H_1(Q) := \left[f_1(Q) + \alpha_k \cdot \left(K_{1e} + K_{1b45} + K_{1c} + K_{t17}\right)\right] \cdot \frac{V\left(Q, D_{h1}, D_{w1.1}\right)^2}{2 \cdot g}$$

$H_1\left(Q_{1'}\right) = 1.452\text{ ft}$ $V\left(Q_{1'}, D_{h1}, D_{w1.1}\right) = 7.692 \dfrac{\text{ft}}{\text{s}}$

Pipe 2 Floor diffuser 2 (node 2 to node 6)

Entrance loss

$Q_{2'} := 130\text{cfs}$ Trial flow rate for loss coefficient estimation

$D_{h2} := 6.5\text{ft}$ Conduit height

$D_{w2} := 6.0\text{ft}$ Conduit width

$L_2 := 0\text{ft}$ Estimation of conduit length

Entrance loss

$K_{2e} := 0.5$ Miller Fig. 14.11

Assumed friction loss negligible

Combining tee loss

$K_{t26} := 8$ Miller Fig 13.10

Pipe 2 summation of losses

$$H_2(Q) := \left[\alpha_k \cdot \left(K_{2e} + K_{t26}\right)\right] \cdot \frac{V\left(Q, D_{h2}, D_{w2}\right)^2}{2 \cdot g} \qquad H_2\left(Q_{2'}\right) = 1.468\text{ ft}$$

$$V\left(Q_{2'}, D_{h2}, D_{w2}\right) = 3.333\ \frac{\text{ft}}{\text{s}}$$

Pipe 3 Floor diffuser 3 (node 3 to node 5)

Entrance loss

$Q_{3'} := 100\text{cfs}$ Trial flow rate for loss coefficient estimation

$D_{h3} := 3\text{ft}$ Conduit height

$D_{w3} := 15\text{ft}$ Conduit width

$L_3 := 15\text{ft}$ Estimation of conduit length

Entrance loss

$K_{3e} := 0.5$ Miller Fig. 14.11

Bend loss

$k'_b := 1.2$ From Miller Fig. 9.9

$\text{Re}\left(Q_{3'}, D_{h3}, D_{w3}\right) = 7.829 \times 10^{5}$ Reynolds number at entrance

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{3'}, D_{h3}, D_{w3}, k_{sr}\right)}{f\left(Q_{3'}, D_{h3}, D_{w3}, k_{ss}\right)}$ $C_f = 1.721$ From Miller Eq. 9.3

$K_{3b90.1} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{3b90.1} = 2.066$ From Miller Eq. 9.4

$K_{3b90.2} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{3b90.2} = 2.066$ From Miller Eq. 9.4

Orifice loss

$K_{3o} := \left(1 - \dfrac{16\text{ft}^2}{D_{h3} \cdot D_{w3}}\right)^2 \cdot \left(\dfrac{D_{h3} \cdot D_{w3}}{16\text{ft}^2}\right)^2$ $K_{3o} = 3.285$ Miller Eq. 14.2

Combining tee loss

$K_{t35} := 1.5$ Miller Fig 13.10

Friction loss Contracted section assumed negligible for friction due to short section

$$f_3(Q) := f\left(Q, D_{h3}, D_{w3}, k_s\right) \cdot \frac{L_3}{D'\left(D_{h3}, D_{w3}\right)}$$

Pipe 3 summation of losses

$$H_3(Q) := \left[f_3(Q) + \alpha_k\left(K_{3e} + K_{3b90.1} + K_{3b90.2} + K_{3o} + K_{t35}\right)\right] \cdot \frac{V\left(Q, D_{h3}, D_{w3}\right)^2}{2 \cdot g}$$

$H_3\left(Q_{3'}\right) = 0.726\,\text{ft}$ $V\left(Q_{3'}, D_{h3}, D_{w3}\right) = 2.222\,\dfrac{\text{ft}}{\text{s}}$

Pipe 4 Floor diffuser 4 (node 4 to node 5)

Entrance loss

$Q_{4'} := 90\text{cfs}$ Trial flow rate for loss coefficient estimation

$D_{h4.1} := 3\text{ft}$ Conduit height, segment 1

$D_{w4.1} := 15\text{ft}$ Conduit width, segment 1

$D_{h4.2} := 8\text{ft}$ Conduit height, segment 2

$D_{w4.2} := 4\text{ft}$ Conduit width, segment 2

$L_{4.1} := 15\text{ft}$ Estimation of conduit length

$L_{4.2} := 15\text{ft}$ Estimation of conduit length

Entrance loss

$K_{4e} := 0.5$ Miller Fig. 14.11

Bend loss, 1 & 2

$k'_b := 1.2$ From Miller Fig. 9.9

$\text{Re}\left(Q_{4'}, D_{h4.1}, D_{w4.1}\right) = 7.046 \times 10^{5}$ Reynolds number at entrance

$C_{Re} := 1.1$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{4'}, D_{h4.1}, D_{w4.1}, k_{sr}\right)}{f\left(Q_{4'}, D_{h4.1}, D_{w4.1}, k_{ss}\right)}$ $C_f = 1.697$ From Miller Eq. 9.3

$K_{4b90.1} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{4b90.1} = 2.24$ From Miller Eq. 9.4

$K_{4b90.2} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{4b90.2} = 2.24$ From Miller Eq. 9.4

Orifice loss

$K_{4o} := \left(1 - \dfrac{16\text{ft}^2}{D_{h4.1} \cdot D_{w4.1}}\right)^2 \cdot \left(\dfrac{D_{h4.1} \cdot D_{w4.1}}{16\text{ft}^2}\right)^2$ $K_{4o} = 3.285$ Miller Eq. 14.2

Bend loss, 3

$k'_b := 1.2$ From Miller Fig. 9.9

$\text{Re}\left(Q_{4'}, D_{h4.2}, D_{w4.2}\right) = 1.057 \times 10^{6}$ Reynolds number at entrance

$C_{Re} := 1$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{4'}, D_{h4.2}, D_{w4.2}, k_{sr}\right)}{f\left(Q_{4'}, D_{h4.2}, D_{w4.2}, k_{ss}\right)}$ $C_f = 1.767$ From Miller Eq. 9.3

$K_{4b90.3} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{4b90.3} = 2.12$ From Miller Eq. 9.4

Combining Tee loss

$K_{t45} := 0.65$ Miller Fig 13.11

Friction loss segment 1

$$f_{4.1}(Q) := f\left(Q, D_{h4.1}, D_{w4.1}, k_s\right) \cdot \frac{L_{4.1}}{D'\left(D_{h4.1}, D_{w4.1}\right)}$$

Friction loss segment 2

$$f_{4.2}(Q) := f\left(Q, D_{h4.2}, D_{w4.2}, k_s\right) \cdot \frac{L_{4.2}}{D'\left(D_{h4.2}, D_{w4.2}\right)}$$

Pipe 4 summation of losses segment 1

$$H_{4.1}(Q) := \left[f_{4.1}(Q) + \alpha_k \cdot \left(K_{4e} + K_{4b90.1} + K_{4b90.2} + K_{4o}\right)\right] \cdot \frac{V\left(Q, D_{h4.1}, D_{w4.1}\right)^2}{2 \cdot g}$$

$$V\left(Q_{4'}, D_{h4.1}, D_{w4.1}\right) = 2\,\frac{\text{ft}}{\text{s}}$$

Pipe 4 summation of losses segment 2

$$H_{4.2}(Q) := \left[f_{4.2}(Q) + \alpha_k\left(K_{4b90.3} + K_{t35}\right)\right] \cdot \frac{V\left(Q, D_{h4.2}, D_{w4.2}\right)^2}{2 \cdot g}$$

$$V\left(Q_{4'}, D_{h4.2}, D_{w4.2}\right) = 2.813\,\frac{\text{ft}}{\text{s}}$$

Pipe 4 summation of losses

$H_4(Q) := H_{4.1}(Q) + H_{4.2}(Q)$ $H_4\left(Q_{4'}\right) = 0.966\ \text{ft}$

Pipe 5 Node 5 to node 6 $Q_5 = Q_3 + Q_4$

Friction loss

$Q_{5'} := Q_{3'} + Q_{4'}$ Trial flow rate for loss coefficient estimation

$D_{h5} := 8\text{ft}$ Conduit height

$D_{w5.1} := 5\text{ft}$ Initial conduit width

$D_{w5.2} := 6\text{ft}$ Final conduit width

$L_5 := 32\text{ft}$ Estimation of conduit length

Combining loss Q3 and Q4 - Used for K_{t45} and K_{t35} above

$$\frac{Q_{3'}}{Q_{5'}} = 0.526$$

Adjust losses above

$$\frac{16\text{ft}^2}{D_{h5} \cdot D_{w5.1}} = 0.4$$

Gate area over entering conduit area

Friction loss

$$f_5(Q) := f\left(Q, D_{h5}, D_{w5.1}, k_s\right) \cdot \frac{L_5}{D'\left(D_{h5}, D_{w5.1}\right)}$$

Combining tee loss

$K_{t56} := 1.0$ Miller Fig. 13.11

Expansion loss

$$\frac{D_{h5} \cdot D_{w5.1}}{64\text{ft}^2} = 0.625$$

64 ft^2 is the main conduit area expansion

$K_{ex} := 0.2$ Miller Fig. 14.15

Pipe 5 summation of losses

$$H_5(Q) := \left[f_5(Q) + \alpha_k \cdot \left(K_{t56} + K_{ex}\right)\right] \cdot \frac{V\left(Q, D_{h5}, D_{w5.1}\right)^2}{2 \cdot g}$$

$H_5\left(Q_{5'}\right) = 0.445\,\text{ft}$ $V\left(Q_{5'}, D_{h5}, D_{w5.1}\right) = 4.75\,\frac{\text{ft}}{\text{s}}$

Pipe 6 Node 6 to node 7 $Q_6 = Q_5 + Q_2$

$Q_{6'} := Q_{5'} + Q_{2'}$ Trial flow rate for loss coefficient estimation

$D_{h6} := 8\text{ft}$ Conduit height

$D_{w6} := 8\text{ft}$ Initial conduit width

$L_6 := 16\text{ft}$ Estimation of conduit length

Combining loss Q5 and Q2 - Used for K_{t56} and K_{t26} above

$$\frac{Q_{2'}}{Q_{5'}} = 0.684$$

Adjust losses above

$$\frac{16\text{ft}^2}{D_{h6} \cdot D_{w6}} = 0.25$$

Friction loss

$$f_6(Q) := f\left(Q, D_{h6}, D_{w6}, k_s\right) \cdot \frac{L_6}{D'\left(D_{h6}, D_{w6}\right)}$$

Combining tee loss

$Q_{7'} := Q_{6'} + Q_{1'}$ $Q_{7'} = 620 \cdot \text{cfs}$

$\frac{Q_{1'}}{Q_{7'}} = 0.484$ $\frac{D_{h1} \cdot D_{w1.2}}{64\text{ft}^2} = 0.528$

$K_{t67} := 0.45$ Miller Fig 13.11

$$H_6(Q) := \left(f_6(Q) + \alpha_k \cdot K_{t67}\right) \cdot \frac{V\left(Q, D_{h6}, D_{w6}\right)^2}{2 \cdot g}$$

$H_6\left(Q_{6'}\right) = 0.185\,\text{ft}$ $V\left(Q_{6'}, D_{h6}, D_{w6}\right) = 5\,\frac{\text{ft}}{\text{s}}$

Pipe 7 Node 7 to AWS chamber

$D_{h7} := 8\text{ft}$ Conduit height

$D_{w7} := 8\text{ft}$ Initial conduit width

$L_7 := 85\text{ft}$ Estimation of conduit length

Friction

$\text{Re}(Q_{7'}, D_{h7}, D_{w7}) = 5.461 \times 10^6$

$f(Q_{7'}, D_{h7}, D_{w7}, k_s) = 0.012$

$$h_{f7}(Q) := f(Q, D_{h7}, D_{w7}, k_s) \cdot \frac{L_7}{D'(D_{h7}, D_{w7})} \cdot \frac{V(Q, D_{h7}, D_{w7})^2}{2 \cdot g}$$

$h_{f7}(Q_{7'}) = 0.193 \cdot \text{ft}$

15 deg bend loss, 1 & 2

$\frac{r}{d} = 6$

$k'_b := 0.05$ From Miller Fig. 9.7

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 0.9$ 6 diameters away, Miller Fig. 9.4

$C_f := \frac{f(Q_{7'}, D_{h7}, D_{w7}, k_{sr})}{f(Q_{7'}, D_{h7}, D_{w7}, k_{ss})}$ $C_f = 1.967$ From Miller Eq. 9.3

$K_{b15.1} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b15.1} = 2.125$ From Miller Eq. 9.4

$K_{b15.2} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b15.2} = 2.125$ From Miller Eq. 9.4

90 deg bend loss
90 deg bend smooth

$\frac{r}{d} = 1$

$k'_b := 0.27$ From Miller Fig. 9.7

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 2.7$ Immediate outlet, Miller Fig. 9.4

$C_f := \dfrac{f(Q_{7'}, D_{h7}, D_{w7}, k_{sr})}{f(Q_{7'}, D_{h7}, D_{w7}, k_{ss})}$ $C_f = 1.967$ From Miller Eq. 9.3

$K_{b90} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b90} = 1.434$ From Miller Eq. 9.4

Exit Loss

$K_e := 1.0$

Pipe 7 Summation of losses

$$H_7(Q) := h_{f7}(Q) + \left[\alpha_k \cdot \left(K_{b15.1} + K_{b15.2} + K_{b90} + K_e\right)\right] \cdot \frac{V(Q, D_{h7}, D_{w7})^2}{2 \cdot g}$$

$H_7(Q_{7'}) = 9.939\,\text{ft}$ $V(Q_{7'}, D_{h7}, D_{w7}) = 9.688\,\dfrac{\text{ft}}{\text{s}}$

Solve for available flow

Trial Flow Rates

$Q_{1'} = 300 \cdot cfs$

$Q_{2'} = 130 \cdot cfs$

$Q_{3'} = 100 \cdot cfs$

$Q_{4'} = 90 \cdot cfs$

$Q_5(Q_3, Q_4) := Q_3 + Q_4$

$Q_6(Q_3, Q_4, Q_2) := Q_2 + Q_3 + Q_4$

$Q_7(Q_1, Q_2, Q_3, Q_4) := Q_1 + Q_2 + Q_3 + Q_4$

Total available driving head

$H_a := \text{Available}$

$H_a = 12.45\,ft$

Q 5, 6 & 7 are function of flow through pipes 1, 2, 3, & 4

Set Solve Block for Equalization of Head losses

Given

$H_1(Q_{1'}) = H_2(Q_{2'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'})$

$H_1(Q_{1'}) = H_3(Q_{3'}) + H_5(Q_{3'} + Q_{4'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'})$

$H_1(Q_{1'}) = H_4(Q_{4'}) + H_5(Q_{3'} + Q_{4'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'})$

$H_2(Q_{2'}) = H_3(Q_{3'}) + H_5(Q_{3'} + Q_{4'})$

$H_2(Q_{2'}) = H_4(Q_{4'}) + H_5(Q_{3'} + Q_{4'})$

$H_3(Q_{3'}) = H_4(Q_{4'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_1(Q_{1'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'}) + H_2(Q_{2'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'}) + H_5(Q_{3'} + Q_{4'}) + H_3(Q_{3'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'}) + H_5(Q_{3'} + Q_{4'}) + H_4(Q_{4'})$

$$\begin{pmatrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \end{pmatrix} := \text{Find}(Q_{1'}, Q_{2'}, Q_{3'}, Q_{4'})$$

$Q_1 = 317.378 \cdot cfs$ $Q_2 = 128.282 \cdot cfs$ $Q_3 = 113.131 \cdot cfs$ $Q_4 = 88.244 \cdot cfs$

$Q_5(Q_3, Q_4) = 201.375 \cdot cfs$ $Q_6(Q_3, Q_4, Q_2) = 329.657 \cdot cfs$ $\boxed{Q_7(Q_1, Q_2, Q_3, Q_4) = 647 \cdot cfs}$

Back check of the solve block

$H_1(Q_1) = 1.625\ \text{ft}$ $H_2(Q_2) + H_6(Q_3 + Q_4 + Q_2) = 1.625\ \text{ft}$

$H_3(Q_3) + H_5(Q_3 + Q_4) + H_6(Q_3 + Q_4 + Q_2) = 1.625\ \text{ft}$

$H_4(Q_4) + H_5(Q_3 + Q_4) + H_6(Q_3 + Q_4 + Q_2) = 1.625\ \text{ft}$

$H_2(Q_2) = 1.429\ \text{ft}$ $H_3(Q_3) + H_5(Q_3 + Q_4) = 1.429\ \text{ft}$

$H_4(Q_4) + H_5(Q_3 + Q_4) = 1.429\ \text{ft}$

$H_3(Q_3) = 0.929\ \text{ft}$ $H_4(Q_4) = 0.929\ \text{ft}$

$H_a = 12.45\ \text{ft}$ $H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_1(Q_1) = 12.45\ \text{ft}$

$H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_6(Q_3 + Q_4 + Q_2) + H_2(Q_2) = 12.45\ \text{ft}$

$H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_6(Q_3 + Q_4 + Q_2) + H_5(Q_3 + Q_4) + H_3(Q_3) = 12.45\ \text{ft}$

$H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_6(Q_3 + Q_4 + Q_2) + H_5(Q_3 + Q_4) + H_4(Q_4) = 12.45\ \text{ft}$

From Additional Culvert

$$Q := \begin{pmatrix} 540 \\ 550 \\ 560 \\ 570 \\ 580 \\ 590 \\ 600 \\ 610 \\ 620 \\ 630 \\ 640 \\ 650 \\ 660 \\ 670 \\ 680 \\ 690 \\ 700 \\ 710 \\ 720 \\ 730 \\ 740 \\ 750 \\ 760 \\ 770 \\ 780 \\ 790 \\ 800 \end{pmatrix} \qquad HW_c := \begin{pmatrix} 98.2 \\ 98.3 \\ 98.5 \\ 98.6 \\ 98.76 \\ 98.9 \\ 99 \\ 99.2 \\ 99.36 \\ 99.52 \\ 99.68 \\ 99.839 \\ 100 \\ 100.16 \\ 100.33 \\ 100.5 \\ 100.68 \\ 100.86 \\ 101.03 \\ 101.2 \\ 101.4 \\ 101.6 \\ 101.77 \\ 101.96 \\ 102.16 \\ 102.35 \\ 102.55 \end{pmatrix}$$

Headwater and flow rate taken from New Conduit from FLAC to AWSC.xcmd. Culverts operate under inlet control over entire range of flow rates. A splining function is used to generate a flow rate as a function of headwater. This will be used inconjuction with the 8 x 8 culvert computations above to identify water surface elevations given varying tailrace conditions.

For any variation in New Conduit from FLAC to AWSC design, Q and HW_c needs to be redeveloped.

$ORIGIN := 1$

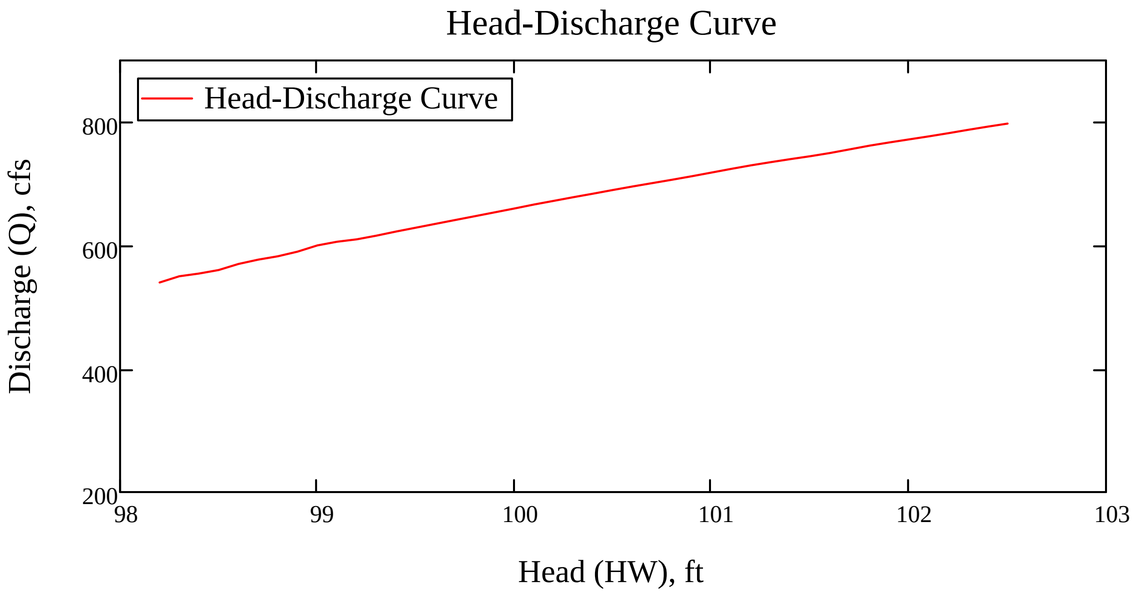
$Data^{\langle 1 \rangle} := HW_c \quad Data^{\langle 2 \rangle} := Q$

$data := csort(Data, 1)$

$HW_c := data^{\langle 1 \rangle} \qquad Q := data^{\langle 2 \rangle}$

$S := cspline(HW_c, Q) \qquad Q_{6fit}(x) := interp\left(S, HW_c, Q, \frac{x}{ft}\right) cfs \qquad x := 98.2ft, 98.3ft .. 102.5ft$

Project Title: Dalles EFL Emergency AWS FLAC to AWS Chamber via 8X8 Box Culver	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery



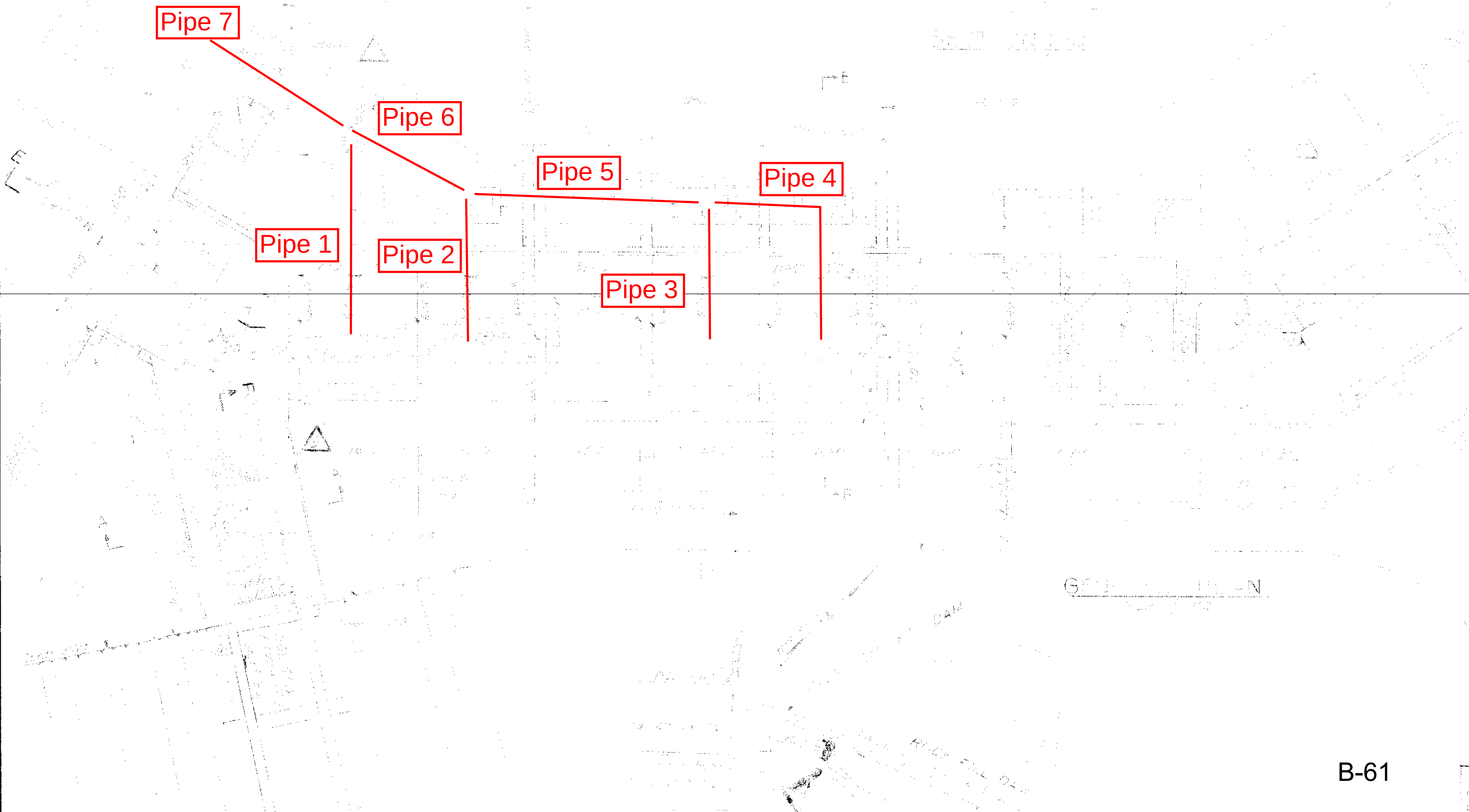
$Q_{8x8} := Q_7(Q_1, Q_2, Q_3, Q_4)$

$Q_{6fit}(HW) = 752.88 \cdot cfs$

$Q_{total} := Q_{8x8} + Q_{6fit}(HW)$

$\boxed{Q_{total} = 1400 \cdot cfs}$

Network overlay for FLAC to AWS Chamber via 8 by 8 AWS Box Culvert



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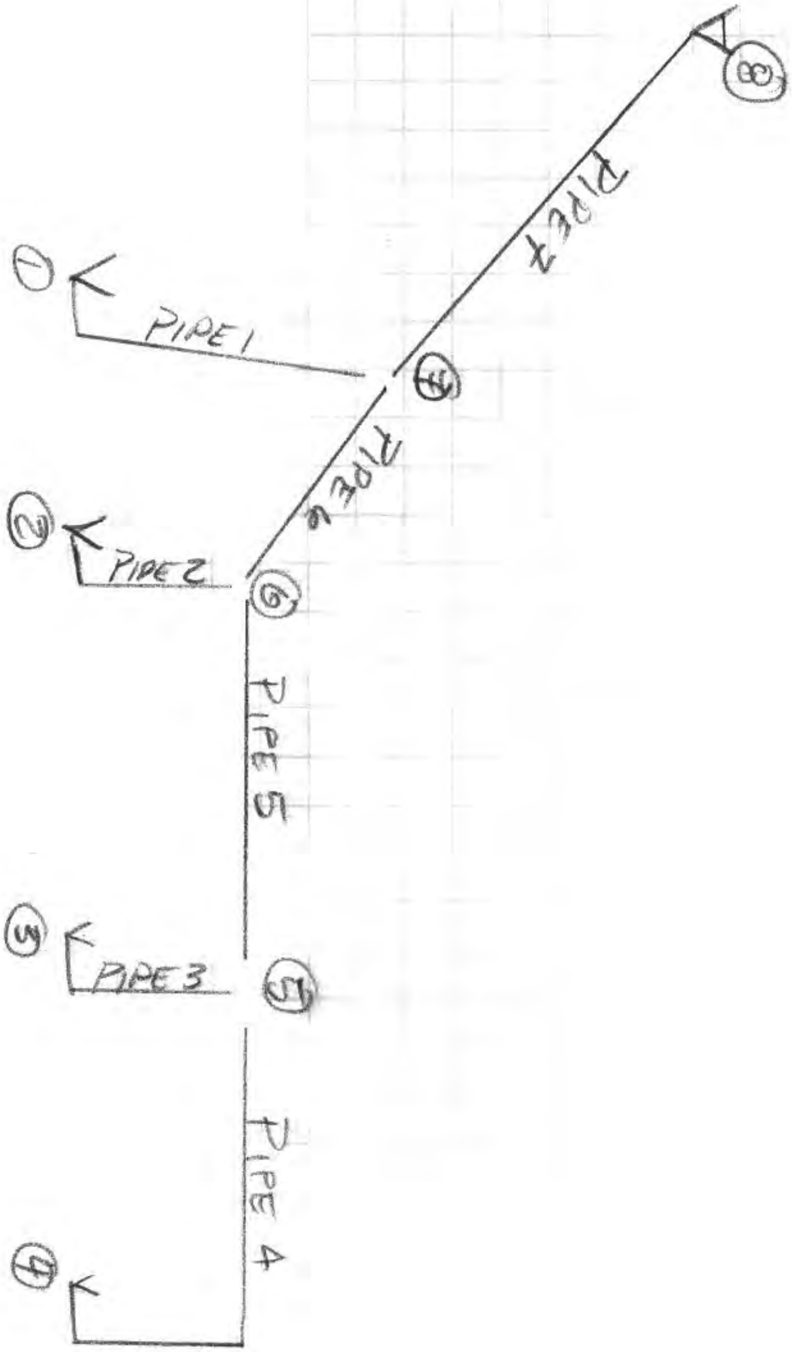
PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' AWS BOX CULVERT & HEADER/INTAKE

BY **DATE** **CHECKED** **PART** **PAGE** **OF**



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PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' AWS BOX CULVERT & INTAKE

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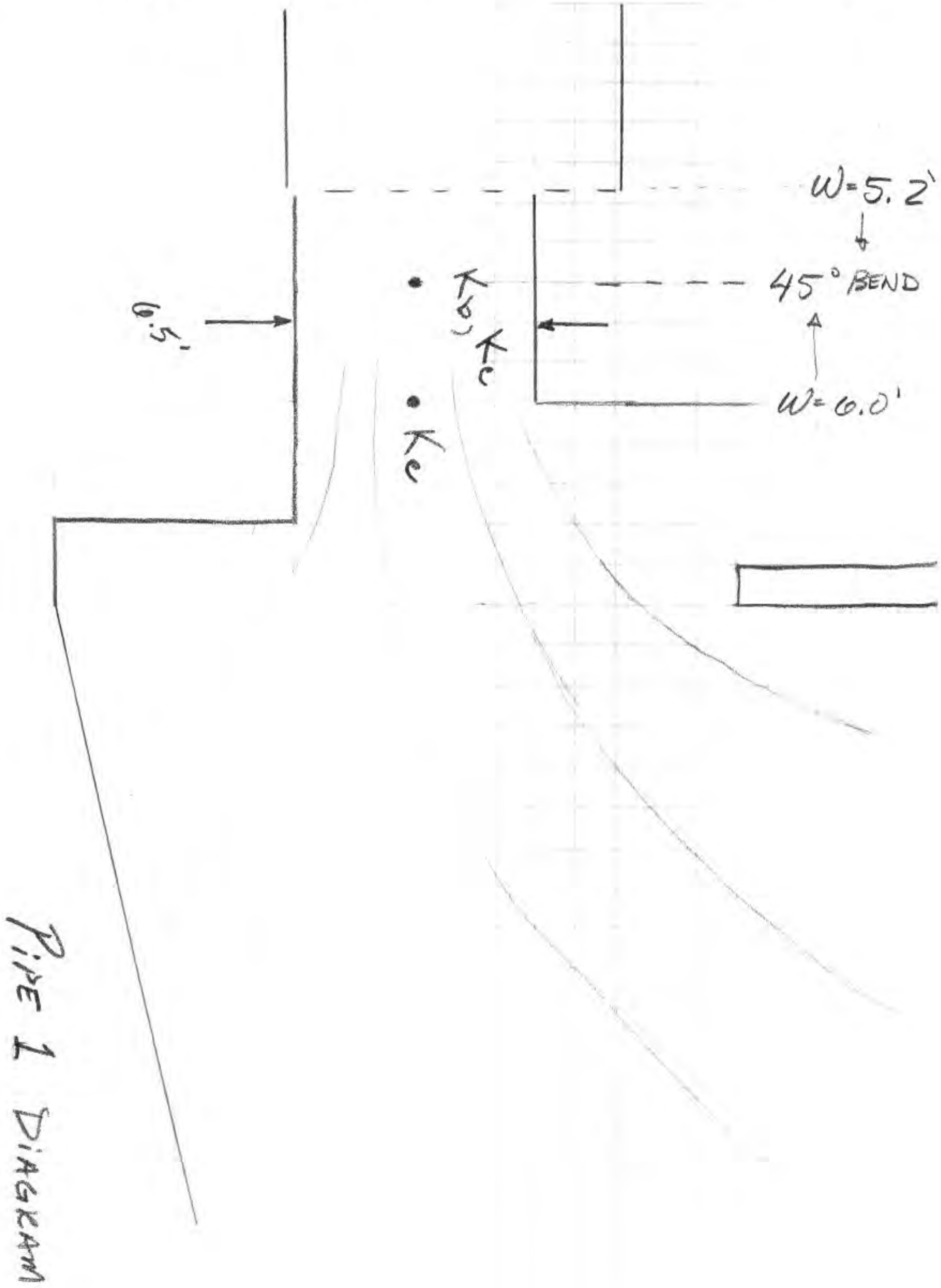

PIPE 1 DIAGRAM

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PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' BOX CULVERT & INTAKE

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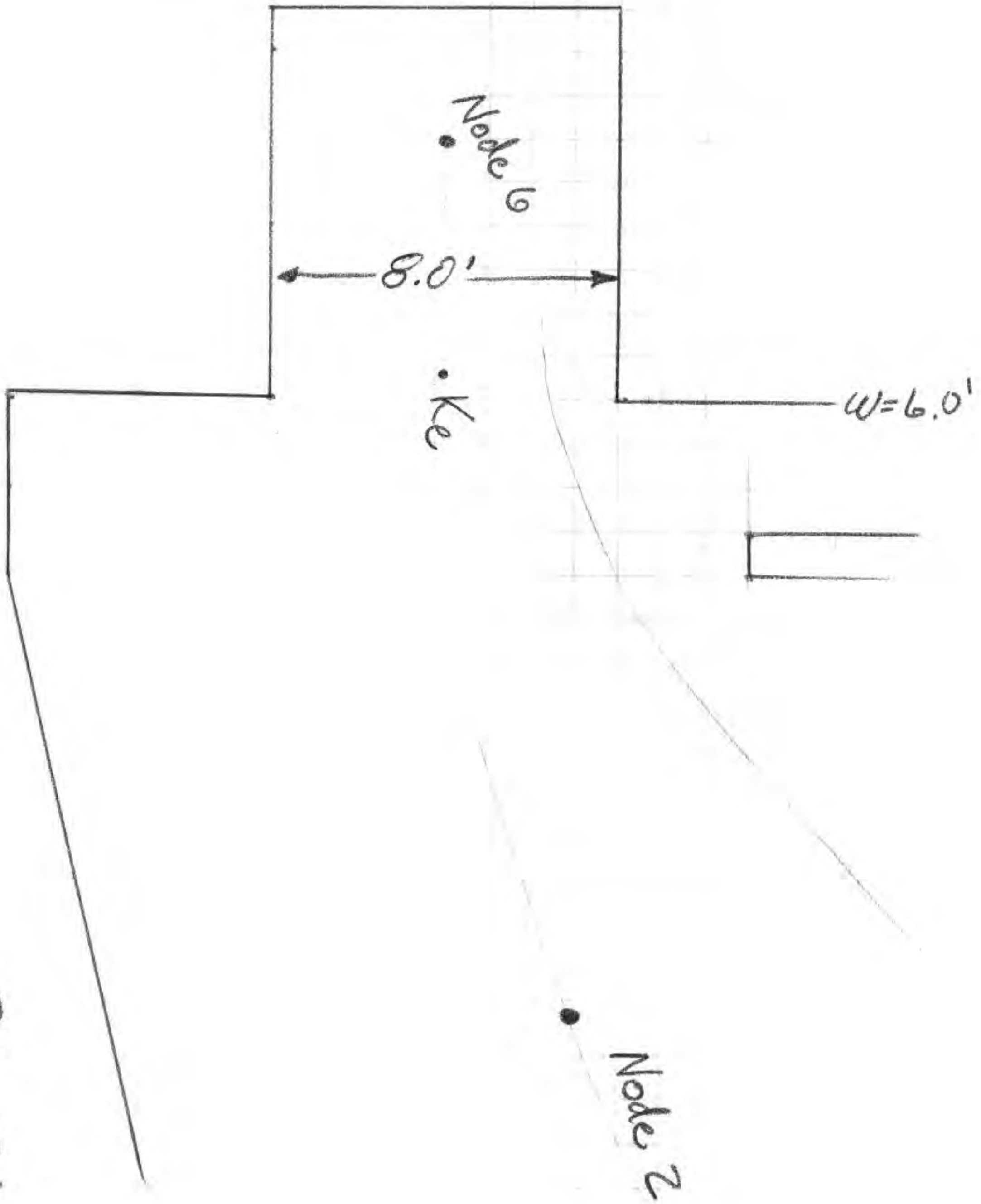

PIPE 2 DIAGRAM

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SUBJECT 8'X8' AWS BOX CULVERT & INTAKE

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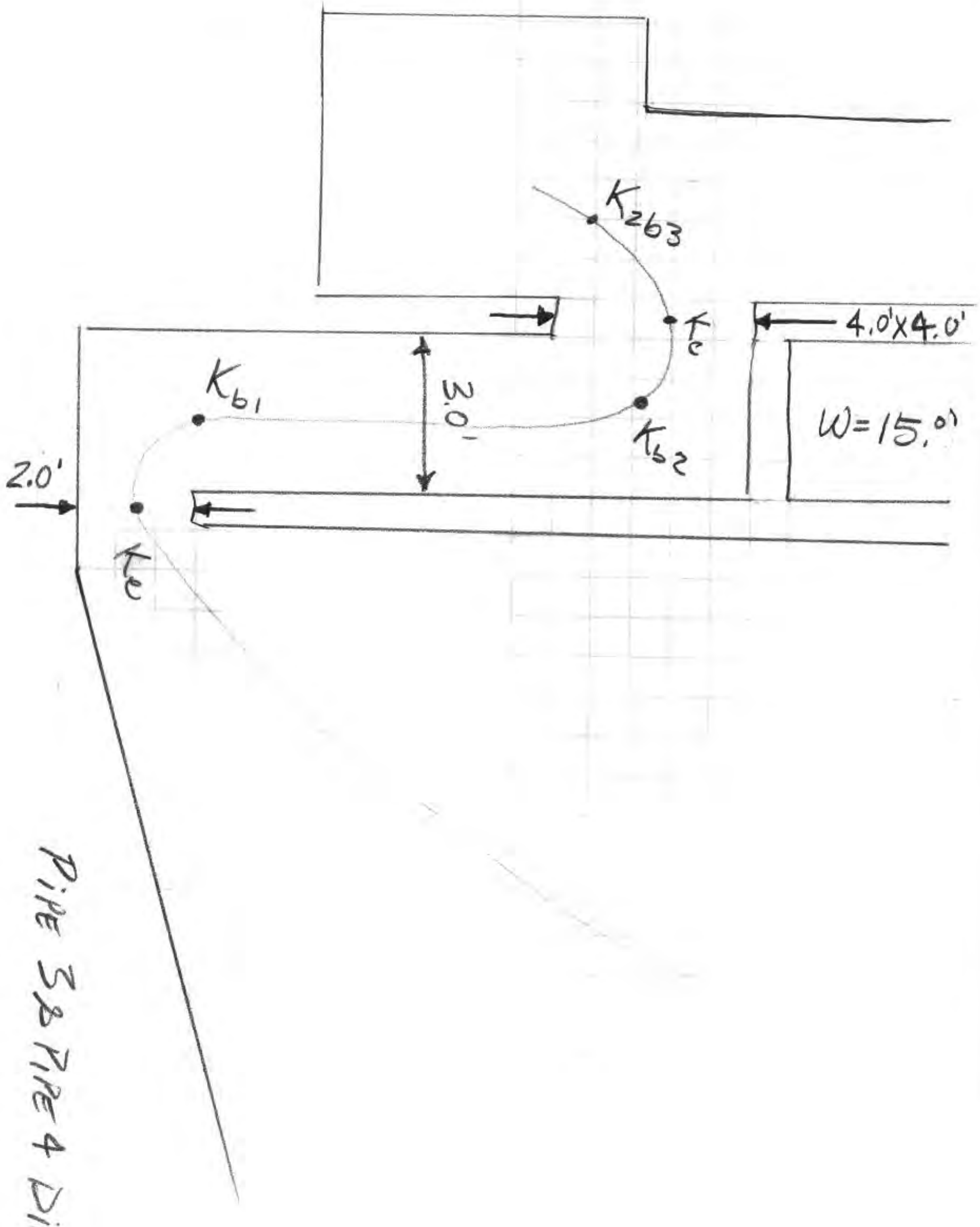

PIPE 3 & PIPE 4 DIAGRAM

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PROJECT DALLES EFL EMERGENCY AWS
SUBJECT 8' X8' AWS BOX CULVERT & INTAKE
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WATER SURFACE ELEVATION

NODE	WSE
1	102.5'
2	102.5'
3	102.5'
4	102.5'
8	90.5' MAX

MAX HEAD AV = 12.0'

HEAD LOSS EQUALITIES

$H_{L1} = H_{L2} + H_{L6}$ ①

$= H_{L3} + H_{L5} + H_{L6}$ ②

$= H_{L4} + H_{L5} + H_{L6}$ ③

$H_{L2} = H_{L3} + H_{L5}$ ④

$= H_{L4} + H_{L5}$ ⑤

$H_{L3} = H_{L4}$ ⑥

MAX HEAD AV. = 12.0 ft

$= H_{L7} + H_{L1}$ ⑦

$= H_{L7} + H_{L6} + H_{L2}$ ⑧

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PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' AWS BOX CULVERT & INTAKE

BY DATE CHECKED PART PAGE OF

$$= H_{L7} + H_{L6} + H_{L5} + H_{L3} \quad ⑨$$

$$= H_{L7} + H_{L6} + H_{L5} + H_{L4} \quad ⑩$$

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Project Title: Dalles EFL Emergency AWS Cavitation Check for Full Flow Thru 8X8 Culvert	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Custom Units Definition

$\mathrm{fps} := \mathrm{ft}\cdot\mathrm{s}^{-1}$ feet per second

$\mathrm{cfs} := \mathrm{ft}^{2}\cdot\mathrm{fps}$ cubic feet per second

Fluid Properties

$\rho := 1000\,\dfrac{\mathrm{kg}}{\mathrm{m}^3}$ $\gamma := 62.41\,\dfrac{\mathrm{lbf}}{\mathrm{ft}^3}$

Assumed temperature deg. F

$T_f := 50$ $T_c := \left(T_f - 32\right)\cdot\dfrac{5}{9}$ $T_c = 10$ Temp. deg. C

$\nu := \dfrac{1.792\cdot10^{-6}}{1.0 + \left(0.0337\cdot T_c + 0.000221\cdot T_c^{\,2}\right)}\cdot\dfrac{\mathrm{m}^2}{\mathrm{s}}$ $\nu = 1.319\times10^{-6}\cdot\dfrac{\mathrm{m}^2}{\mathrm{s}}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function Reynolds number Average velocity

$A(d) := d^2$ $\mathrm{Re}(Q,d) := \dfrac{Q\cdot d}{A(d)\cdot\nu}$ $V(Q,d) := \dfrac{Q}{A(d)}$

Jain's equation for friction factor

$$f\left(Q,d,k_s\right) := \frac{0.25}{\log\left(\dfrac{k_s}{3.7\cdot d} + \dfrac{5.74}{\mathrm{Re}(Q,d)^{0.9}}\right)^{2}}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Project Title: Dalles EFL Emergency AWS Cavitation Check for Full Flow Thru 8X8 Culvert	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

$Q := 1400 \frac{ft^3}{s}$ Target flowrate for 8-ft by 8-ft culvert

$D := 8ft$ Characteristic dimension/diameter of the culvert

$R := 7ft$ Radius of curvature at upwell

$\frac{R}{D} = 0.875$

$V := \frac{Q}{A(D)}$ $V = 21.875 \cdot fps$ Velocity of 1400 cfs through the culvert

$AWS_{ws} := 79.6ft$ Minimum water surface elevation in Auxiliary Water Supply chamber

$FAC_{ws} := 102.5ft$ Maximum water surface elevation in Fishlock Approach Channel

$Ele_{bend} := 50.0ft$ Elevation of centerline at 90 degree turn into AWS

$h_{max} := FAC_{ws} - Ele_{bend}$ $h_{max} = 52.5\,ft$ Maximum available head at bend $h_{pmax} := h_{max} \cdot \gamma$ $h_{pmax} = 22.754\,psi$

$h_{min} := AWS_{ws} - Ele_{bend}$ $h_{min} = 29.6\,ft$ Minimum available head at bend $h_{pmin} := h_{min} \cdot \gamma$ $h_{pmin} = 12.829\,psi$

$h_v := 0.18psi$ Vapor pressue of water at assumed temperature

Cavitation parameter with extreme minimum head

$$\sigma_{bmin} := \frac{h_{pmin} - h_v}{\gamma \cdot \frac{V^2}{2 \cdot g}} \qquad \sigma_{bmin} = 3.925$$

Cavitation parameter with extreme maximum head

$$\sigma_{bmax} := \frac{h_{pmax} - h_v}{\gamma \cdot \frac{V^2}{2 \cdot g}} \qquad \sigma_{bmax} = 7.004$$

Project Title: Dalles EFL Emergency AWS	6/1/2013	By: Logan Negherbon
Cavitation Check for Full Flow Thru 8X8 Culvert		Checked By: Ryan Laughery

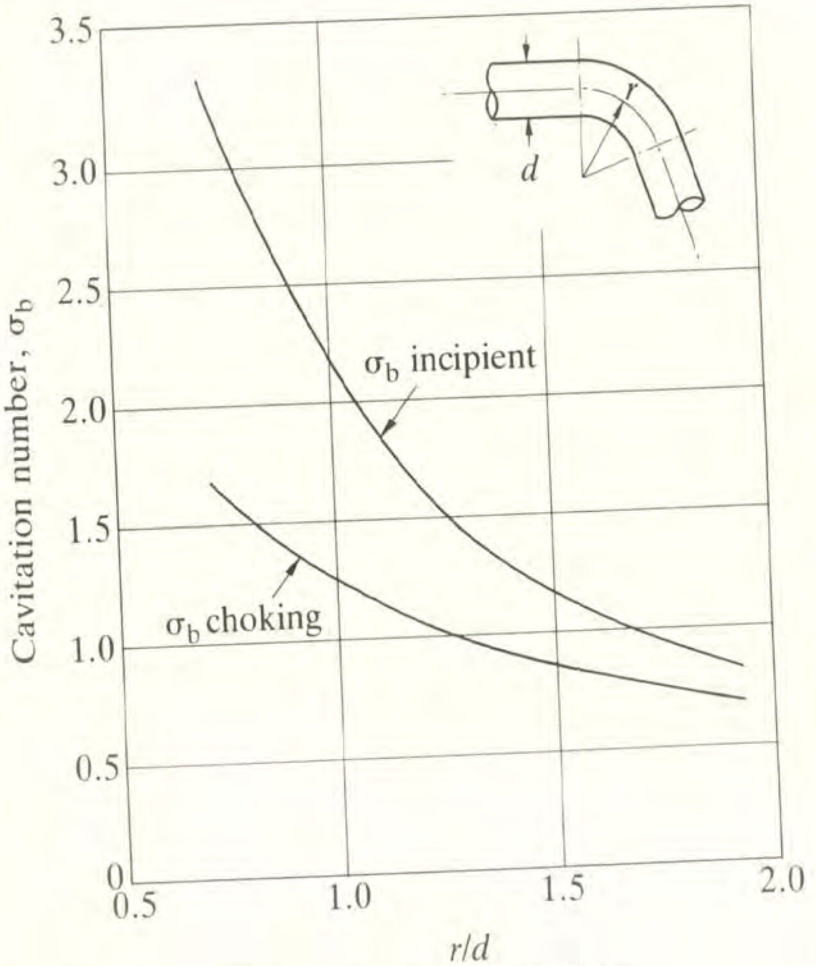

Fig. 6.10. Cavitation parameter for bends

The ratio of the radius of curvature (r) to the characteristic diameter (d) is approximately 0.85 at the upwell into the AWSC. No friction losses are accounted for in the maximum cavitation parameter potential. The minimum potential cavitation parameter lies abover the incipient cavitation curve. This assumption applies all friction losses and is conservative; however, the true cavitation parameter is likely to be closer to the minumum cavitation parameter provided as the majority of the head losses through the conduit will occur upstream of this bend.

Figure from D.S. Miller's *Internal Flow Systems*

From Corps Guidance

$C := \frac{D}{2}$ $C = 4\ \text{ft}$ Half of the characteristic diameter

$R = 7\ \text{ft}$ Radius of curvater at centerline

$$C_p := \left[\frac{2}{\left(\frac{R}{C} - 1\right)\cdot \ln\left(\frac{\frac{R}{C}+1}{\frac{R}{C}-1}\right)}\right]^2 - 1 \qquad C_p = 3.212$$

Minimum pressure guidance for bends (EM 1110-2-1602 Plate C-20)

$\sigma_{bmin} = 3.925$ $\sigma_{bmax} = 7.004$

As the actual conditions are likely to be closer to the minumum cavitation parameter given the majority of the head losses through the conduit will occur upstream of this bend. The guidance is for circular conduits and do not account for localized pressure differentials at the corners. This preliminary calculation is for the rounded vertical turn into the upwell and does not take into account the abrupt ~30 degree horizontal bend (DDF-1-4-5/V13) which is likely to induce greater cavitation potential.

Project Title: Dalles EFL Emergency AWS Trashrack Calculations	6/1/2013	By: Logan Negherbon Check by: Ryan Laughery

Units definition

$cfs := ft^3 \cdot s^{-1}$ cubic feet per second

$fps := ft \cdot s^{-1}$ feet per second

Hydraulic Properties

$\rho := 1000 \frac{kg}{m^3}$ Fluid density

Assumed temperature deg. F

$T_f := 50$ $T_c := (T_f - 32) \cdot \frac{5}{9}$ $T_c = 10$ Temp. deg. C

$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + (0.0337 \cdot T_c + 0.000221 \cdot T_c^2)} \cdot \frac{m^2}{s}$ $\nu = 1.319 \times 10^{-6} \cdot \frac{m^2}{s}$ Kinematic viscosity of water from temp. relationship

Design Parameters

$Q := 1400\text{cfs}$ Design flow rate

$V := 3\text{fps}$ Velocity limitation for trashrack approach velocity - EM 1110-2-1602

$V_{thr} := 5\text{fps}$ Recommended thru velocity maximum for cleaning accessible trashracks from Bureau of Reclamation - Design of Small Dams

$A_{req} := \frac{Q}{V}$ $A_{req} = 466.667\ \text{ft}^2$ Area required to meet trashrack approach velocity limitation

$h_t = K_t \cdot \frac{v_n^2}{2 \cdot g}$ $K_t = 1.45 - 0.45 \cdot \frac{a_n}{a_g} - \left(\frac{a_n}{a_g}\right)^2$ Equation 11, Design of Small Dams - BoR

$a_n := 0.75\text{in}$ Design bar spacing per EDR

$a_g := \frac{5}{16}\text{in} + a_n$ Assummed unit thickness for bar and space

$\frac{a_n}{a_g} = 0.706$ Resultant porosity

$K_t := 1.45 - 0.45 \cdot \frac{a_n}{a_g} - \left(\frac{a_n}{a_g}\right)^2$ $K_t = 0.634$ Resultant loss coefficient

$v_n := V_{thr}$ Thru velocity for head loss differential

$h_t := K_t \cdot \frac{v_n^2}{2 \cdot g}$ $h_t = 0.246\ \text{ft}$ Resultant head differential

$A_{req} := \frac{Q}{v_n} \cdot \frac{a_g}{a_n}$ $A_{req} = 396.667\ \text{ft}^2$ Based on thru velocity limitations $\boxed{A_{req} := 466\text{ft}^2}$ Area required based on approach velocity limitations - Controlling

Required trashrack height based on 15 foot width

$H := \frac{A_{req}}{15\text{ft}}$ $H = 31.067\ \text{ft}$

Required trashrack height based on 20 foot width

$H := \frac{A_{req}}{20\text{ft}}$ $H = 23.3\ \text{ft}$

Trashracks for the intake are sized with a 3 fps approach velocity and a flow of 1400 cfs. Velocity criterion was determined during the EDR phase of design and based off of EM 1110-2-1602. A through bar velocity of 5 fps is recommended by the Bureau of Reclamation *Design of Small Dams* publication. An assumed porosity of 70 percent for the trashrack results in a required gross area of 350 square feet; however, in order to meet the approach velocity a required gross area of trashrack is required to be 466 square feet.

$A_{req} = 466\,ft^2$

$R_h := 160ft$ $R_l := 155ft$ $CL := 116.5ft$ $p_t := h_t \cdot \rho \cdot g$ $p_t = 0.107\,psi$

$P_1 := (R_h - CL) \cdot g \cdot \rho$ $P_1 = 18.858\,psi$ $p_1 := R_h - CL$

$P_2 := P_1 - h_t \cdot g \cdot \rho$ $P_2 = 18.752\,psi$ $p_2 := p_1 - h_t$

$\beta := 100\%$ Debris blockage factor (% open area)

$V_1 := V = 3\,\frac{ft}{s}$ $V_2 := \dfrac{Q}{\beta A_{req} \cdot \dfrac{a_n}{a_g}} = 4.256\,\frac{ft}{s}$

$F_r := (P_1 - P_2) \cdot A_{req} \cdot \left(1 - \beta \dfrac{a_n}{a_g}\right) + \rho \cdot Q \cdot (V_2 - V_1)$ Equation for force imparted by momentum and pressure differential

$F_r = 5.52 \cdot kip$ Resultant force from momentum and pressure differential

$\dfrac{F_r}{A_{req}} = 11.845 \cdot psf$ Resultant pressure resistance from momentum and pressure differential

$V_{thr} := \dfrac{Q}{A_{req}} \cdot \dfrac{a_g}{a_n}$

$V_{thr} = 4.256\,\frac{ft}{s}$

$\beta := 50\%$ Debris blockage factor (% open area)

$V_1 := V = 3\,\frac{ft}{s}$ $V_2 := \dfrac{Q}{\beta A_{req} \cdot \dfrac{a_n}{a_g}} = 8.512\,\frac{ft}{s}$

$F_r := (P_1 - P_2) \cdot A_{req} \cdot \left(1 - \beta \dfrac{a_n}{a_g}\right) + \rho \cdot Q \cdot (V_2 - V_1)$ Equation for force imparted by momentum and pressure differential

$F_r = 19.611 \cdot kip$ Resultant force from momentum and pressure differential

$\dfrac{F_r}{A_{req}} = 42.083 \cdot psf$ Resultant pressure resistance from momentum and pressure differential

$V_{thr} := \dfrac{Q}{A_{req}} \cdot \dfrac{a_g}{a_n}$

$V_{thr} = 4.256\,\frac{ft}{s}$

Project Title: Dalles EFL Emergency AWS - 10-ft Conduit Calcs	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Sensitivities

- 10% increase minor losses
- 10% decrease minor losses
- 10x increase in relative roughness
- 0.1x decrease in relative roughness

$\alpha_k := 0.9$ minor loss sensitivity coeff.

$\alpha_f := 0.1$ friction loss sensitivity coeff.

10 degree temperature increase/decrease makes negligible changes and is not varried in sensitivity matrix

Factors of 1.0 indicate assumed losses

Custom Units Definition

$\mathrm{fps} := \mathrm{ft}\cdot\mathrm{s}^{-1}$ feet per second

$\mathrm{cfs} := \mathrm{ft}^2\cdot\mathrm{fps}$ cubic feet per second

Fluid Properties

$\rho := 1000\frac{\mathrm{kg}}{\mathrm{m}^3}$ $\quad\gamma := 62.41\frac{\mathrm{lbf}}{\mathrm{ft}^3}$

Assumed temperature deg. F

$T_f := 50$ $\quad T_c := \left(T_f - 32\right)\cdot\frac{5}{9}$ $\quad T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792\cdot10^{-6}}{1.0 + \left(0.0337\cdot T_c + 0.000221\cdot T_c^{\,2}\right)}\cdot\frac{\mathrm{m}^2}{\mathrm{s}}$$

$\nu = 1.319\times10^{-6}\cdot\frac{\mathrm{m}^2}{\mathrm{s}}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function

$A(d) := \frac{\pi d^2}{4}$

Reynolds number

$Re(Q,d) := \frac{Q\cdot d}{A(d)\cdot\nu}$

Average velocity

$V(Q,d) := \frac{Q}{A(d)}$

Jain's equation for friction factor

$$f\left(Q,d,k_s\right) := \frac{0.25}{\log\left(\frac{k_s}{3.7\cdot d} + \frac{5.74}{Re(Q,d)^{0.9}}\right)^2}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Design Parameters

$Q := 1400\text{cfs}$ Design flow rate

	Diameter	Length	Roughness - Assumed epoxy coating	
Pipe 1	$D_1 := 10\text{ft}$	$L_1 := 300\text{ft}$	$k := \alpha_f \cdot 0.025\text{mm}$	Through new pipe (Miller Table 8.1 - Plastic)
Pipe 2 - contraction	$D_2 := 7\text{ft}$	$L_2 := 7\text{ft}$	$k_{sr} := 0.025\text{mm}$	Rough (Miller Table 8.1- no lining)
Final diameter before valve	$D_3 := 7\text{ft}$		$k_{ss} := 0\text{mm}$	Fully smooth

Pipe 1 Losses

Trash rack - See Trashrack Calculations.xcmd

Entrance loss

17 deg bend loss 1 & 2

90 deg bend loss 1 & 2

Minor bend - 40 deg

Contraction

Friction Losses

$\text{Re}(Q, D_1) = 1.256 \times 10^7$ Reynolds number

Trash rack loss from other worksheet $K_t := 0.634$ ---> $h_t := 0.246\text{ft}$

Entrance loss $K_e := 0.16$ Assumed loss based on guidance from EM 1110-2-1602 (Section 3-7)

17 deg bend loss

$\frac{r}{d} = 1$

$k'_b := 0.03$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1.0$ No outlet, Miller Fig. 9.4

$C_f := \frac{f(Q, D_1, k_{sr})}{f(Q, D_1, k_{ss})}$ $C_f = 1.111$ From Miller Eq. 9.3

$K_{b17} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b17} = 0.033$ From Miller Eq. 9.4

90 deg bend loss

90 deg bend made up of three 30 deg mitered bends

$\frac{r}{d} = 2$

$k'_b := 0.275$ From Miller Fig. 9.10

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1.0$ No outlet, Miller Fig. 9.4

$C_f := \frac{f(Q, D_1, k_{sr})}{f(Q, D_1, k_{ss})}$ $C_f = 1.111$ From Miller Eq. 9.3

$K_{b90} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b90} = 0.306$ From Miller Eq. 9.4

40 deg bend loss

triple-mitered bend

$\frac{r}{d} = 2$

$k'_b := 0.22$ From Miller Fig. 9.9, conservatively based on single miter

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 0.5$ No outlet, Miller Fig. 9.4

$C_f := \frac{f(Q, D_2, k_{sr})}{f(Q, D_2, k_{ss})}$ $C_f = 1.179$ From Miller Eq. 9.3

$K_{b40} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b40} = 0.13$ Miller Eq. 9.4

Contraction loss

Length of contraction over contracted radius

$A(D_1) = 78.54\,ft^2$

$A(D_2) = 38.485\,ft^2$

$\frac{A(D_1)}{A(D_2)} = 2.041$

$\frac{N}{R} = 2$ $N = 7ft$ $K_{c1} := 0.05$ From Miller Fig. 14.14(1)

Friction loss

$f_1 := f(Q, D_1, k)$ $f_1 = 7.998 \times 10^{-3}$

$f_2 := f(Q, D_2, k)$ $f_2 = 7.707 \times 10^{-3}$

Total losses

Velocity head $H_{v1} := \frac{V(Q,D_1)^2}{2g}$ $H_{v1} = 4.938\ \text{ft}$ $V(Q,D_1) = 17.825 \cdot \text{fps}$

$H_{v2} := \frac{V(Q,D_2)^2}{2g}$ $H_{v2} = 20.566\ \text{ft}$ $V(Q,D_2) = 36.378 \cdot \text{fps}$

$H_{v3} := \frac{V(Q,D_3)^2}{2g}$ $H_{v3} = 20.566\ \text{ft}$ $V(Q,D_3) = 36.378 \cdot \text{fps}$

$$H_{p1} := \left[f_1 \cdot \frac{L_1}{D_1} + \alpha_k \cdot \left(K_e + 2 \cdot K_{b17} + 2 \cdot K_{b90} + K_{b40} \right) \right] H_{v1}$$

$L_1 = 300\ \text{ft}$

$H_{p1} = 5.485\ \text{ft}$ Head loss through 10-ft diameter conduit

$$H_{p2} := \left[f_2 \cdot \frac{L_2}{D_2} + \alpha_k \cdot \left(K_{c1} \right) \right] H_{v2}$$

$L_2 = 7\ \text{ft}$

$H_{p2} = 1.084\ \text{ft}$ Head loss through 7-ft diameter conduit

Maximum Operating Forebay

$R_h := 160\text{ft}$ $FL_h := R_h - h_t - H_{p1} - H_{p2}$ $FL_h = 153.185\ \text{ft}$

Miniumum Operating Forebay

$R_l := 155\text{ft}$ $FL_l := R_l - h_t - H_{p1} - H_{p2}$ $FL_l = 148.185\ \text{ft}$

$WSE_{fl} := 102.5\text{ft}$ Water surface in FLAC

$H_{vH} := FL_h - WSE_{fl}$ $\boxed{H_{vH} = 50.685\ \text{ft}}$ Energy to dissipate at high pool

$H_{vL} := FL_l - WSE_{fl}$ $\boxed{H_{vL} = 45.685\ \text{ft}}$ Energy to dissipate at low pool

Thrust force calculations for new bypass - First 90 degree bend

$V(Q, D_1) = 17.825 \frac{ft}{s}$ Thrust velocity

$V_1 := V(Q, D_1)$ $V_{1x} := V_1 \cdot \cos(0)$ $V_{1x} = 17.825 \frac{ft}{s}$

$V_{1y} := V_1 \cdot \sin(0)$ $V_{1y} = 0 \frac{ft}{s}$

$V_2 := V(Q, D_1)$ $V_{2x} := V_2 \cdot \cos\left(\frac{\pi}{2}\right)$ $V_{2x} = 1.091 \times 10^{-15} \frac{ft}{s}$

$V_{2y} := V_2 \cdot \sin\left(\frac{\pi}{2}\right)$ $V_{2y} = 17.825 \frac{ft}{s}$

$z := 104.5ft$ Approximated center of pipe elevation

$R_1 := 160ft$

$$H_z := R_1 - h_t - \left(f_1 \cdot \frac{50ft}{D_1} + K_e + 2 \cdot K_{b17}\right) H_{v1}$$

$H_z = 158.437\ ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z) \cdot \rho \cdot g$ $p = 23.383\ psi$

$A_1 := A(D_1) = 78.54\ ft^2$

$A_2 := A(D_1) = 78.54\ ft^2$

Cavitation check

$h_u := p$ $h_v := 0.18psi$

$$\sigma_b := \frac{h_u - h_v}{\gamma \cdot \frac{V(Q, D_1)^2}{2 \cdot g}}$$

$\sigma_b = 10.842$

Cavitation parameter is greater than incipient cavitation for r/d = 1

$\sigma_{bi} := 2.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1

$p_1 := p$ $\quad p_{1x} := p_1 \cdot \cos(0)$ $\quad p_{1x} = 23.383\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0)$ $\quad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{b90} \cdot H_{v1} \cdot \rho \cdot g$ $\quad p_{2x} := p_2 \cdot \cos\left(-\frac{\pi}{2}\right)$ $\quad p_{2x} = 1.392 \times 10^{-15}\,\text{psi}$

$p_{2y} := p_2 \cdot \sin\left(\frac{-\pi}{2}\right)$ $\quad p_{2y} = -22.729\,\text{psi}$

$$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$$0 = F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

Thrust Restraint Force

$$F_{rx} := p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$F_{rx} = 312.88 \cdot \text{kip}$ Force in the plane of the bend acting towards the dam

$$F_{ry} := -\left[p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)\right]$$

$F_{ry} = 305.482 \cdot \text{kip}$ Force in the plane of the bend acting in line with the downstream flow $\quad \sqrt{F_{rx}^{\,2} + F_{ry}^{\,2}} = 437.28 \cdot \text{kip}$

Thrust force calculations for new bypass - Second 90 degree bend

$V(Q, D_1) = 17.825 \frac{ft}{s}$ Thrust velocity

$V_1 := V(Q, D_1)$ $V_{1x} := V_1 \cdot \cos(0)$ $V_{1x} = 17.825 \frac{ft}{s}$

$V_{1y} := V_1 \cdot \sin(0)$ $V_{1y} = 0 \frac{ft}{s}$

$V_2 := V(Q, D_1)$ $V_{2x} := V_2 \cdot \cos\left(\frac{-\pi}{2}\right)$ $V_{2x} = 1.091 \times 10^{-15} \frac{ft}{s}$

$V_{2y} := V_2 \cdot \sin\left(\frac{-\pi}{2}\right)$ $V_{2y} = -17.825 \frac{ft}{s}$

$z := 104.5ft$ Approximated center of pipe elevation

$R_1 := 160ft$

$$H_z := R_1 - h_t - \left(f_1 \cdot \frac{220ft}{D_1} + K_e + 2 \cdot K_{b17} + K_{b90}\right) H_{v1}$$

$H_z = 156.257\ ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z) \cdot \rho \cdot g$ $p = 22.438\ psi$

$A_1 := A(D_1) = 78.54\ ft^2$

$A_2 := A(D_1) = 78.54\ ft^2$

$h_u := p$ $h_v := 0.18psi$

$$\sigma_b := \frac{h_u - h_v}{\gamma \cdot \frac{V(Q, D_1)^2}{2 \cdot g}}$$ $\sigma_b = 10.401$

Cavitation parameter is greater than incipient choking for r/d = 1

$\sigma_{bi} := 2.2$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 1

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$p_1 := p$ $\quad p_{1x} := p_1 \cdot \cos(0)$ $\quad p_{1x} = 22.438\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0)$ $\quad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{b90} \cdot H_{v1} \cdot \rho \cdot g$ $\quad p_{2x} := p_2 \cdot \cos\left(\frac{\pi}{2}\right)$ $\quad p_{2x} = 1.334 \times 10^{-15}\,\text{psi}$

$p_{2y} := p_2 \cdot \sin\left(\frac{\pi}{2}\right)$ $\quad p_{2y} = 21.784\,\text{psi}$

$$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$$0 = -F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

Thrust Restraint Force

$$F_{rx} := p_{1x} \cdot A_1 + p_{2x} \cdot A_2 + \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$F_{rx} = 205.347 \cdot \text{kip}$ Force in the plane of the bend acting away from the dam

$$F_{ry} := p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

$F_{ry} = 294.792 \cdot \text{kip}$ Force in the plane of the bend acting against with the upstream flow $\quad \sqrt{F_{rx}^{\,2} + F_{ry}^{\,2}} = 359.263 \cdot \text{kip}$

Thrust force calculations for 40 degree bend

$V_1 := V(Q, D_2)$ $V_{1x} := V_1 \cdot \cos(0)$ $V_{1x} = 36.378 \frac{ft}{s}$

$V_{1y} := V_1 \cdot \sin(0)$ $V_{1y} = 0 \frac{ft}{s}$

$V_2 := V(Q, D_2)$ $V_{2x} := V_2 \cdot \cos(-40deg)$ $V_{2x} = 27.867 \frac{ft}{s}$

$V_{2y} := V_2 \cdot \sin(-40deg)$ $V_{2y} = -23.384 \frac{ft}{s}$

$z := 104.5ft$ Approximated center of pipe elevation

$R_1 := 160ft$

$$H_z := R_1 - h_t - \left(f_1 \cdot \frac{230ft}{D_1} + K_e + 2K_{b90} + K_{c1}\right) H_{v1} - f_2 \cdot 20 \frac{ft}{D_2} \cdot H_{v2}$$

$H_z = 154.338\ ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z) \cdot \rho \cdot g$ $p = 21.606\ psi$

$A_1 := A(D_2) = 38.485\ ft^2$

$A_2 := A(D_2) = 38.485\ ft^2$

$h_u := p$ $h_v := 0.18psi$

$$\sigma_b := \frac{h_u - h_v}{\gamma \cdot \frac{V(Q, D_2)^2}{2 \cdot g}}$$

$\sigma_b = 2.404$

$\sigma_{bi} := 0.75$ Incipient cavitation parameter from Miller Fig 6.10 with r/d = 2

Cavitation parameter is greater than incipient cavitation for r/d = 2 with a 8 ft conduit -> ok

$p_1 := p \qquad p_{1x} := p_1 \cdot \cos(0) \qquad p_{1x} = 21.606\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0) \qquad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{b40} \cdot H_{v2} \cdot \rho \cdot g \qquad p_{2x} := p_2 \cdot \cos(140\text{deg}) \qquad p_{2x} = -15.665\,\text{psi}$

$p_{2y} := p_2 \cdot \sin(140\text{deg}) \qquad p_{2y} = 13.145\,\text{psi}$

$$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot (V_{2x} - V_{1x})$$

$$0 = -F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot (V_{2y} - V_{1y})$$

Thrust Restraint Force

$$F_{rx} := \left[p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot (V_{2x} - V_{1x})\right]$$

$F_{rx} = 56.043 \cdot \text{kip}$ Force in the plane of the bend acting towards the dam

$$F_{ry} := p_{1y} \cdot A_1 + p_{2y} \cdot A_2 - \rho \cdot Q \cdot (V_{2y} - V_{1y})$$

$F_{ry} = 136.365 \cdot \text{kip}$ Force in the plane of the bend acting perpendicular with the upstream flow $\sqrt{F_{rx}^{\,2} + F_{ry}^{\,2}} = 147.432 \cdot \text{kip}$

Thrust force calculations for contraction

$V(Q, D_1) = 17.825 \frac{ft}{s}$ Thrust velocity

$V_1 := V(Q, D_1)$ $V_{1x} := V_1 \cdot \cos(0)$ $V_{1x} = 17.825 \frac{ft}{s}$

$V_{1y} := V_1 \cdot \sin(0)$ $V_{1y} = 0 \frac{ft}{s}$

$V_2 := V(Q, D_2)$ $V_{2x} := V_2 \cdot \cos(0)$ $V_{2x} = 36.378 \frac{ft}{s}$

$V_{2y} := V_2 \cdot \sin(0)$ $V_{2y} = 0 \frac{ft}{s}$

$z := 88.25 ft$ Approximated center of pipe elevation

$R_1 := 160 ft$

$$H_z := R_1 - h_t - \left(f_1 \cdot \frac{230 ft}{D_1} + K_e + 2K_{b90}\right) H_{v1}$$

$H_z = 155.038\ ft$ Resulting hydraulic grade with entrance and friction loss assumption

$p := (H_z - z) \cdot \rho \cdot g$ $p = 28.954\ psi$

$A_1 := A(D_1) = 78.54\ ft^2$

$A_2 := A(D_2) = 38.485\ ft^2$

$p_1 := p$ $\qquad p_{1x} := p_1 \cdot \cos(0)$ $\qquad p_{1x} = 28.954\,\text{psi}$

$p_{1y} := p_1 \cdot \sin(0)$ $\qquad p_{1y} = 0\,\text{psi}$

$p_2 := p - K_{c1} \cdot H_{v2} \cdot \rho \cdot g$ $\qquad p_{2x} := p_2 \cdot \cos(\pi)$ $\qquad p_{2x} = -28.509\,\text{psi}$

$p_{2y} := p_2 \cdot \sin(\pi)$ $\qquad p_{2y} = 3.491 \times 10^{-15}\,\text{psi}$

$$0 = -F_{rx} + p_{1x} \cdot A_1 + p_{2x} \cdot A_2 - \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$$0 = F_{ry} + p_{1y} \cdot A_1 + p_{2y} \cdot A - \blacksquare + \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

Thrust Restraint Force

$$F_{rx} := p_{1x} \cdot A_1 + p_{2x} \cdot A_2 + \rho \cdot Q \cdot \left(V_{2x} - V_{1x}\right)$$

$F_{rx} = 219.876 \cdot \text{kip}$ Force in the plane of the bend acting towards the dam

$$F_{ry} := p_{1y} \cdot A_1 + p_{2y} \cdot A_2 + \rho \cdot Q \cdot \left(V_{2y} - V_{1y}\right)$$

$F_{ry} = 1.935 \times 10^{-14} \cdot \text{kip}$ Force in the plane of the bend acting opposite the direction of flow $\qquad \sqrt{F_{rx}^{\,2} + F_{ry}^{\,2}} = 219.876 \cdot \text{kip}$

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Preliminary Hydraulic Transient Analysis for Valve Closure

Reference
- EM 1110-3-173 Pumping System Design
- Hydroelectric Handbook by Creager and Justin
- Fundamentals of Hydraulic Engineering by Prasuhn
- Handbook of Hydraulics by King and Brater

Custom Units Definition

$\mathrm{fps} := \mathrm{ft} \cdot \mathrm{s}^{-1}$ feet per second

$\mathrm{cfs} := \mathrm{ft}^2 \cdot \mathrm{fps}$ cubic feet per second

Fluid Properties

$\rho := 1000 \frac{\mathrm{kg}}{\mathrm{m}^3}$

$\gamma := 62.41 \frac{\mathrm{lbf}}{\mathrm{ft}^3}$

Assumed temperature deg. F

$T_f := 50$

$T_c := \left(T_f - 32\right) \cdot \frac{5}{9}$

$T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + \left(0.0337 \cdot T_c + 0.000221 \cdot T_c^{\,2}\right)} \cdot \frac{\mathrm{m}^2}{\mathrm{s}}$$

$\nu = 1.319 \times 10^{-6} \cdot \frac{\mathrm{m}^2}{\mathrm{s}}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function

$A(d) := \frac{\pi d^2}{4}$

Reynolds number

$Re(Q, d) := \frac{Q \cdot d}{A(d) \cdot \nu}$

Average velocity

$V(Q, d) := \frac{Q}{A(d)}$

Design Parameters

$Q := 1400\mathrm{cfs}$ Design flow rate

	Diameter	Length
Pipe 1	$D_1 := 10\mathrm{ft}$	$L_1 := 300\mathrm{ft}$
Pipe 2 - contraction	$D_2 := 7\mathrm{ft}$	$L_2 := 7\mathrm{ft}$

EM 1110-3-173 Pumping System Design (Water Hammer Guidance)

$a_{min} := 2700\text{fps}$ Minimum wave speed for steel pipe

$a_{max} := 3900\text{fps}$ Maximum wave speed for steel pipe

$T_c := \frac{2\cdot(L_1 + L_2)}{a_{min}}$ $T_c = 0.227\ \text{s}$ Maximum time of closure

$T_c := \frac{2\cdot(L_1 + L_2)}{a_{max}}$ $T_c = 0.157\ \text{s}$ Minimum time of closure

$h_w := \frac{a_{min}\cdot V(Q, D_1)}{g}$ $h_w = 1496\ \text{ft}$ Theoretical surge in head due to instantaneous closure (using min. wave speed for steel pipe)

$h_w := \frac{a_{max}\cdot V(Q, D_1)}{g}$ $h_w = 2161\ \text{ft}$ Maximum theoretical surge in head due to instantaneous closure (using max. wave speed for steel pipe)

$t = FS\,\frac{L\cdot V}{g\cdot H_{av}}$ Time of closure for specified head surge

$t := 20\text{s}$ Trial time of closure

$FS := 4$ Factor of safety (typical range of FS from 1 to 4)

$H(t) := FS\,\frac{L_1\cdot V(Q, D_1)}{g\cdot t}$ Reorganized to solve for head with respect to time

$H(t) = 33.242\ \text{ft}$ $H(t)\cdot\gamma = 14.407\ \text{psi}$ Head/pressure increase due to closure at specified time.

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Hydroelectric Handbook (Chapter 34)

$\mu = \frac{2 \cdot L}{a}$ Critical time - Eq 1

$h = \frac{a \cdot \Delta v}{g}$ Head increase - Eq 2

$a = \frac{4675}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e}\right)}} fps$ Pressure wave speed - Eq 3

For simple burried section of 10-ft diameter pipe

$d := 10ft$ Diameter

$e_{min} := 0.5in$ Potential minimum thickness of pipe $e_{max} := 1.5in$ Potential maximum thickness of pipe

$k := 294000 \frac{lbf}{in^2}$ Voluminal modulus of elasticity of water in compression

$E := 29400000 \frac{lbf}{in^2}$ Modulus of elasticity of the sidewall material (steel)

$a := \frac{4675fps}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e_{min}}\right)}}$ $a = 2535 \cdot fps$ $a := \frac{4675fps}{\sqrt{1 + \left(\frac{k \cdot d}{E \cdot e_{max}}\right)}}$ $a = 3485 \cdot fps$

For section of 10-ft diameter pipe encased in concrete/grout thru dam

$d := 10ft$ Diameter

$\frac{k \cdot d}{E \cdot e} = 0$ For a pipe in solid concrete, this fraction becomes infintesimal and the limiting value of 4675 is reached for *a*, this being the velocity of sound in water.

$a_c := 4675fps$ Max potential wave speed due to concrete encasement

Fundamentals of Hydraulic Engineering - Prasuhn

$\rho = 1.94 \cdot \frac{slug}{ft^3}$ $\rho = 62.428 \frac{lb}{ft^3}$ $\gamma = 62.41 \cdot \frac{lbf}{ft^3}$ $L := L_1 = 300\,ft$

$K := 294000 \frac{lbf}{in^2}$ Voluminal modulus of elasticity of water in compression

$E := 29400000 \frac{lbf}{in^2}$ Modulus of elasticity of the sidewall material (steel)

$D := d = 10\,ft$ Diameter

$t := 0.5in$ Thickness

$C_o := 1$ Eq 6-41c (Assuming pipe is anchored against axial movement throughout its length, but provided with expansion joints at regular intervals)

$$c := \frac{\sqrt{\frac{K}{\rho}}}{\sqrt{1 + \frac{K}{E} \cdot \frac{D}{t} \cdot C_o}}$$

Eq 6-45 Wave speed calculation $c = 2533.254 \cdot fps$

$$H = \frac{c \cdot V_o}{g} + \frac{f}{\sqrt{2}} \cdot \frac{L}{D} \cdot \frac{V_o^2}{2g} = \frac{V_o^2}{2g} \cdot \left(\frac{2 \cdot c}{V_o} + \frac{f \cdot L}{\sqrt{2 \cdot D}} \right)$$

Eq 6-47 Maximum increase in head at valve due to water hammer including friction

$$H_f = \frac{h_l}{\sqrt{2}}$$

Eq 6-46 Approximation of reduced friction loss seen at the valve at closure

$$\Delta p = \left(\rho \cdot c \cdot V_o \right) \cdot \frac{2 \cdot \frac{L}{c}}{t_c} = \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$$

Eq 6-48 Pressure rise do to time of closure

$V_o := V(Q, d)$ $V_o = 17.825 \frac{ft}{s}$ Velocity in 10-ft pipe $T_c := \frac{2 \cdot L}{c}$ $T_c = 0.237\,s$

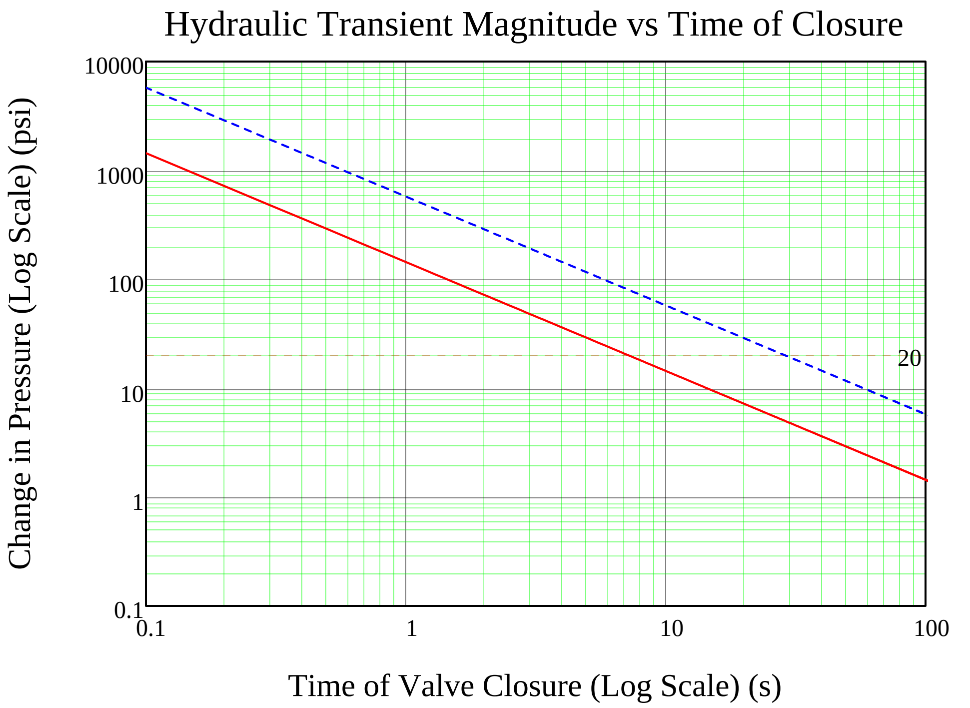
$\Delta p_{max} := \left(\rho \cdot c \cdot V_o \right)$ $\Delta p_{max} = 608.454\,psi$ Maximum pressure increase using wave speed derived from Prasuhn method

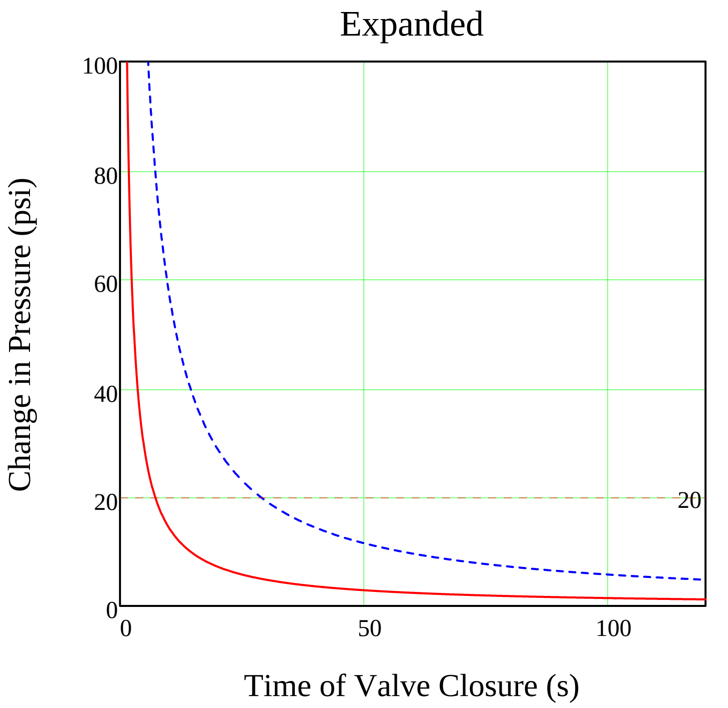
$\Delta p_{max} := \left(\rho \cdot a_c \cdot V_o \right)$ $\Delta p_{max} = 1122.873\,psi$ Maximum pressure increase using wave speed derived from Hydroelectric Handbook

$h_l := \frac{\gamma \cdot 15\text{ft}}{\sqrt{2}} = 4.597\ \text{psi}$ Losses through the 10-ft conduit due to friction that will be not be present when velocity equals 0 for rapid closure cases.

$\Delta p(t_c) := \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$ $t_c := 0.1\text{s}, 0.2\text{s} .. 120\text{s}$ $\Delta p(20\text{s}) = 7.206 \cdot \text{psi}$ Pressure increase due to 20s valve closure time

$FS\Delta p(t_c) := FS \frac{2 \cdot L \cdot V_o \cdot \rho}{t_c}$ Applied factor of safety noted above from EM 1110-3-173 $FS = 4$ $FS\Delta p(20\text{s}) = 28.822\ \text{psi}$ Pressure increase due to 20s valve closure time with FS





Further analysis will be completed upon defining valve actuation limitations and valve manufacture recommendations.

It is noted that the conduit will be partially encased in concrete causing the waves speed to be accelerated to the speed of sound traveling through water. However, the wave speed is not accounted for in time of closure calculations and does not affect out operating limitations. EM 1110-3-175 will be used as primary design guidance; however, approximations with other methods will be used to assess the applied factor of safety.

Project Title: Dalles EFL Emergency AWS - Energy Dissipation	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Custom Units Definition

$\mathrm{fps} := \mathrm{ft}\cdot \mathrm{s}^{-1}$ feet per second

$\mathrm{cfs} := \mathrm{ft}^2\cdot \mathrm{fps}$ cubic feet per second

Fluid Properties

$\rho := 1000\,\frac{\mathrm{kg}}{\mathrm{m}^3}$ Assumed density

Assumed temperature deg. F

$T_f := 50$ $T_c := (T_f - 32)\cdot\frac{5}{9}$ $T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792\cdot 10^{-6}}{1.0 + \left(0.0337\cdot T_c + 0.000221\cdot T_c^{\,2}\right)}\cdot\frac{\mathrm{m}^2}{\mathrm{s}}$$

$\nu = 1.319 \times 10^{-6}\cdot\frac{\mathrm{m}^2}{\mathrm{s}}$ Kinematic viscosity of water from temp. relationship

Area function Reynolds number Average velocity

$A(d) := \frac{\pi d^2}{4}$ $Re(Q,d) := \frac{Q\cdot d}{A(d)\cdot\nu}$ $V(Q,d) := \frac{Q}{A(d)}$

Jain's equation for friction factor

$$f(Q,d,k_s) := \frac{0.25}{\log\left(\frac{k_s}{3.7\cdot d} + \frac{5.72}{Re(Q,d)^{0.9}}\right)^2}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Design Parameters

$Q := 1400\text{cfs}$ Design flow rate

$d := 7\text{ft}$ Trial Diameter

$R_h := 160\text{ft}$ Maximum forebay operating range

$R_l := 155\text{ft}$ Minimum forebay operating range

$TW := 102.5\text{ft}$ Design tailwater for stilling basin

$H_h := R_h - TW$ $H_h = 57.5\text{ ft}$ Maximum driving head

$H_l := R_l - TW$ $H_l = 52.5\text{ ft}$ Minimum driving head

$H := 45.6\text{ft}$ Minium head at valve with friction losses from 2 - 10 ft Supply.xmcd

Basin design sizing and valve selection

$C := 0.7$ Typical hollow-jet valve discharge coefficient

$A := \frac{Q}{C\cdot\sqrt{2g\cdot(H)}}$ $A = 36.922\text{ ft}^2$ Required area

$d := \sqrt{\frac{4A}{\pi}}$ $d = 6.856\text{ ft}$ $d_o := d$ Recommended diameter

$d := 7\text{ft}$ Selected diameter

$\text{Check\_d} := \begin{cases} \text{"ok"} & \text{if } d_o \le d \\ \text{"fix d"} & \text{otherwise} \end{cases}$ $\text{Check\_d} = \text{"ok"}$ Diameter selection check

$A := \pi\cdot\frac{d^2}{4}$ Cross sectional valve area

$C := \frac{Q}{A\cdot\sqrt{2g\cdot(H)}}$ $C = 0.672$ Coefficient of discharge needed

Note: 7-foot Howell Bunger valve provides more efficient C value of 0.87 at max opening, it should be capable of achieving design discharge

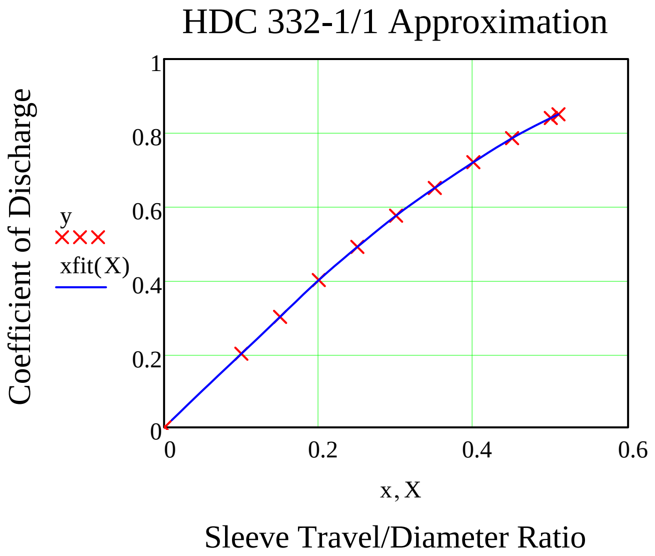
$Q_{max} := 0.85\cdot\left[A\cdot\sqrt{2g\cdot(H)}\right]$ $Q_{max} = 1772\cdot cfs$ Maximum available flow given low pool

HDC 332-1/1 Discharge Coefficients for sleeve travel/diameter ratios on a six-vanes howell-bunger valve

$$data := \begin{pmatrix} 0.001 & 0.001 \\ 0.1 & 0.2 \\ 0.15 & 0.3 \\ 0.2 & 0.4 \\ 0.25 & 0.49 \\ 0.3 & 0.575 \\ 0.35 & 0.65 \\ 0.4 & 0.72 \\ 0.45 & 0.785 \\ 0.5 & 0.84 \\ 0.51 & 0.85 \end{pmatrix}$$

$Data := csort(data, 0)$ $x := Data^{\langle 0 \rangle}$ $y := Data^{\langle 1 \rangle}$

$splinefit := cspline(x, y)$ $X := 0.01, 0.02 .. 0.51$ $xfit(X) := interp(splinefit, x, y, X)$



$0.4\cdot d = 2.8\,ft$

$xfit(0.34) = 0.636$

$V_c := \frac{Q}{A}$ $V_c = 36.378\,\frac{ft}{s}$

From the USACE HDC 332-1, a four- and six-vane Howell-Bunger (HB) valve produces discharge valve coefficients at 100% open of 0.82 and 0.87, respectively.

Using the provided charts, the operating opening for a six-vane HB valve under the stated assumptions is 70% open or 0.34 times the valve diameter in sleeve travel.

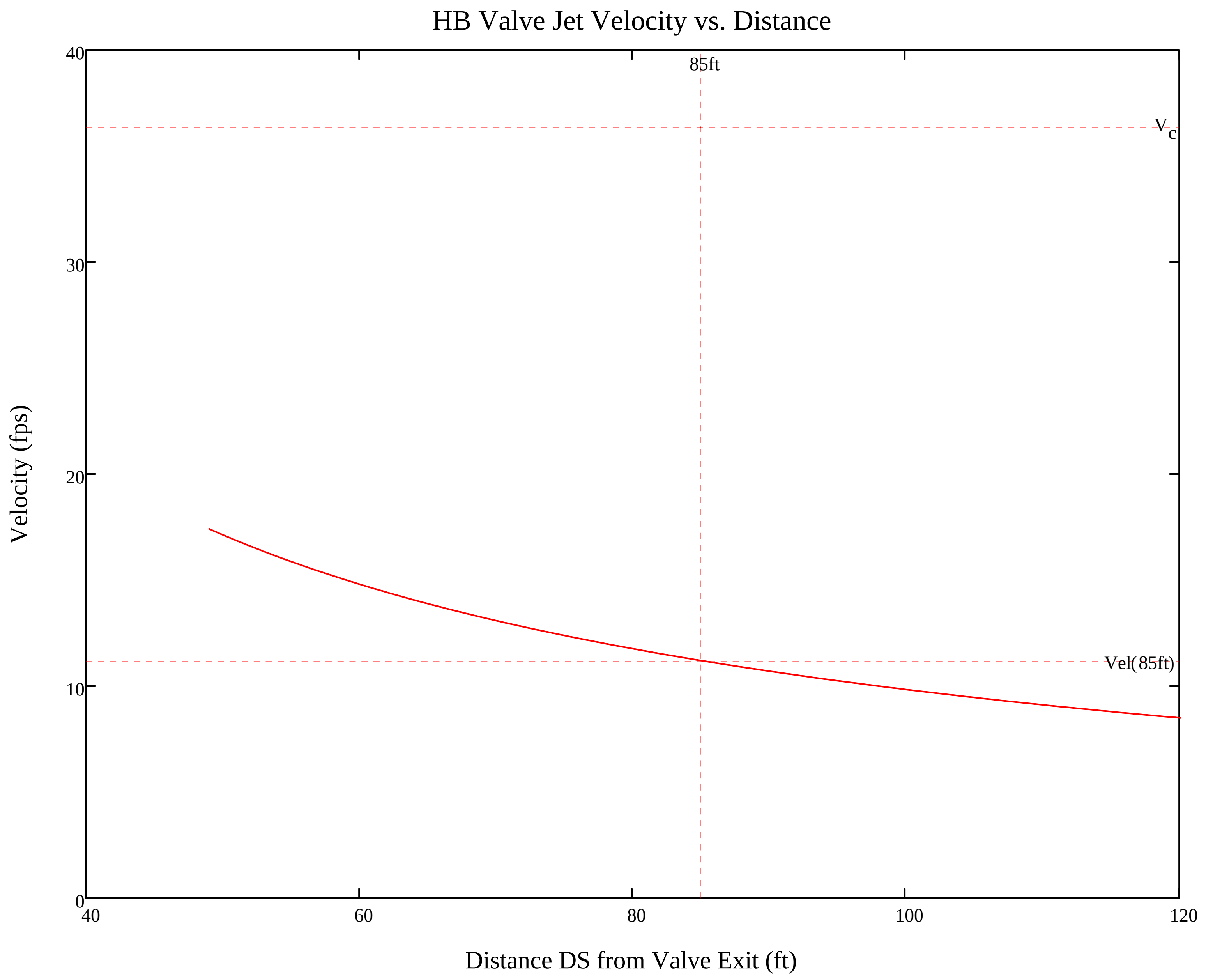
The design elevation for the valve is set to be submerged during emergency auxiliary water supply to the east fishladder entrance at half the channel depth.

$El_{valve} := 88.25ft$

$Submergence := TW - El_{valve}$ $Submergence = 14.25\,ft$

$Vel(dist) := V_c \cdot 2.27 \cdot \left(\frac{dist}{d}\right)^{-0.80}$ $Vel(85ft) = 11.205\,\frac{ft}{s}$ Longitudinal velocity profile based on USBR publication PAP-560

$dist := 7 \cdot d, 7.1d \,..\, 25d$


HB Valve Jet Velocity vs. Distance
Velocity (fps)
Distance DS from Valve Exit (ft)
0
10
20
30
40
40
60
80
100
120
85ft
V_c
Vel(85ft)

Stilling basin assessment

Assuming that the valve acts like a 7-ft by 7-ft sluice gate opening,
BoR Design of Small Dams was used to estimate required sequent depth
for the stilling basin.

$Q = 1400 \cdot \text{cfs}$

$w := 7\text{ft}$

$q := \dfrac{Q}{w}$ $\qquad q = 200 \cdot \dfrac{\text{cfs}}{\text{ft}}$

$H_t := 160\text{ft} - 102.5\text{ft}$

$H_t = 57.5\,\text{ft}$ Maximum energy

$H_t := 155\text{ft} - 102.5\text{ft}$

$H_t = 52.5\,\text{ft}$ Minimum energy

For the maximum energy potential, a sequent depth of 29 ft is required for a 7 ft wide continuous channel, the FAC has 30 ft of depth at the valve discharge and increases depth downstream in the channel with a continuous width of 20 ft. The extimated 29 ft is a conservative value

DESIGN OF SMALL DAMS

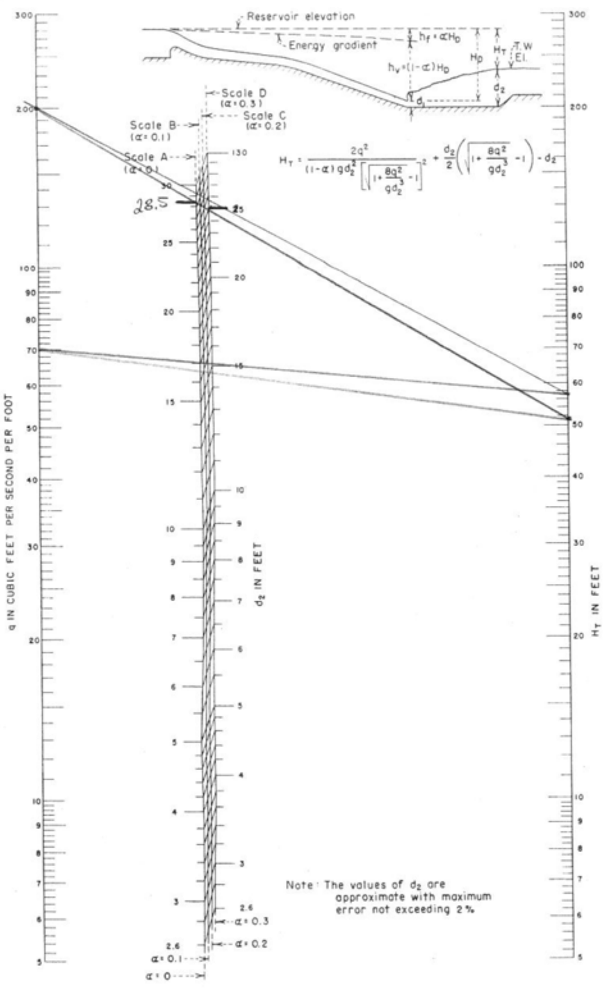


Figure 9-43.—Stilling basin depths versus hydraulic heads for various channel losses. 288-D-2428.

EM 1110-2-1602 Basin Guidance

Still assuming 7-ft diameter valve behaves as 7-ft by 7-ft square jet.

e. Elevation fo Stilling Basin Floor

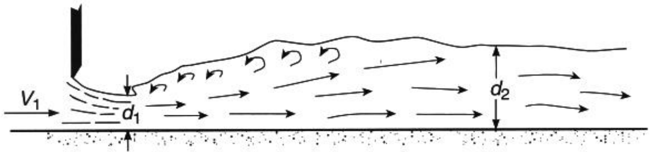
$V_c = 36.378\,\frac{ft}{s}$ Exit velocity of 1400 cfs thru 7 ft valve.

$d_1 := 7ft$

$Fr := \frac{V_c}{\sqrt{g \cdot d_1}}$ $Fr = 2.424$ Froude is less than 2.5, considered prejump stage (Sturm - Open Channel Hydraulics image below)

$d_2 := d_1\left(0.5 \cdot \sqrt{1 + 8 \cdot Fr^2} - 1\right)$ Eq 5-4 EM 1110-2-1602

$d_2 = 17.251\,ft$ Required sequent depth for 7-ft by 7-ft square sluice jet



F_1 Between 1.7 and 2.5
Form A—Prejump stage

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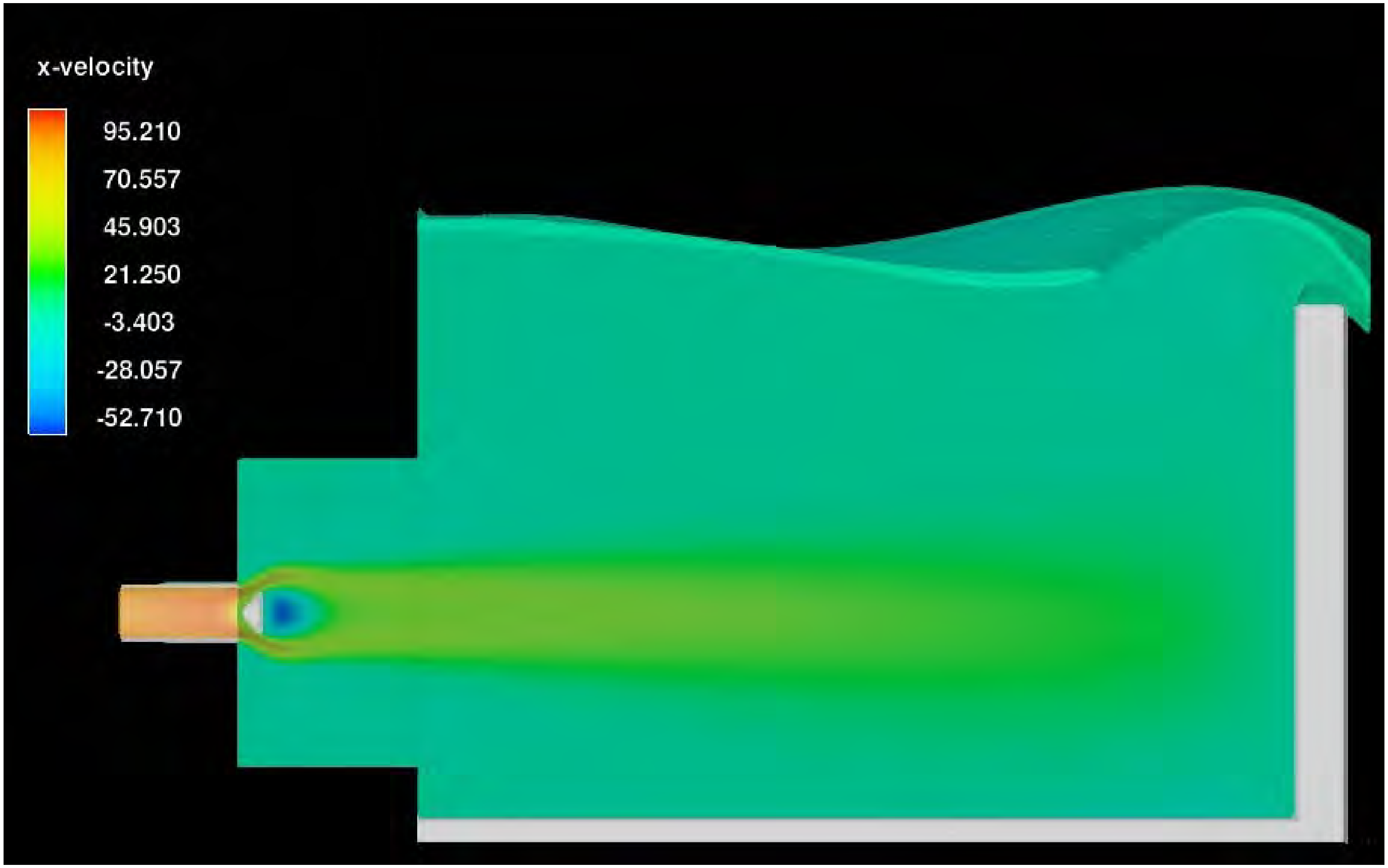
Rodney Hunt, a commercial manufacturer of hollow jet cone valves, supplied this graphic of the CFD modeling depicting submerged flow pattern of a Howell-Bunger type hollow jet cone valve with similar conditions to the intended application (exact conditions not disclosed by supplier).



Units Definition $cfs := ft^3 \cdot s^{-1}$ Units Coefficient $C_u := 1.486\sqrt[3]{ft} \cdot s^{-1}$ Energy Coefficient $\alpha := 1$

Culvert Computations **Circular Culvert (Clean)** **Input** **Output**

Data Input

Pipe Diameter $D := 6ft = 72 \cdot in$

Pipe Manning's n $n := 0.01$

Pipe Slope $S_o := 0.000001$ Flow Rate $Q := 350cfs$ Per culvert

FHWA Table 9 Coefficients

$K := 0.0045$	$M := 2.0$	$c := 0.0317$	$Y := 0.69$	Circular, concrete groove end projecting
$K := 0.0018$	$M := 2.0$	$c := 0.0292$	$Y := 0.74$	Circular, concrete groove end with headwall entrance
$K := 0.0098$	$M := 2.0$	$c := 0.0398$	$Y := 0.67$	Circular, concrete with square edge headwall entrance

Culvert Length $L := 50ft$

Outlet Invert Ele. $OInv_{el} := 92ft$ TW Elevation $TW_{el} := 90.5ft$

Inlet Invert Ele. $InInv_{el} := OInv_{el} + S_o \cdot L$ $InInv_{el} = 92\,ft$

Loss Coefficients, Sturm pg 226

$k_e := 0.5$ Entrance loss $k_o := 1.0$ Exit loss

Hydraulic Geometry

Angle Functions $\theta(y) := 2 \cdot acos\left(1 - 2 \cdot \frac{y}{D}\right)$ $A_f := \frac{\pi \cdot D^2}{4}$

Area Functions $A(\theta) := \frac{D^2}{8} \cdot (\theta - \sin(\theta))$

Perimeter Functions $P(\theta) := \frac{D}{2} \cdot (\theta)$

Hydraulic Radius $R_H(\theta) := A(\theta) \cdot P(\theta)^{-1}$

Top Width $T(\theta) := D \cdot \sin\left(\frac{\theta}{2}\right)$

Full Pipe Condition

$y_f := 0.90D$ $y_f = 5.4\,ft$ $\theta_f := 2 \cdot acos\left(1 - 2\frac{y_f}{D}\right)$ $\theta_f = 4.996$

Inlet Control Computations

Critical Depth Computations

$N_f = \frac{V}{\sqrt{\alpha \cdot g \cdot D}}$ $Z_c := \frac{Q^2}{g \cdot \alpha}$ $Z_c = 3.807 \times 10^3\,ft^5$ Critical Section Factor

$\theta := 1.5\pi$ Trial value

Given Solve block for critical depth angle

$\frac{A(\theta)^3}{T(\theta)} = Z_c$ $\theta_c := Find(\theta)$ $\theta_c = 4.664$ $\theta_c := \begin{cases} (2\cdot\pi) & \text{if } \theta_c > 2\cdot\pi \\ \theta_c & \text{otherwise} \end{cases}$ $\theta_c = 4.664$

$y_c := \begin{cases} D & \text{if } \theta_c > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_c}{2}\right)\right) & \text{otherwise} \end{cases}$ $y_c = 5.069\,ft$ Critical Depth

Hydraulic Radius $R_H(\theta_c) = 1.821\,ft$

Percent Full $Per_{full}(y) := \frac{y}{D}$ $Per_{full}(y_c) = 84.481\cdot\%$

Velocity $V_c := Q\cdot A(\theta_c)^{-1}$ $V_c = 13.736\,\frac{ft}{s}$ Critical Velocity

Top Width $T(\theta_c) = 4.345\,ft$

Critical Slope $S_c := \frac{Q^2 \cdot n^2}{C_u{}^2 \cdot A(\theta_c)^2 \cdot \sqrt[3]{R_H(\theta_c)^4}}$ $S_c = 0.384\cdot\%$

Inlet Condition Factor $N := \frac{Q\cdot cfs^{-1}}{A_f \cdot ft^{-2} \cdot \sqrt{D \cdot ft^{-1}}}$ $N = 5.054$

Specific Head at Critical Depth

$H_c := y_c + \frac{V_c{}^2}{2\cdot g}$ $H_c = 8.001\,ft$

Calculate Headwater For Inlet Control, feet above culvert invert at the inlet:

$HW_{inlet} := \begin{cases} \left[H_c + D\cdot\left(K\cdot N^M - 0.5\cdot S_o\right)\right] & \text{if } N < 3.5 \\ \left[D\cdot\left(c\cdot N^2 + Y - 0.5\cdot S_o\right)\right] & \text{otherwise} \end{cases}$ $HW_{inlet} = 10.119\,ft$ $\frac{HW_{inlet}}{D} = 1.686$

Outlet Control Computations

Normal Depth Computation

Trial depth angle $\theta := 2.5\pi$

Given $Q = \frac{C_u}{n} \cdot A(\theta) \cdot R_H(\theta)^{\frac{2}{3}} \cdot \sqrt{S_o}$ $\theta_n := \text{Find}(\theta)$ $\theta_n = 399.151$

$$\theta_n := \begin{vmatrix} (2\cdot\pi) & \text{if } \theta_n > 2\cdot\pi \\ \theta_n & \text{otherwise} \end{vmatrix}$$

$\theta_n = 6.283$

Normal Depth Critical Depth

$$y_n := \begin{vmatrix} D & \text{if } \theta_n > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_n}{2}\right)\right) & \text{otherwise} \end{vmatrix}$$

$y_n = 6\ \text{ft}$ $y_c = 5.069\ \text{ft}$

Flow Area $A(\theta_n) = 28.274\ \text{ft}^2$

Hydraulic Radius $R_H(\theta_n) = 1.5\ \text{ft}$

Percent Full $\text{Per}_{\text{full}}(y_n) = 100\cdot\%$

Velocity $V_n := Q\cdot A(\theta_n)^{-1}$ $V_n = 12.379\ \frac{\text{ft}}{\text{s}}$

Top Width $T(\theta_n) = 0\ \text{ft}$

Hydraulic Depth $D_{hn} := \frac{A(\theta_n)}{T(\theta_n)}$ $D_{hn} = 3.848 \times 10^{16}\ \text{ft}$

Calculate Headwater For Outlet Control, feet above culvert invert at the inlet:

$k_f := \frac{2\cdot g\cdot n^2\cdot L}{C_u^{\,2}\cdot\sqrt[3]{R_H(\theta_f)^4}}$ Friction loss based on full pipe $k_f = 0.067$

$TW := TW_{el} - OInv_{el}$ $TW = -1.5\ \text{ft}$ Tailwater depth $\frac{TW}{D} = -0.25$

$$\text{PipeCondition} := \begin{vmatrix} \text{"pipe full"} & \text{if } TW > D \\ \text{"part-full pipe"} & \text{otherwise} \end{vmatrix}$$

$\text{PipeCondition} = \text{"part-full pipe"}$

Calculation of Energy Loss

$H := (k_e + k_o + k_f)\cdot\frac{V_n^{\,2}}{2\cdot g}$ $H = 3.732\ \text{ft}$

Outlet Head

$$h_o := \left|\begin{array}{l} TW \;\; \text{if} \;\; TW > \dfrac{y_c + D}{2} \\ \dfrac{y_c + D}{2} \end{array}\right. \qquad h_o = 5.534\,ft$$

$$HW_{out} := h_o - S_o \cdot L + H \qquad HW_{out} = 9.266\,ft$$

Control and Headwater

$$HW\_Condition := \left|\begin{array}{l} \text{"Inlet"} \;\; \text{if} \;\; HW_{inlet} > HW_{out} \\ \text{"Outlet"} \;\; \text{otherwise} \end{array}\right. \qquad HW := \left|\begin{array}{l} HW_{inlet} \;\; \text{if} \;\; HW_{inlet} > HW_{out} \\ HW_{out} \;\; \text{otherwise} \end{array}\right.$$

$HW_{inlet} = 10.119\,ft$

$HW_{out} = 9.266\,ft$

$HW\_Condition = \text{"Inlet"}$ $\qquad HW = 10.119\,ft$

Design Summary - (Project)

$D = 6\,ft$	Culvert Diameter	$L = 50\,ft$	Culvert Length
$S_o = 1 \times 10^{-6}$	Invert Slope	$n = 0.01$	Manning's n for pipe
$Q = 350 \cdot cfs$	Discharge		
$y_c = 5.069\,ft$	Critical Depth		
$y_n = 6\,ft$	Normal Depth		

$HW\_Condition = \text{"Inlet"}$	Headwater Condition
$HW = 10.119\,ft$	Headwater Depth

$WSE_{inlet} := HW + InInv_{el}$

$WSE_{inlet} = 102.119\,ft$ Water surface elevation in FLAC

$$V_o := \frac{Q}{A_f} \qquad V_o = 12.379\,\frac{ft}{s}$$

Exit velocity

Exit Trajectory Analysis

$EL_{imp\_min} := 80.5ft$ Minimum Depth in AWSC

$EL_{imp\_max} := 90.0ft$ Maximum Depth in AWSC

$OInv_{el} = 92\,ft$ Invert Elevation of Culvert Outlet

$Ocl_{el} := OInv_{el} + \frac{y_c}{2}$ Centerline Elevation of Culver Outlet

$Ocl_{el} = 94.534\,ft$

$y_{imp\_max} := Ocl_{el} - EL_{imp\_min}$ Maximum fall distance from centerline

$y_{imp\_max} = 14.034\,ft$

$y_{imp\_min} := Ocl_{el} - EL_{imp\_max}$ Minimum fall distance from centerline

$y_{imp\_min} = 4.534\,ft$

$$t_{max} := \sqrt{\frac{y_{imp\_max} \cdot 2}{g}}$$

$t_{max} = 0.934\,s$

$$t_{min} := \sqrt{\frac{y_{imp\_min} \cdot 2}{g}}$$

$t_{min} = 0.531\,s$

$x(t) := V_o \cdot t$ $x(t_{max}) = 11.562\,ft$

$y(t) := -g \cdot \frac{t^2}{2}$ $x(t_{min}) = 6.572\,ft$

$v_y(t) := -g \cdot t$ $v_y(t_{max}) = -30.051\,\frac{ft}{s}$ $v_y(t_{min}) = -17.082\,\frac{ft}{s}$

$v_x := V_o$

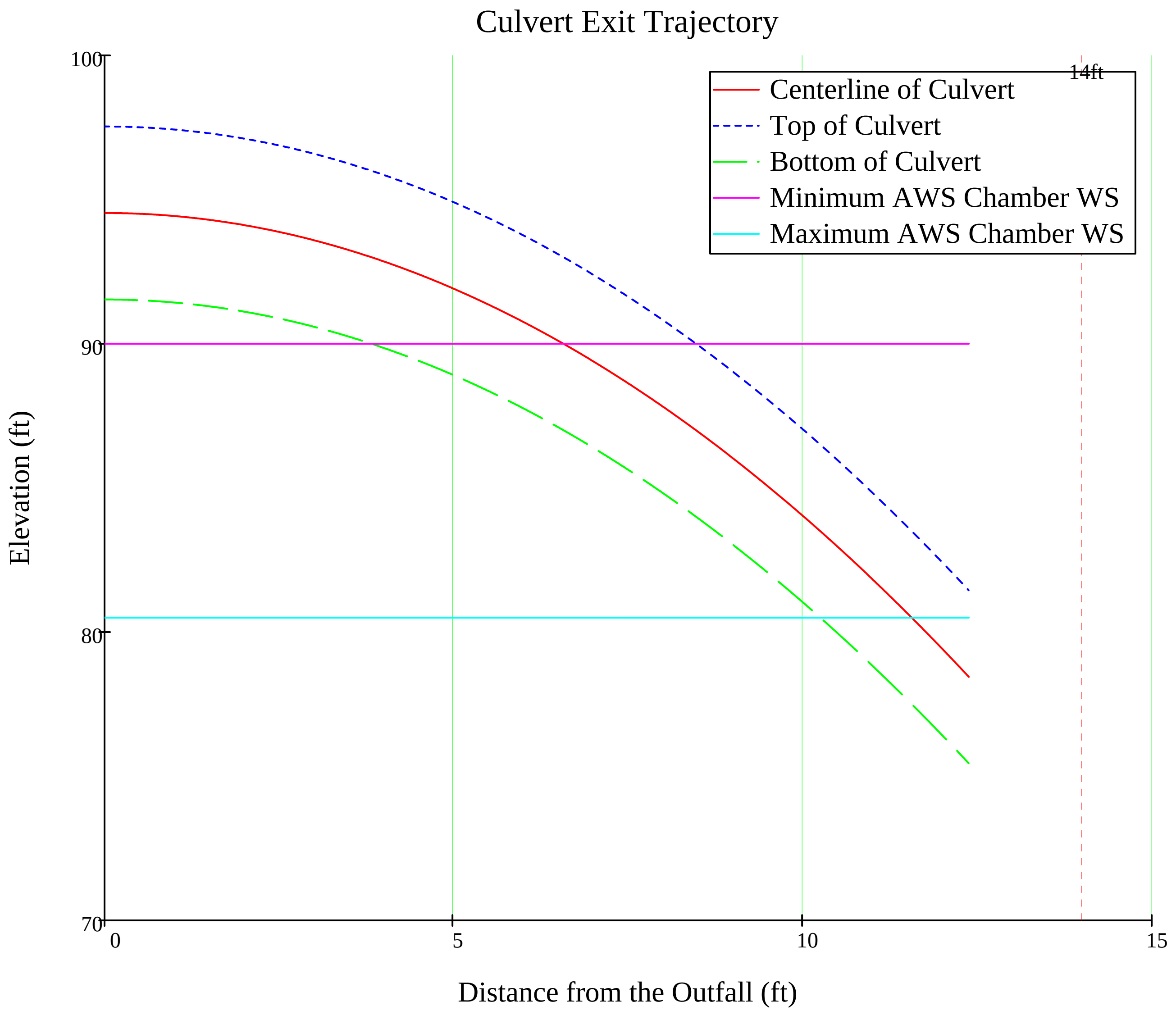
$\theta_{imp\_min} := atan\left(\frac{v_y(t_{min})}{v_x}\right)$ $\theta_{imp\_min} = -54.07 \cdot deg$

$\theta_{imp\_max} := atan\left(\frac{v_y(t_{max})}{v_x}\right)$ $\theta_{imp\_max} = -67.612 \cdot deg$

$v_{max} := \sqrt{v_y(t_{max})^2 + v_x^2}$ $v_{max} = 32.501\,\frac{ft}{s}$

$v_{min} := \sqrt{v_y(t_{min})^2 + v_x^2}$ $v_{min} = 21.095\,\frac{ft}{s}$

$t := 0s, 0.001s .. 1s$


Culvert Exit Trajectory
Centerline of Culvert
Top of Culvert
Bottom of Culvert
Minimum AWS Chamber WS
Maximum AWS Chamber WS
14ft
100
90
80
70
0
5
10
15
Elevation (ft)
Distance from the Outfall (ft)

WSP Computations **Circular channel** **Input** **Output**

Data Input

Bed slope $S_o := 0.000001$ Diameter $D := 6\text{ft}$ Channel discharge $Q := 200\text{cfs}$

Manning's n $n := 0.01$ Channel Length $L := 50\text{ft}$

No. of steps $N := 300$

Hydraulic Geometry

$A(\theta) := \frac{D^2}{8}\cdot(\theta - \sin(\theta))$ $T(\theta) := D\cdot\sin\left(\frac{\theta}{2}\right)$ $y_f := 0.9\cdot D$

$R(\theta) := \frac{D}{4}\cdot\left(1 - \frac{\sin(\theta)}{\theta}\right)$ $P(\theta) := \frac{D}{2}\cdot\theta$ $\theta(y) := 2\cdot\text{acos}\left[1 - 2\cdot\frac{(y)}{D}\right]$

$\theta_f := 2\cdot\text{acos}\left(1 - 2\frac{y_f}{D}\right)$ $\theta_f = 4.996$

Critical Depth Computations

$Z_c := \frac{Q^2}{g\cdot\alpha}$ $Z_c = 1.243 \times 10^3\,\text{ft}^5$ Critical section factor $\theta_t := 1.5\cdot\pi$ Trial value

Solve block for critical depth angle

Given

$\frac{A(\theta_t)^3}{T(\theta_t)} = Z_c$ $\theta_c := \text{Find}(\theta_t)$ $\theta_c = 3.727$

Critical Depth Angle Critical Depth

$\theta_c := \begin{cases} (2\cdot\pi) & \text{if } \theta_c > 2\pi \\ \theta_c & \text{otherwise} \end{cases}$ $\theta_c = 3.727$ $y_c := \begin{cases} D & \text{if } \theta_c > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_c}{2}\right)\right) & \text{otherwise} \end{cases}$ $y_c = 3.866\text{ ft}$

$V_c := \frac{Q}{A(\theta_c)}$

$V_c = 10.385\,\frac{\text{ft}}{\text{s}}$

Normal Depth Computation

Trial depth angle $\theta_t = 4.712$

Solve block for normal depth angle

Given $Q = \left(\frac{C_u}{n}\cdot A(\theta_t)\cdot R(\theta_t)^{\frac{2}{3}}\cdot\sqrt{S_o}\right)$ $\theta_n := \text{Find}(\theta_t)$ $\theta_n = 228.92$

Normal Depth Angle Normal Depth

$\theta_n := \begin{cases} (2\cdot\pi) & \text{if } \theta_n > 2\pi \\ \theta_n & \text{otherwise} \end{cases}$ $\theta_n = 6.283$ $y_n := \begin{cases} D & \text{if } \theta_n > \theta_f \\ \frac{D}{2}\cdot\left(1 - \cos\left(\frac{\theta_n}{2}\right)\right) & \text{otherwise} \end{cases}$ $y_n = 6\text{ ft}$

Profile Identification and Step Selection

$tw := y_c$ Control Depth

$y_o := -1ft$ Mild sloped with downstream control

Control depth definition

```
$y_1 :=$
    $tw$ if $y_o = -1ft$
    $y_o$ otherwise
```

$y_1 = 3.866 \cdot ft$

Profile Type and Definition

ORIGIN := 1

```
Type :=
    if $y_c > y_n$
        type ← "S1" if $y_1 > y_c$
        type ← "S2" if $y_n < y_1 \le y_c$
        type ← "S3" otherwise
    if $y_c < y_n$
        type ← "M1" if $y_n < y_1$
        type ← "M2" if $y_c \le y_1 < y_n$
        type ← "M3" otherwise
    otherwise
        type ← "This profile is not steep or mild"
        return type
```

Type = "M2"

$y_1 = 3.866 \text{ ft}$ $y_n = 6 \text{ ft}$ $y_c = 3.866 \text{ ft}$

Define Computational Step

```
$\Delta y :=$
    if $y_n < y_c$
        $\Delta y \leftarrow y_c - 0.99y_1$ if Type = "S1"
        $\Delta y \leftarrow 1.01y_n - y_1$ if Type = "S2"
        $\Delta y \leftarrow 0.99y_n - y_1$ if Type = "S3"
    if $y_c < y_n$
        $\Delta y \leftarrow 1.01y_n - y_1$ if Type = "M1"
        $\Delta y \leftarrow 0.99y_n - y_1$ if Type = "M2"
        $\Delta y \leftarrow y_c - y_1$ if Type = "M3"
    return $\Delta y$
```

$\Delta y = 2.074 \cdot ft$

$y_1 := y_1$

Profile Computations

Direct Step Program

```
$AProfile(y) :=$
    $x_1 \leftarrow 0.0ft$
    $dy \leftarrow \Delta y \cdot N^{-1}$
    $E_1 \leftarrow y_1 + \frac{\alpha \cdot Q^2}{2 \cdot g \cdot A(\theta(y_1))^2}$
    $R_1 \leftarrow A(\theta(y_1)) \cdot P(\theta(y_1))^{-1}$
    $Sf_1 \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_1)) \cdot \sqrt[3]{(R_1)^2}}\right]^2$
    for $i \in 2..N$
        $y_i \leftarrow y_{i-1} + dy$
        $E_i \leftarrow y_i + \alpha \cdot Q^2 \cdot \left(2 \cdot g \cdot A(\theta(y_i))^2\right)^{-1}$
        $R_i \leftarrow A(\theta(y_i)) \cdot P(\theta(y_i))^{-1}$
        $Sf_i \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_i)) \cdot \sqrt[3]{(R_i)^2}}\right]^2$
        $S_f \leftarrow (Sf_i + Sf_{i-1}) \cdot 0.5$
        $\Delta x \leftarrow \frac{E_{i-1} - E_i}{S_f - S_o}$
        $x_i \leftarrow x_{i-1} + \Delta x$
        $WSP_{1,1} \leftarrow x_1$
        $WSP_{2,1} \leftarrow y_1$
        $WSP_{1,i} \leftarrow x_i$
        $WSP_{2,i} \leftarrow y_i$
    $WSP$
```

Numerical Integration Program

```
$BProfile(y) :=$
    $x_1 \leftarrow 0ft$
    $dy \leftarrow \frac{\Delta y}{N} \cdot 0.999$
    $R_1 \leftarrow \frac{A(\theta(y_1))}{P(\theta(y_1))}$
    $Sf_1 \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_1)) \cdot \sqrt[3]{(R_1)^2}}\right]^2$
    $V_1 \leftarrow \frac{Q}{A(\theta(y_1))}$
    $D_{h_1} \leftarrow \frac{A(\theta(y_1))}{T(\theta(y_1))}$
    $NF_1 \leftarrow \frac{V_1}{\sqrt{g \cdot D_{h_1}}}$
    $Gy_1 \leftarrow \frac{1 - (NF_1)^2}{S_o - Sf_1}$
    for $i \in 2..N$
        $y_i \leftarrow y_{i-1} + dy$
        $R_i \leftarrow \frac{A(\theta(y_i))}{P(\theta(y_i))}$
        $Sf_i \leftarrow \left[\frac{Q \cdot n}{C_u \cdot A(\theta(y_i)) \cdot \sqrt[3]{(R_i)^2}}\right]^2$
        $V_i \leftarrow \frac{Q}{A(\theta(y_i))}$
        $D_{h_i} \leftarrow \frac{A(\theta(y_i))}{T(\theta(y_i))}$
        $NF_i \leftarrow \frac{V_i}{\sqrt{g \cdot D_{h_i}}}$
        $Gy_i \leftarrow \frac{1 - (NF_i)^2}{S_o - Sf_i}$
```

```
    $\Delta x \leftarrow (y_i - y_{i-1}) \cdot \frac{Gy_{i-1} + Gy_i}{2}$
    $x_i \leftarrow x_{i-1} + \Delta x$
    $WSP_{1,1} \leftarrow x_1$
    $WSP_{2,1} \leftarrow y_1$
    $WSP_{1,i} \leftarrow x_i$
    $WSP_{2,i} \leftarrow y_i$
WSP
```

$i := 1..N$

Direct Step Computation Results

$y_n = 6\cdot ft$ $y_c = 3.866\cdot ft$ $x_1 := AProfile(y)_{1,1}$ $x_1 = 0\ ft$ $y_1 := AProfile(y)_{2,1}$ $y_1 = 3.866\ ft$

$Adepth_i := AProfile(y)_{2,i}$ $Adistance_i := AProfile(y)_{1,i}$

$AY_{final} := AProfile(y)_{2,N}$ $AY_{final} = 5.933\ ft$

$AX_{final} := AProfile(y)_{1,N}$ $AX_{final} = -911.715\ ft$

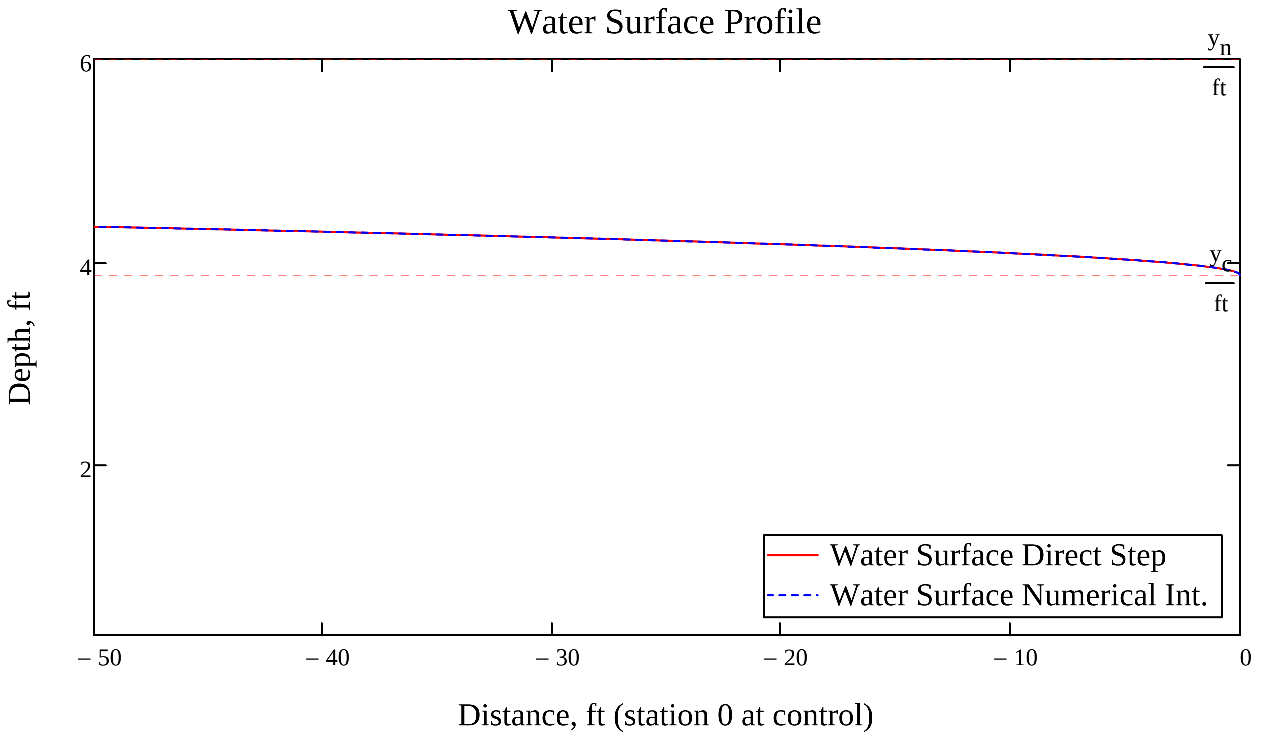
Numerical Integration Computation Results

$y_n = 6\cdot ft$ $y_c = 3.866\cdot ft$ $x_1 := BProfile(y)_{1,1}$ $x_1 = 0\ ft$ $y_1 := BProfile(y)_{2,1}$ $y_1 = 3.866\ ft$

$Bdepth_i := BProfile(y)_{2,i}$ $Bdistance_i := BProfile(y)_{1,i}$

$BY_{final} := BProfile(y)_{2,N}$ $BY_{final} = 5.931\ ft$

$BX_{final} := BProfile(y)_{1,N}$ $BX_{final} = -910.128\ ft$



Type = "M2"

$$Hydraulic\_condition := \left| \begin{array}{ll} \text{"Short"} & \text{if } |AX_{final}| > L \\ \text{"Long"} & \text{otherwise} \end{array} \right.$$

Hydraulic_condition = "Short"

$\text{AProfile}(y)^T =$ (ft)

	1	2
1	0	3.866
2	-0.01	3.873
3	-0.04	3.879
4	-0.091	3.886
5	-0.162	3.893
6	-0.253	3.9
7	-0.365	3.907
8	-0.497	3.914
9	-0.65	3.921
10	-0.823	3.928
11	-1.017	3.935
12	-1.231	3.942
13	-1.466	3.949
14	-1.722	3.956
15	-1.998	3.962
16	-2.295	...

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8 ft by 8 ft Culvert and Header Computations

Custom Units Definition

$fps := ft \cdot s^{-1}$ feet per second

$cfs := ft^{2} \cdot fps$ cubic feet per second

Fluid Properties

$\rho := 999.7 \frac{kg}{m^{3}}$ fluid density

Assumed temperature deg. F

$T_f := 50$ $T_c := (T_f - 32) \cdot \frac{5}{9}$ $T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + (0.0337 \cdot T_c + 0.000221 \cdot T_c^{2})} \cdot \frac{m^{2}}{s}$$

$\nu = 1.319 \times 10^{-6} \cdot \frac{m^{2}}{s}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function: $A(h,w) := h \cdot w$

Equivalent diameter for rectangular conduit: $D'(h,w) := \frac{4 \cdot A(h,w)}{2 \cdot h + 2 \cdot w}$

Reynolds number: $Re(Q,h,w) := \frac{Q \cdot D'(h,w)}{A(h,w) \cdot \nu}$

Average velocity: $V(Q,h,w) := \frac{Q}{A(h,w)}$

Jain's equation for friction factor

$$f(Q,h,w,k_s) := \frac{0.25}{\log\left(\frac{k_s}{3.7 \cdot D'(h,w)} + \frac{5.74}{Re(Q,h,w)^{0.9}}\right)^{2}}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Assumed concrete equivalent sand grain roughness

$\alpha_f := 1.0$ friction loss sensitivity coefficient

$\alpha_k := 1.0$ minor loss sensitivity coefficient

$k_s := \alpha_f \cdot 0.25mm$ assumed roughness

$k_{sr} := 2.0mm$ extremely rough

$k_{ss} := 0.025mm$ smooth roughness

Roughness values taked from Miller Table 8.1

Driving head characteristics

$Tailrace_{max} := 86.0ft$ $Tailrace := 86ft$ $Tailrace_{min} := 76.4ft$

$Diffuser_{head} := 2.2ft$ $Attraction_{head} := 1.0ft$

$TW := Tailrace + Attraction_{head} + Diffuser_{head}$

WSE in FLAC WSE in AWS chamber

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$HW := 101.65ft$ $TW = 89.2\ ft$ $Available := HW - TW$ $Available = 12.45\ ft$

▼

For the header losses through modified diffusers

Pipe 1 Floor diffuser 1 (node 1 to node 7)

$Q_{1'} := 300\text{cfs}$	Trial flow rate for loss coefficient estimation
$D_{h1} := 6.5\text{ft}$	Conduit height
$D_{w1.1} := 6.0\text{ft}$	Initial conduit width
$D_{w1.2} := 5.2\text{ft}$	Final conduit width
$L_1 := 5\text{ft}$	Estimation of conduit length

Entrance loss

$K_{1e} := 0.5$ Miller Fig. 14.11

Bend loss 45 deg

$k'_b := 0.3$ From Miller Fig. 9.9

$\text{Re}\left(Q_{1'}, D_{h1}, D_{w1.1}\right) = 3.382 \times 10^6$ Reynolds number at entrance

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{1'}, D_{h1}, D_{w1.1}, k_{sr}\right)}{f\left(Q_{1'}, D_{h1}, D_{w1.1}, k_{ss}\right)}$ $C_f = 1.962$ From Miller Eq. 9.3

$K_{1b45} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{1b45} = 0.589$ From Miller Eq. 9.4

Contraction loss

$$\frac{A\left(D_{h1}, D_{w1.2}\right)}{A\left(D_{h1}, D_{w1.1}\right)} = 0.867$$

$K_{1c} := 0.08$ Miller Fig. 14.14

Combining tee loss

$K_{t17} := 0.4$ Miller Fig 13.10

Friction loss

Contracted section assumed negligible for friction due to short section

$$f_1(Q) := f\left(Q, D_{h1}, D_{w1.1}, k_s\right) \cdot \frac{L_1}{D'\left(D_{h1}, D_{w1.1}\right)}$$

Pipe 1 summation of losses

$$H_1(Q) := \left[f_1(Q) + \alpha_k \cdot \left(K_{1e} + K_{1b45} + K_{1c} + K_{t17}\right)\right] \cdot \frac{V\left(Q, D_{h1}, D_{w1.1}\right)^2}{2 \cdot g}$$

$H_1\left(Q_{1'}\right) = 1.452\ \text{ft}$ $V\left(Q_{1'}, D_{h1}, D_{w1.1}\right) = 7.692\ \dfrac{\text{ft}}{\text{s}}$

Pipe 2 Floor diffuser 2 (node 2 to node 6)

Entrance loss

$Q_{2'} := 130\text{cfs}$	Trial flow rate for loss coefficient estimation
$D_{h2} := 6.5\text{ft}$	Conduit height
$D_{w2} := 6.0\text{ft}$	Conduit width
$L_2 := 0\text{ft}$	Estimation of conduit length

Entrance loss

$K_{2e} := 0.5$ Miller Fig. 14.11

Assumed friction loss negligible

Combining tee loss

$K_{t26} := 8$ Miller Fig 13.10

Pipe 2 summation of losses

$$H_2(Q) := \left[\alpha_k \cdot \left(K_{2e} + K_{t26}\right)\right] \cdot \frac{V\left(Q, D_{h2}, D_{w2}\right)^2}{2 \cdot g} \qquad H_2\left(Q_{2'}\right) = 1.468\ \text{ft}$$

$$V\left(Q_{2'}, D_{h2}, D_{w2}\right) = 3.333\ \frac{\text{ft}}{\text{s}}$$

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Pipe 3 Floor diffuser 3 (node 3 to node 5)

Entrance loss

$Q_{3'} := 100\text{cfs}$ Trial flow rate for loss coefficient estimation

$D_{h3} := 3\text{ft}$ Conduit height

$D_{w3} := 15\text{ft}$ Conduit width

$L_3 := 15\text{ft}$ Estimation of conduit length

Entrance loss

$K_{3e} := 0.5$ Miller Fig. 14.11

Bend loss

$k'_b := 1.2$ From Miller Fig. 9.9

$\text{Re}\left(Q_{3'}, D_{h3}, D_{w3}\right) = 7.829 \times 10^5$ Reynolds number at entrance

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{3'}, D_{h3}, D_{w3}, k_{sr}\right)}{f\left(Q_{3'}, D_{h3}, D_{w3}, k_{ss}\right)}$ $C_f = 1.721$ From Miller Eq. 9.3

$K_{3b90.1} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{3b90.1} = 2.066$ From Miller Eq. 9.4

$K_{3b90.2} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{3b90.2} = 2.066$ From Miller Eq. 9.4

Orifice loss

$K_{3o} := \left(1 - \dfrac{16\text{ft}^2}{D_{h3} \cdot D_{w3}}\right)^2 \cdot \left(\dfrac{D_{h3} \cdot D_{w3}}{16\text{ft}^2}\right)^2$ $K_{3o} = 3.285$ Miller Eq. 14.2

Combining tee loss

$K_{t35} := 1.5$ Miller Fig 13.10

Friction loss Contracted section assumed negligible for friction due to short section

$$f_3(Q) := f\left(Q, D_{h3}, D_{w3}, k_s\right) \cdot \frac{L_3}{D'\left(D_{h3}, D_{w3}\right)}$$

Pipe 3 summation of losses

$$H_3(Q) := \left[f_3(Q) + \alpha_k\left(K_{3e} + K_{3b90.1} + K_{3b90.2} + K_{3o} + K_{t35}\right)\right] \cdot \frac{V\left(Q, D_{h3}, D_{w3}\right)^2}{2 \cdot g}$$

$H_3\left(Q_{3'}\right) = 0.726\text{ ft}$ $V\left(Q_{3'}, D_{h3}, D_{w3}\right) = 2.222\ \dfrac{\text{ft}}{\text{s}}$

Pipe 4 Floor diffuser 4 (node 4 to node 5)

Entrance loss

$Q_{4'} := 90\text{cfs}$ Trial flow rate for loss coefficient estimation

$D_{h4.1} := 3\text{ft}$ Conduit height, segment 1

$D_{w4.1} := 15\text{ft}$ Conduit width, segment 1

$D_{h4.2} := 8\text{ft}$ Conduit height, segment 2

$D_{w4.2} := 4\text{ft}$ Conduit width, segment 2

$L_{4.1} := 15\text{ft}$ Estimation of conduit length

$L_{4.2} := 15\text{ft}$ Estimation of conduit length

Entrance loss

$K_{4e} := 0.5$ Miller Fig. 14.11

Bend loss, 1 & 2

$k'_b := 1.2$ From Miller Fig. 9.9

$\text{Re}\left(Q_{4'}, D_{h4.1}, D_{w4.1}\right) = 7.046 \times 10^{5}$ Reynolds number at entrance

$C_{Re} := 1.1$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{4'}, D_{h4.1}, D_{w4.1}, k_{sr}\right)}{f\left(Q_{4'}, D_{h4.1}, D_{w4.1}, k_{ss}\right)}$ $C_f = 1.697$ From Miller Eq. 9.3

$K_{4b90.1} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{4b90.1} = 2.24$ From Miller Eq. 9.4

$K_{4b90.2} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{4b90.2} = 2.24$ From Miller Eq. 9.4

Orifice loss

$$K_{4o} := \left(1 - \frac{16\text{ft}^2}{D_{h4.1} \cdot D_{w4.1}}\right)^2 \cdot \left(\frac{D_{h4.1} \cdot D_{w4.1}}{16\text{ft}^2}\right)^2 \qquad K_{4o} = 3.285$$

Miller Eq. 14.2

Bend loss, 3

$k'_b := 1.2$ From Miller Fig. 9.9

$\text{Re}\left(Q_{4'}, D_{h4.2}, D_{w4.2}\right) = 1.057 \times 10^{6}$ Reynolds number at entrance

$C_{Re} := 1$ From Miller Fig. 9.3

$C_o := 1$ Miller Fig. 9.4

$C_f := \frac{f(Q_{4'}, D_{h4.2}, D_{w4.2}, k_{sr})}{f(Q_{4'}, D_{h4.2}, D_{w4.2}, k_{ss})}$ $C_f = 1.767$ From Miller Eq. 9.3

$K_{4b90.3} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{4b90.3} = 2.12$ From Miller Eq. 9.4

Combining Tee loss

$K_{t45} := 0.65$ Miller Fig 13.11

Friction loss segment 1

$$f_{4.1}(Q) := f(Q, D_{h4.1}, D_{w4.1}, k_s) \cdot \frac{L_{4.1}}{D'(D_{h4.1}, D_{w4.1})}$$

Friction loss segment 2

$$f_{4.2}(Q) := f(Q, D_{h4.2}, D_{w4.2}, k_s) \cdot \frac{L_{4.2}}{D'(D_{h4.2}, D_{w4.2})}$$

Pipe 4 summation of losses segment 1

$$H_{4.1}(Q) := \left[f_{4.1}(Q) + \alpha_k \cdot (K_{4e} + K_{4b90.1} + K_{4b90.2} + K_{4o})\right] \cdot \frac{V(Q, D_{h4.1}, D_{w4.1})^2}{2 \cdot g}$$

$$V(Q_{4'}, D_{h4.1}, D_{w4.1}) = 2 \frac{ft}{s}$$

Pipe 4 summation of losses segment 2

$$H_{4.2}(Q) := \left[f_{4.2}(Q) + \alpha_k (K_{4b90.3} + K_{t35})\right] \cdot \frac{V(Q, D_{h4.2}, D_{w4.2})^2}{2 \cdot g}$$

$$V(Q_{4'}, D_{h4.2}, D_{w4.2}) = 2.813 \frac{ft}{s}$$

Pipe 4 summation of losses

$H_4(Q) := H_{4.1}(Q) + H_{4.2}(Q)$ $H_4(Q_{4'}) = 0.966\ ft$

Pipe 5 Node 5 to node 6 $Q_5 = Q_3 + Q_4$

Friction loss

$Q_{5'} := Q_{3'} + Q_{4'}$ Trial flow rate for loss coefficient estimation

$D_{h5} := 8\text{ft}$ Conduit height

$D_{w5.1} := 5\text{ft}$ Initial conduit width

$D_{w5.2} := 6\text{ft}$ Final conduit width

$L_5 := 32\text{ft}$ Estimation of conduit length

Combining loss Q3 and Q4 - Used for K_{t45} and K_{t35} above

$$\frac{Q_{3'}}{Q_{5'}} = 0.526$$

Adjust losses above

$$\frac{16\text{ft}^2}{D_{h5} \cdot D_{w5.1}} = 0.4$$

Gate area over entering conduit area

Friction loss

$$f_5(Q) := f\left(Q, D_{h5}, D_{w5.1}, k_s\right) \cdot \frac{L_5}{D'\left(D_{h5}, D_{w5.1}\right)}$$

Combining tee loss

$K_{t56} := 1.0$ Miller Fig. 13.11

Expansion loss

$$\frac{D_{h5} \cdot D_{w5.1}}{64\text{ft}^2} = 0.625$$

$64\ \text{ft}^2$ is the main conduit area expansion

$K_{ex} := 0.2$ Miller Fig. 14.15

Pipe 5 summation of losses

$$H_5(Q) := \left[f_5(Q) + \alpha_k \cdot \left(K_{t56} + K_{ex}\right)\right] \cdot \frac{V\left(Q, D_{h5}, D_{w5.1}\right)^2}{2 \cdot g}$$

$H_5\left(Q_{5'}\right) = 0.445\ \text{ft}$ $V\left(Q_{5'}, D_{h5}, D_{w5.1}\right) = 4.75\ \frac{\text{ft}}{\text{s}}$

Pipe 6 Node 6 to node 7 $Q_6 = Q_5 + Q_2$

$Q_{6'} := Q_{5'} + Q_{2'}$ Trial flow rate for loss coefficient estimation

$D_{h6} := 8\text{ft}$ Conduit height

$D_{w6} := 8\text{ft}$ Initial conduit width

$L_6 := 16\text{ft}$ Estimation of conduit length

Combining loss Q5 and Q2 - Used for K_{t56} and K_{t26} above

$$\frac{Q_{2'}}{Q_{5'}} = 0.684$$

Adjust losses above

$$\frac{16\text{ft}^2}{D_{h6} \cdot D_{w6}} = 0.25$$

Friction loss

$$f_6(Q) := f\left(Q, D_{h6}, D_{w6}, k_s\right) \cdot \frac{L_6}{D'\left(D_{h6}, D_{w6}\right)}$$

Combining tee loss

$Q_{7'} := Q_{6'} + Q_{1'}$ $Q_{7'} = 620 \cdot \text{cfs}$

$\frac{Q_{1'}}{Q_{7'}} = 0.484$ $\frac{D_{h1} \cdot D_{w1.2}}{64\text{ft}^2} = 0.528$

$K_{t67} := 0.45$ Miller Fig 13.11

$$H_6(Q) := \left(f_6(Q) + \alpha_k \cdot K_{t67}\right) \cdot \frac{V\left(Q, D_{h6}, D_{w6}\right)^2}{2 \cdot g}$$

$H_6\left(Q_{6'}\right) = 0.185\text{ ft}$ $V\left(Q_{6'}, D_{h6}, D_{w6}\right) = 5\,\frac{\text{ft}}{\text{s}}$

Pipe 7 Node 7 to AWS chamber

$D_{h7} := 8\text{ft}$ Conduit height

$D_{w7} := 8\text{ft}$ Initial conduit width

$L_7 := 85\text{ft}$ Estimation of conduit length

Friction

$\text{Re}\left(Q_{7'}, D_{h7}, D_{w7}\right) = 5.461 \times 10^{6}$

$f\left(Q_{7'}, D_{h7}, D_{w7}, k_s\right) = 0.012$

$$h_{f7}(Q) := f\left(Q, D_{h7}, D_{w7}, k_s\right) \cdot \frac{L_7}{D'\left(D_{h7}, D_{w7}\right)} \cdot \frac{V\left(Q, D_{h7}, D_{w7}\right)^2}{2 \cdot g}$$

$h_{f7}\left(Q_{7'}\right) = 0.193 \cdot \text{ft}$

15 deg bend loss, 1 & 2

$\frac{r}{d} = 6$

$k'_b := 0.05$ From Miller Fig. 9.7

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 0.9$ 6 diameters away, Miller Fig. 9.4

$C_f := \frac{f\left(Q_{7'}, D_{h7}, D_{w7}, k_{sr}\right)}{f\left(Q_{7'}, D_{h7}, D_{w7}, k_{ss}\right)}$ $C_f = 1.967$ From Miller Eq. 9.3

$K_{b15.1} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b15.1} = 2.125$ From Miller Eq. 9.4

$K_{b15.2} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b15.2} = 2.125$ From Miller Eq. 9.4

90 deg bend loss
90 deg bend smooth

$\frac{r}{d} = 1$

$k'_b := 0.27$ From Miller Fig. 9.7

$C_{Re} := 1.0$ From Miller Fig. 9.3

$C_o := 2.7$ Immediate outlet, Miller Fig. 9.4

$C_f := \dfrac{f\left(Q_{7'}, D_{h7}, D_{w7}, k_{sr}\right)}{f\left(Q_{7'}, D_{h7}, D_{w7}, k_{ss}\right)}$ $C_f = 1.967$ From Miller Eq. 9.3

$K_{b90} := k'_b \cdot C_{Re} \cdot C_o \cdot C_f$ $K_{b90} = 1.434$ From Miller Eq. 9.4

Exit Loss

$K_e := 1.0$

Pipe 7 Summation of losses

$$H_7(Q) := h_{f7}(Q) + \left[\alpha_k \cdot \left(K_{b15.1} + K_{b15.2} + K_{b90} + K_e\right)\right] \cdot \frac{V\left(Q, D_{h7}, D_{w7}\right)^2}{2 \cdot g}$$

$H_7\left(Q_{7'}\right) = 9.939\ \text{ft}$ $V\left(Q_{7'}, D_{h7}, D_{w7}\right) = 9.688\ \frac{\text{ft}}{\text{s}}$

Solve for available flow

Trial Flow Rates

$Q_{1'} = 300 \cdot \text{cfs}$

$Q_{2'} = 130 \cdot \text{cfs}$

$Q_{3'} = 100 \cdot \text{cfs}$

$Q_{4'} = 90 \cdot \text{cfs}$

$Q_5(Q_3, Q_4) := Q_3 + Q_4$

$Q_6(Q_3, Q_4, Q_2) := Q_2 + Q_3 + Q_4$

$Q_7(Q_1, Q_2, Q_3, Q_4) := Q_1 + Q_2 + Q_3 + Q_4$

Total available driving head

$H_a := \text{Available}$

$H_a = 12.45\,\text{ft}$

Q 5, 6 & 7 are function of flow through pipes 1, 2, 3, & 4

Set Solve Block for Equalization of Head losses

Given

$H_1(Q_{1'}) = H_2(Q_{2'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'})$

$H_1(Q_{1'}) = H_3(Q_{3'}) + H_5(Q_{3'} + Q_{4'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'})$

$H_1(Q_{1'}) = H_4(Q_{4'}) + H_5(Q_{3'} + Q_{4'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'})$

$H_2(Q_{2'}) = H_3(Q_{3'}) + H_5(Q_{3'} + Q_{4'})$

$H_2(Q_{2'}) = H_4(Q_{4'}) + H_5(Q_{3'} + Q_{4'})$

$H_3(Q_{3'}) = H_4(Q_{4'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_1(Q_{1'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'}) + H_2(Q_{2'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'}) + H_5(Q_{3'} + Q_{4'}) + H_3(Q_{3'})$

$H_a = H_7(Q_{3'} + Q_{4'} + Q_{2'} + Q_{1'}) + H_6(Q_{3'} + Q_{4'} + Q_{2'}) + H_5(Q_{3'} + Q_{4'}) + H_4(Q_{4'})$

$$\begin{pmatrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \end{pmatrix} := \text{Find}(Q_{1'}, Q_{2'}, Q_{3'}, Q_{4'})$$

$Q_1 = 317.378 \cdot \text{cfs}$ $Q_2 = 128.282 \cdot \text{cfs}$ $Q_3 = 113.131 \cdot \text{cfs}$ $Q_4 = 88.244 \cdot \text{cfs}$

$Q_5(Q_3, Q_4) = 201.375 \cdot \text{cfs}$ $Q_6(Q_3, Q_4, Q_2) = 329.657 \cdot \text{cfs}$ $\boxed{Q_7(Q_1, Q_2, Q_3, Q_4) = 647 \cdot \text{cfs}}$

Back check of the solve block

$H_1(Q_1) = 1.625\ \text{ft}$ $H_2(Q_2) + H_6(Q_3 + Q_4 + Q_2) = 1.625\ \text{ft}$

$H_3(Q_3) + H_5(Q_3 + Q_4) + H_6(Q_3 + Q_4 + Q_2) = 1.625\ \text{ft}$

$H_4(Q_4) + H_5(Q_3 + Q_4) + H_6(Q_3 + Q_4 + Q_2) = 1.625\ \text{ft}$

$H_2(Q_2) = 1.429\ \text{ft}$ $H_3(Q_3) + H_5(Q_3 + Q_4) = 1.429\ \text{ft}$

$H_4(Q_4) + H_5(Q_3 + Q_4) = 1.429\ \text{ft}$

$H_3(Q_3) = 0.929\ \text{ft}$ $H_4(Q_4) = 0.929\ \text{ft}$

$H_a = 12.45\ \text{ft}$ $H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_1(Q_1) = 12.45\ \text{ft}$

$H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_6(Q_3 + Q_4 + Q_2) + H_2(Q_2) = 12.45\ \text{ft}$

$H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_6(Q_3 + Q_4 + Q_2) + H_5(Q_3 + Q_4) + H_3(Q_3) = 12.45\ \text{ft}$

$H_7(Q_3 + Q_4 + Q_2 + Q_1) + H_6(Q_3 + Q_4 + Q_2) + H_5(Q_3 + Q_4) + H_4(Q_4) = 12.45\ \text{ft}$

From Additional Culvert

$$Q := \begin{pmatrix} 540 \\ 550 \\ 560 \\ 570 \\ 580 \\ 590 \\ 600 \\ 610 \\ 620 \\ 630 \\ 640 \\ 650 \\ 660 \\ 670 \\ 680 \\ 690 \\ 700 \\ 710 \\ 720 \\ 730 \\ 740 \\ 750 \\ 760 \\ 770 \\ 780 \\ 790 \\ 800 \end{pmatrix} \qquad HW_c := \begin{pmatrix} 98.2 \\ 98.3 \\ 98.5 \\ 98.6 \\ 98.76 \\ 98.9 \\ 99 \\ 99.2 \\ 99.36 \\ 99.52 \\ 99.68 \\ 99.839 \\ 100 \\ 100.16 \\ 100.33 \\ 100.5 \\ 100.68 \\ 100.86 \\ 101.03 \\ 101.2 \\ 101.4 \\ 101.6 \\ 101.77 \\ 101.96 \\ 102.16 \\ 102.35 \\ 102.55 \end{pmatrix}$$

Headwater and flow rate taken from New Conduit from FLAC to AWSC.xcmd. Culverts operate under inlet control over entire range of flow rates. A splining function is used to generate a flow rate as a function of headwater. This will be used inconjuction with the 8 x 8 culvert computations above to identify water surface elevations given varying tailrace conditions.

For any variation in New Conduit from FLAC to AWSC design, Q and HW_c needs to be redeveloped.

$$ORIGIN := 1$$

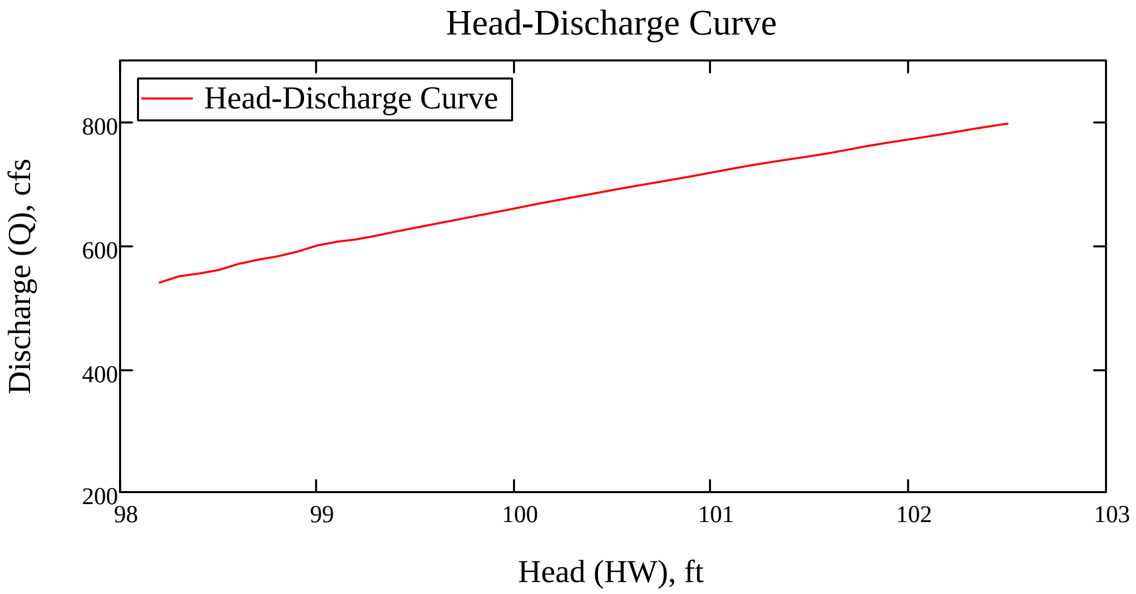
$$Data^{\langle 1 \rangle} := HW_c \quad Data^{\langle 2 \rangle} := Q$$

$$data := csort(Data, 1)$$

$$HW_c := data^{\langle 1 \rangle} \qquad Q := data^{\langle 2 \rangle}$$

$$S := cspline\left(HW_c, Q\right) \qquad Q_{6fit}(x) := interp\left(S, HW_c, Q, \frac{x}{ft}\right) cfs \qquad x := 98.2ft, 98.3ft .. 102.5ft$$

Project Title: Dalles EFL Emergency AWS FLAC to AWS Chamber via 8X8 Box Culver	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery



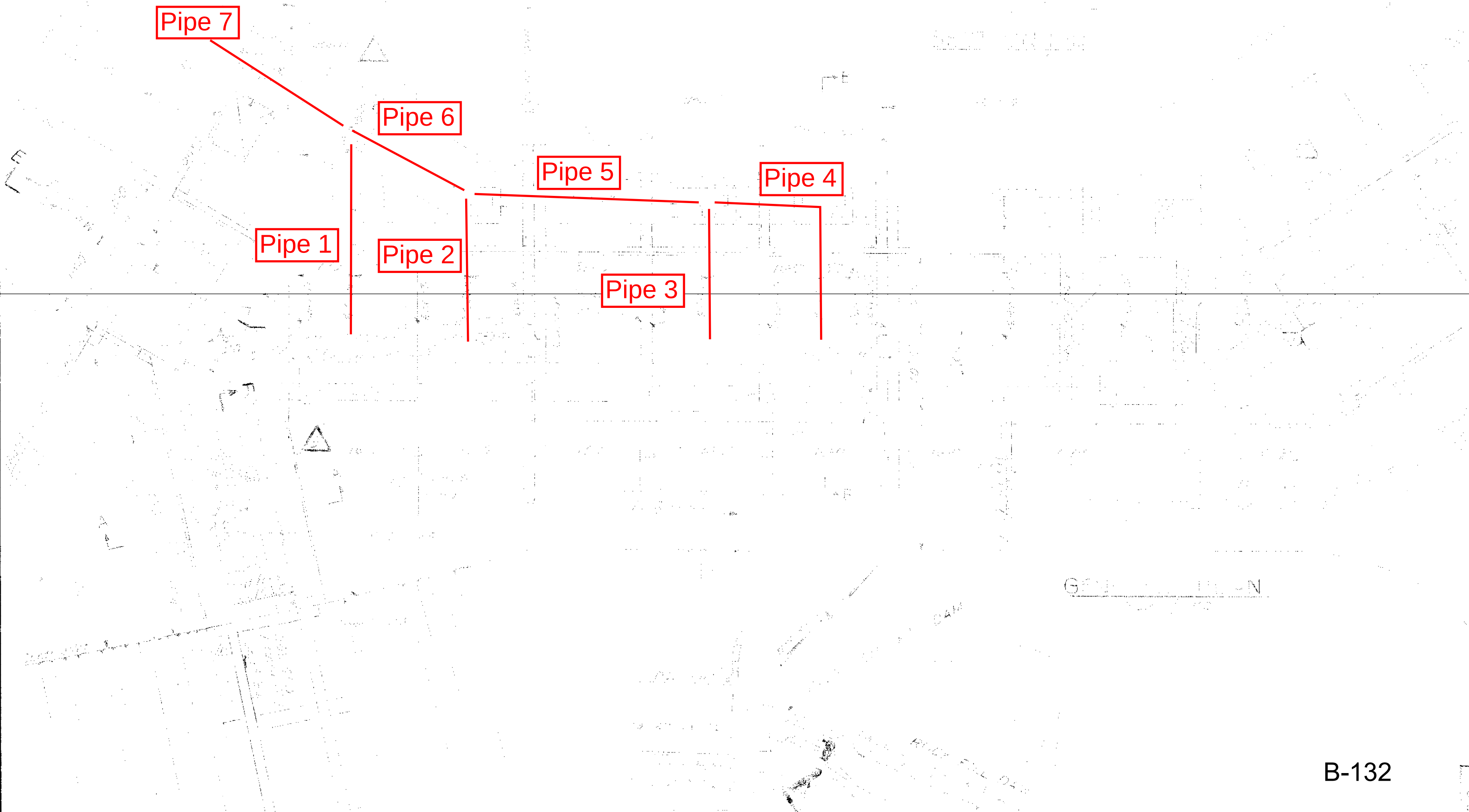
$Q_{8x8} := Q_7(Q_1, Q_2, Q_3, Q_4)$

$Q_{6fit}(HW) = 752.88 \cdot cfs$

$Q_{total} := Q_{8x8} + Q_{6fit}(HW)$

$\boxed{Q_{total} = 1400 \cdot cfs}$

Network overlay for FLAC to AWS Chamber via 8 by 8 AWS Box Culvert



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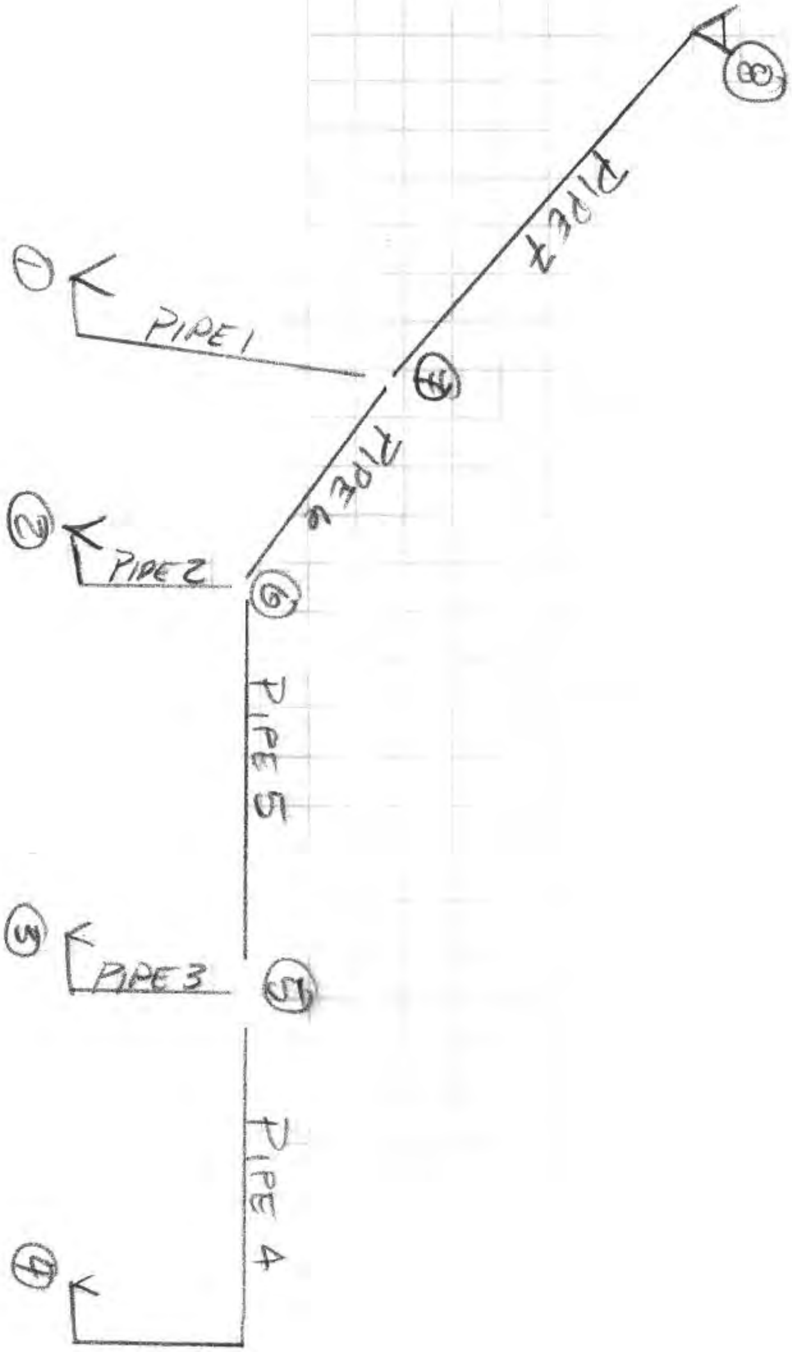
ESC DIVISION H BRANCH HYDRAULICS SECTION

PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' AWS BOX CULVERT & HEADER/INTAKE

BY DATE CHECKED PART PAGE OF



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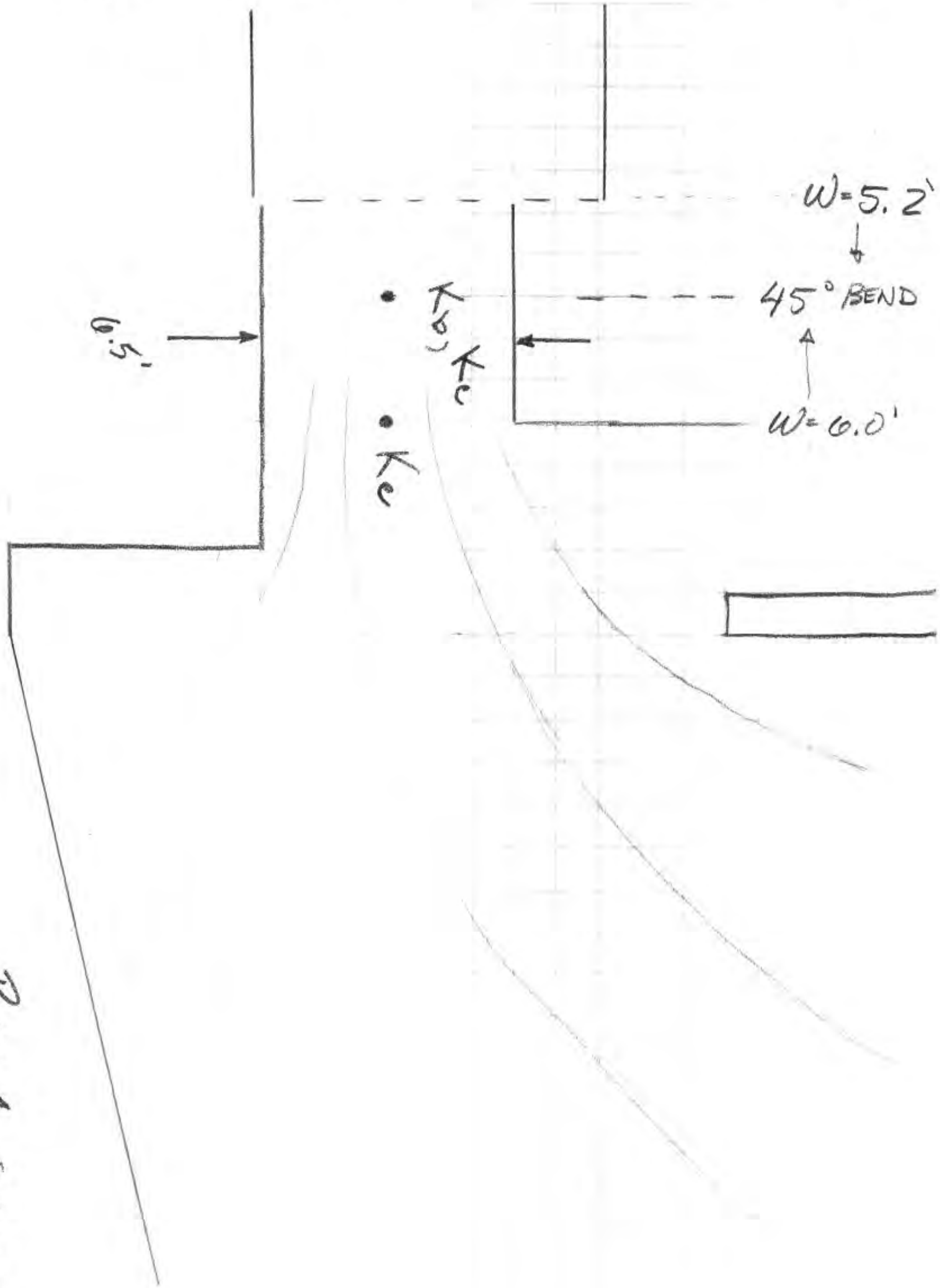
DIVISION **BRANCH** **SECTION**

PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' AWS BOX CULVERT & INTAKE

BY **DATE** **CHECKED** **PART** **PAGE** **OF**



PIPE 1 DIAGRAM

NPD Form 7A
June 1962

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RP
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PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' BOX CULVERT & INTAKE

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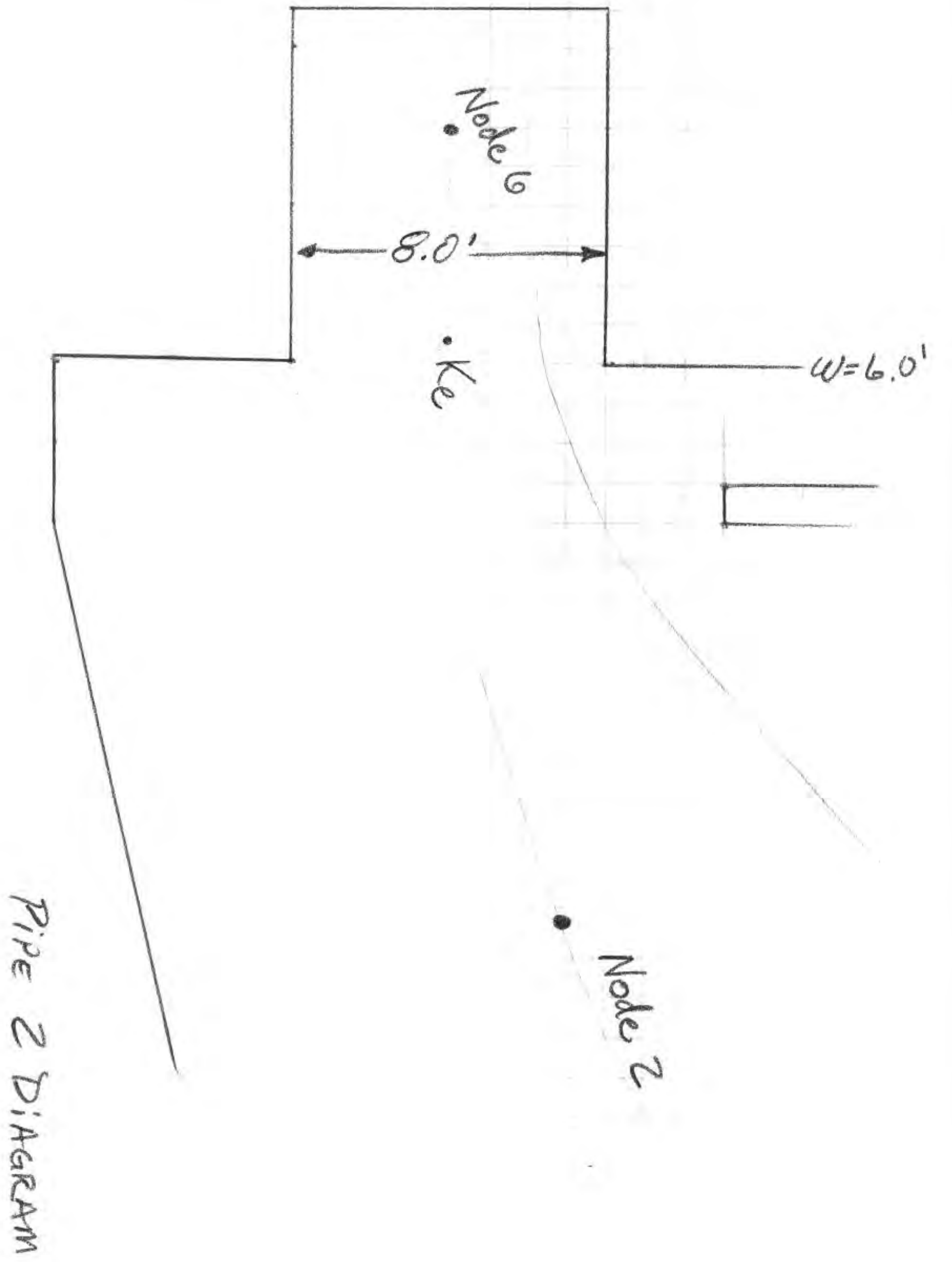

NPD Form June 1962 7A

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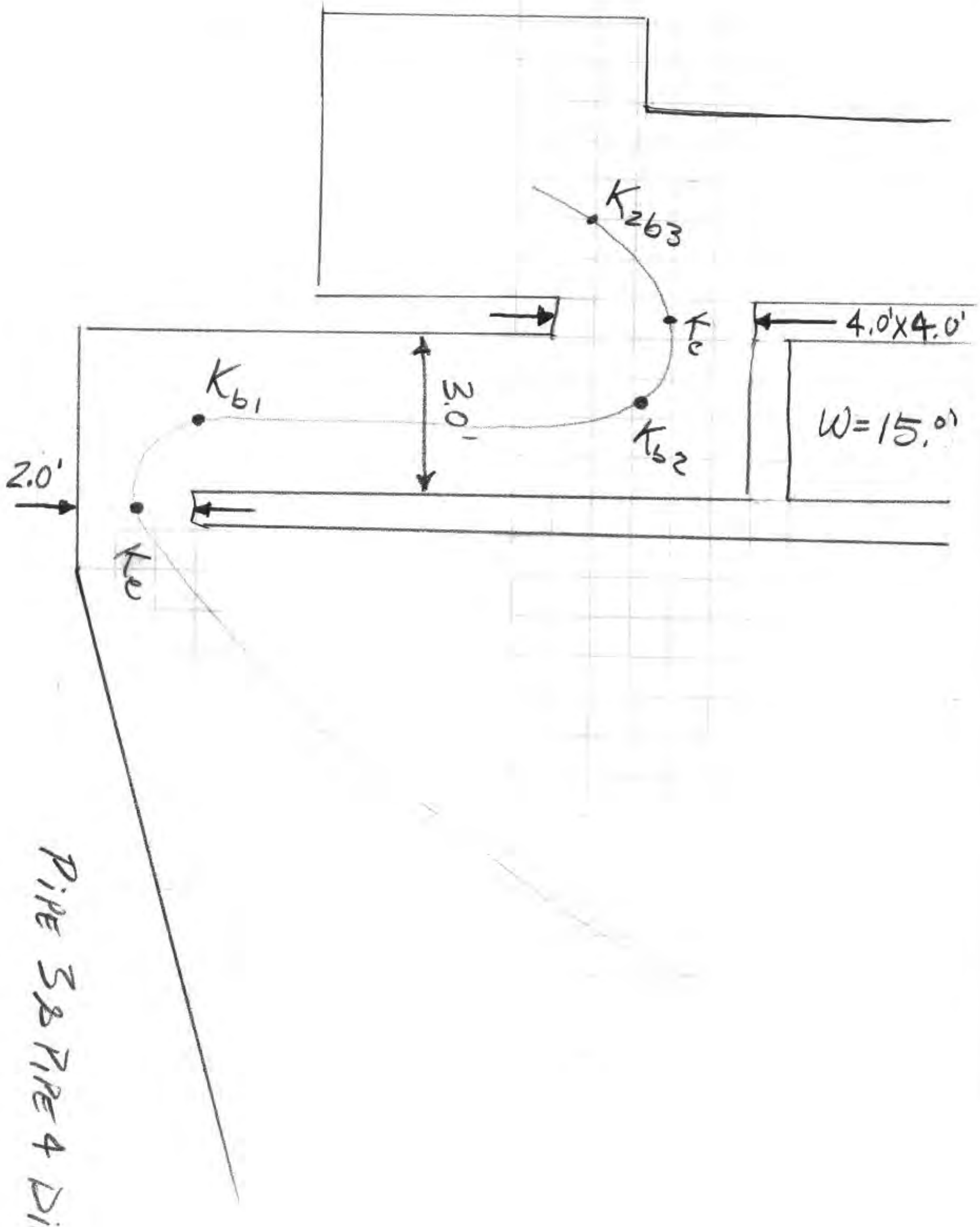
PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' AWS BOX CULVERT & INTAKE

BY DATE CHECKED PART PAGE OF



PIPE 3 & PIPE 4 DIAGRAM

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DIVISION BRANCH SECTION

PROJECT DALLES EFL EMERGENCY AWS
SUBJECT 8' X8' AWS BOX CULVERT & INTAKE
BY DATE CHECKED PART PAGE OF

WATER SURFACE ELEVATION

NODE	WSE	
1	102.5'	
2	102.5'	MAX HEAD AV = 12.0'
3	102.5'	
4	102.5'	
8	90.5' MAX	

HEAD LOSS EQUALITIES

$H_{L1} = H_{L2} + H_{L6}$ ①

$= H_{L3} + H_{L5} + H_{L6}$ ②

$= H_{L4} + H_{L5} + H_{L6}$ ③

$H_{L2} = H_{L3} + H_{L5}$ ④

$= H_{L4} + H_{L5}$ ⑤

$H_{L3} = H_{L4}$ ⑥

MAX HEAD AV. = 12.0 ft

$= H_{L7} + H_{L1}$ ⑦

$= H_{L7} + H_{L6} + H_{L2}$ ⑧

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PROJECT DALLES EFL EMERGENCY AWS

SUBJECT 8'X8' AWS BOX CULVERT & INTAKE

BY DATE CHECKED PART PAGE OF

$= H_{L7} + H_{L6} + H_{L5} + H_{L3}$ ⑨

$= H_{L7} + H_{L6} + H_{L5} + H_{L4}$ ⑩

Project Title: Dalles EFL Emergency AWS Cavitation Check for Full Flow Thru 8X8 Culvert	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

Custom Units Definition

$fps := ft \cdot s^{-1}$ feet per second

$cfs := ft^2 \cdot fps$ cubic feet per second

Fluid Properties

$\rho := 1000 \frac{kg}{m^3}$ $\gamma := 62.41 \frac{lbf}{ft^3}$

Assumed temperature deg. F

$T_f := 50$ $T_c := (T_f - 32) \cdot \frac{5}{9}$ $T_c = 10$ Temp. deg. C

$$\nu := \frac{1.792 \cdot 10^{-6}}{1.0 + \left(0.0337 \cdot T_c + 0.000221 \cdot T_c^2\right)} \cdot \frac{m^2}{s}$$

$\nu = 1.319 \times 10^{-6} \cdot \frac{m^2}{s}$ Kinematic viscosity of water from temp. relationship

Global Functions

Area function

$A(d) := d^2$

Reynolds number

$Re(Q,d) := \frac{Q \cdot d}{A(d) \cdot \nu}$

Average velocity

$V(Q,d) := \frac{Q}{A(d)}$

Jain's equation for friction factor

$$f(Q,d,k_s) := \frac{0.25}{\log\left(\frac{k_s}{3.7 \cdot d} + \frac{5.74}{Re(Q,d)^{0.9}}\right)^2}$$

Ref: Swamee and Jain, 1976, "Explicit equations for pipe-flow problems," Journal of Hydr. Div. ASCE, Vol. 102, No. HY5, pp. 657-664

Project Title: Dalles EFL Emergency AWS Cavitation Check for Full Flow Thru 8X8 Culvert	6/1/2013	By: Logan Negherbon Checked By: Ryan Laughery

$Q := 1400 \frac{ft^3}{s}$ Target flowrate for 8-ft by 8-ft culvert

$D := 8ft$ Characteristic dimension/diameter of the culvert

$R := 7ft$ Radius of curvature at upwell

$\frac{R}{D} = 0.875$

$V := \frac{Q}{A(D)}$ $V = 21.875 \cdot fps$ Velocity of 1400 cfs through the culvert

$AWS_{ws} := 79.6ft$ Minimum water surface elevation in Auxiliary Water Supply chamber

$FAC_{ws} := 102.5ft$ Maximum water surface elevation in Fishlock Approach Channel

$Ele_{bend} := 50.0ft$ Elevation of centerline at 90 degree turn into AWS

$h_{max} := FAC_{ws} - Ele_{bend}$ $h_{max} = 52.5\,ft$ Maximum available head at bend $h_{pmax} := h_{max} \cdot \gamma$ $h_{pmax} = 22.754\,psi$

$h_{min} := AWS_{ws} - Ele_{bend}$ $h_{min} = 29.6\,ft$ Minimum available head at bend $h_{pmin} := h_{min} \cdot \gamma$ $h_{pmin} = 12.829\,psi$

$h_v := 0.18psi$ Vapor pressue of water at assumed temperature

Cavitation parameter with extreme minimum head

$$\sigma_{bmin} := \frac{h_{pmin} - h_v}{\gamma \cdot \frac{V^2}{2 \cdot g}} \qquad \sigma_{bmin} = 3.925$$

Cavitation parameter with extreme maximum head

$$\sigma_{bmax} := \frac{h_{pmax} - h_v}{\gamma \cdot \frac{V^2}{2 \cdot g}} \qquad \sigma_{bmax} = 7.004$$

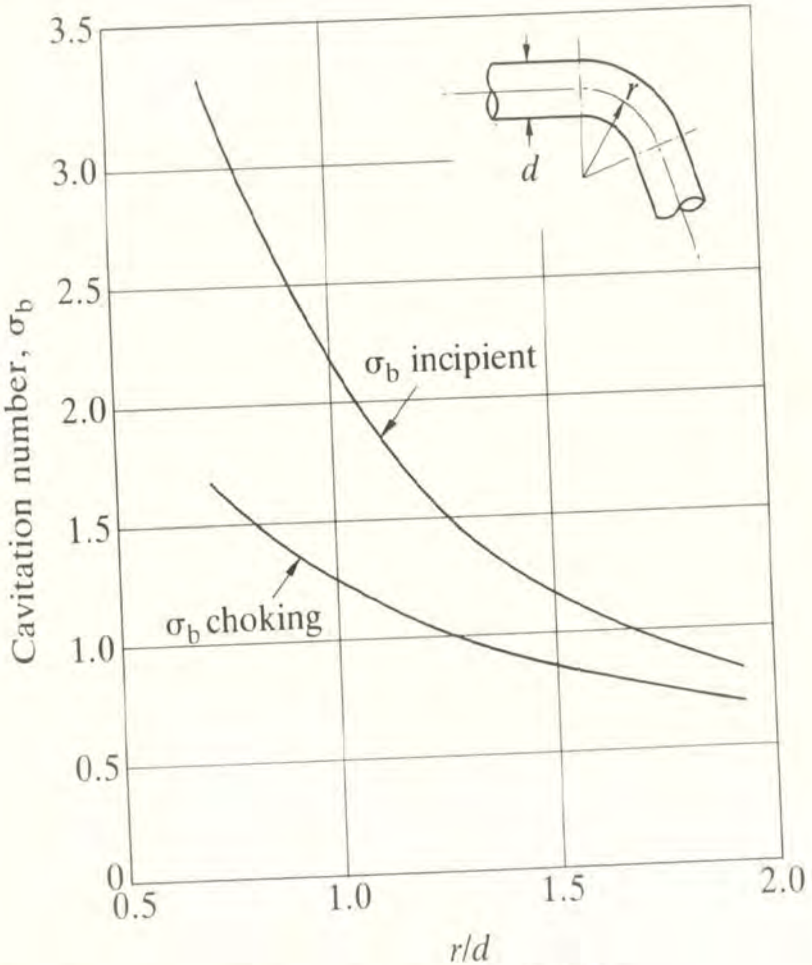


Fig. 6.10. Cavitation parameter for bends

The ratio of the radius of curvature (r) to the characteristic diameter (d) is approximately 0.85 at the upwell into the AWSC. No friction losses are accounted for in the maximum cavitation parameter potential. The minimum potential cavitation parameter lies abover the incipient cavitation curve. This assumption applies all friction losses and is conservative; however, the true cavitation parameter is likely to be closer to the minumum cavitation parameter provided as the majority of the head losses through the conduit will occur upstream of this bend.

Figure from D.S. Miller's *Internal Flow Systems*

From Corps Guidance

$C := \frac{D}{2}$ $C = 4\ \text{ft}$ Half of the characteristic diameter

$R = 7\ \text{ft}$ Radius of curvater at centerline

$$C_p := \left[\frac{2}{\left(\frac{R}{C}-1\right)\cdot\ln\left(\frac{\frac{R}{C}+1}{\frac{R}{C}-1}\right)}\right]^2 - 1$$

$C_p = 3.212$ Minimum pressure guidance for bends (EM 1110-2-1602 Plate C-20)

$\sigma_{bmin} = 3.925$ $\sigma_{bmax} = 7.004$

As the actual conditions are likely to be closer to the minumum cavitation parameter given the majority of the head losses through the conduit will occur upstream of this bend. The guidance is for circular conduits and do not account for localized pressure differentials at the corners. This preliminary calculation is for the rounded vertical turn into the upwell and does not take into account the abrupt ~30 degree horizontal bend (DDF-1-4-5/V13) which is likely to induce greater cavitation potential.

The Dalles East Fish Ladder Auxiliary Water Backup System

60 Percent Design Documentation Report

APPENDIX C

Structural

U.S. ARMY CORPS OF ENGINEERS OFFICE SYMBOL:

PROJECT:	**COMPUTED BY:**	**DATE:**
SUBJECT: Cul-de-sac Logs	**CHECKED BY:**	**SHT.** 1 **OF** 2 **PART:**

Cul de sac enterana closure.

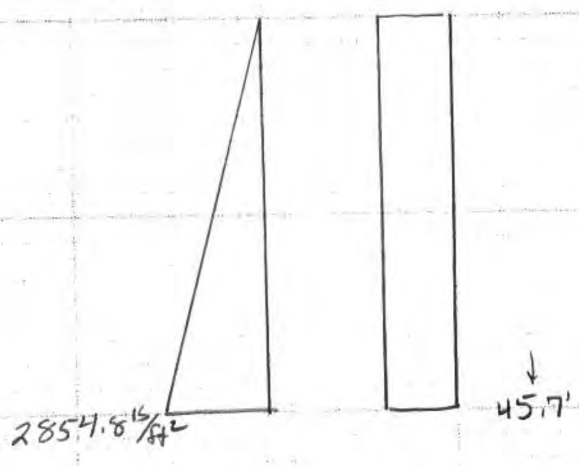
1) use ~~concrete~~ precast concrete logs grout in place.

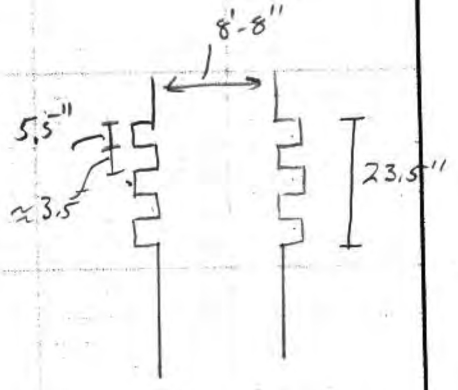
Ref. DDF-1-4-4/5 DDF-1-4-4/27

$\Delta water = 104.25 - 58.5 \Rightarrow 45.75'$

use weir B as a guide

EM 1110-2-2104 ref.





make logs 23½" Thick to fit in wier slot - grout in place

$w = \underline{2854.8 \, lb/ft^2 (2')} = 5709 \, lb/ft$

$M_u = \frac{wl^2}{8} = \frac{(5709 \frac{lb}{ft})(8.67ft)^2}{8} \overset{\text{water factor}}{(1.4)} \overset{\text{EM factor}}{(1.3)}$

$M_u = 53642 \text{ - lb-ft} \Rightarrow \underline{\underline{53.64 \text{ k-ft}}} = 644 \text{ k-in}$

$V_u = \frac{wl}{2} = \frac{2854.8(8.67)}{2} = 12.6^k$

8 GRID

U.S. ARMY CORPS OF ENGINEERS OFFICE SYMBOL:

PROJECT:	**COMPUTED BY:**	**DATE:**
SUBJECT: Cul-de-Sac Logs	**CHECKED BY:**	**SHT.** 2 **OF** 2 **PART:**

Calc Flexure.

assume 4" cover.

$$M_n = \phi A_s f_y \left(d - \frac{a}{2}\right) = (.9)(A_s)(60 ksi)\left(19.5 - \frac{A_s(60 ksi)}{(.85)(4 ksi)(24")}\frac{1}{2}\right)$$

$M_u = M_n$
644 k-in

$A_{s_{req}} = 0.619 in^2$ ∴ minimal temp + shrink. Req

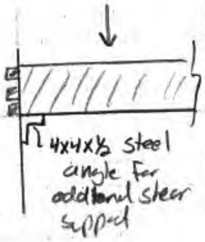
Will work for 30% DDR - can make work for 100% design

Could go thiner and save some concrete.

$\forall$ of concrete.

$$\left(\frac{23.5}{12}\right)(8.667')(45.7') = 775 ft^3 \Rightarrow 29 yd.$$

$wt = 755 ft^3 (150 lb/ft) = 116.250 lb$


4x4x½ steel angle for additional shear support

Number of logs # N	D (kips)	kips Wt/log	
5	9.1	23.2 k	⇒ 11.6 Tons
6	7.6	19.3	⇒ 9.65 Tons
7	6.5	16.5	⇒ 8.25 Tons
8	5.7	14.5	⇒ 7.25 Tons

← choose - less than 10 Tons - crane can setup on opposite side and boom 35-40 ft and should have capacity - note could put Notes on drawing that contractor determines height of logs to best fit there cranes

concrete only

$V_c = 2\sqrt{f'_c}\, b\, d$

$= 2\sqrt{4000}(24")(19.5")$

$= 29.5^k \Rightarrow$ Shear is ok.

$V_c = 2\sqrt{f'_c}(24')(5")$
4000

$= 15$ kips.

if assume 1-5" wier w/o rebar - shear is ok - but would add steel angle to be safe.

8 GRID

Design Criteria:

Ref 1- EM 1110-2-2105-Design hof Hydraulic Steel Structures
Ref 2- EM 1110-2-2701-Vertical Lift Gates
Ref 3-EM 1110-2-2703-Lock Gates and Operating Equipment
Ref 4-AISC 360-05 Steel Construction Manual

This calc check flexure for a simple support beam (built up girder)- for the gate will need to check moments at ends due to guide wheels loading.

Note: Applied EM HSS factors at end.

Material - Steel ASTM A709 Gr. 50. Zone 2

$F_y := 50 \cdot ksi$

$F_u := 65 \cdot ksi$

$E := 29000 \cdot ksi$

$\alpha := 0.85$ — *There is a redundant system to stop water. Diffuser valve.*

$\phi_b := 0.9$ — *Flexural reduction factor*

$F_{lim} := \alpha \cdot \phi_b \cdot F_y = 38.25 \cdot ksi$ — *Ref 1 eqn B-5*

$H := 70 \cdot ft$ — *Design Hydraulic head-max head*

$a := 32 \cdot in$ — *Girder Spacing*

$b := 10 \cdot ft$ — *Stiffener Spacing (Intercostal)*

$t_s := 0.75 \cdot in$ — *Skinplate Thickness*

$$W := H \cdot 62.4 \cdot pcf = 4.4 \times 10^3 \cdot \frac{lbf}{ft^2}$$

$$t_{min} := \sqrt{\frac{0.5 \cdot W \cdot b^2}{F_{lim} \cdot \left[1 + 0.623 \left(\frac{b}{a}\right)^6\right]}} = 0.057 \cdot in$$

Ref 1 eqn B-5

$$Skin\_Plate\_Thickness\_is := \begin{cases} \text{"OK"} & \text{if } t_s \geq t_{min} \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$$\delta_s := \frac{0.0284 \cdot W \cdot b^4}{\left[1 + 1.056 \left(\frac{b}{a}\right)^5\right] \cdot E \cdot t_s^3} = 0.019 \cdot in$$

Ref 1 eqn Section B-3(b)

$$\delta_2 := \frac{0.0065 \cdot W \cdot 12 \cdot in \cdot a^4}{E \cdot \frac{1}{12} \cdot 12 \cdot in \cdot t_s^3} = 0.203 \cdot in$$

Based on skin plate spanning 4 members, displacement from AISC 360-05 Table 3-23 Deflection for 4 equal loaded spans assumes 1 foot distributed width with no stiffeners.

$\Delta_{smax} := 0.4 \cdot t_s = 0.3 \cdot in$ *Max Skinplate Deflection* *Ref 2 eqn Section 3-6(b)*

$$D_{skin\_is} := \left| \begin{array}{l} \text{"OK"} \quad \text{if } \delta_s \le \Delta_{smax} \\ \text{"Not OK"} \quad \text{otherwise} \end{array} \right. = \text{"OK"}$$

Applied loads

$L := 14.5 \cdot ft$

$$M_u := \frac{W \cdot a \cdot L^2}{8} = 306.124 \cdot kip \cdot ft$$

Determine the N. A., Flange of T as base line.

Will build a WT out of Plate- Value will be close to WT prosperities in Code.

$$\frac{b}{t} = 0.38 \cdot \sqrt{\frac{E}{F_y}}$$

$$b_s := 2 \cdot t_s \cdot 0.38 \sqrt{\frac{E}{F_y}} = 13.727 \cdot in$$

effective width of skip plate while keeping compact criteria. *Ref 4 Table B4.1 Case 2 Compact member*

$A_{sp.eff} := b_s \cdot t_s = 10.296 \cdot in^2$ *effective skinplate area that will act as a built up member*

$b_{fc} := 10 \cdot in$ *Compression Flange*

$t_{fc} := (1) \cdot in$

$b_{ft} := b_s = 13.727 \cdot in$ *Tension Flange Skin Plate, b.ft will be governed by skinplate effective width*

$t_{ft} := t_s = 0.75 \cdot in$

$h := 16 \cdot in$ *Web*

$t_w := \frac{1}{2} \cdot in$

$d := h + t_{fc} + t_{ft} = 17.75 \cdot in$ *Solving for Modulus of elasticity*

$A_{fc} := b_{fc} \cdot t_{fc} = 10 \cdot in^2$

$d_w := d - t_{fc} - t_{ft} = 16 \cdot in$

$A_w := d_w \cdot t_w = 8 \cdot in^2$

$A_{ft} := b_{ft} \cdot t_{ft} = 10.296 \cdot in^2$

$A_{fc} := b_{fc} \cdot t_{fc} = 10 \cdot in^2$

$A_g := A_{ft} + A_{fc} + A_w = 28.296 \cdot in^2$

$$Y_{bar} := \frac{A_{fc}\cdot\left(\frac{t_{fc}}{2}\right) + A_w\cdot\left(\frac{h}{2} + t_{fc}\right) + A_{ft}\cdot\left(\frac{t_{ft}}{2} + h + t_{fc}\right)}{A_g} = 9.043\cdot in$$

Neutral Axis of built-up member, calculated from compression flange

$$I_w := \frac{1}{12}\cdot t_w\cdot h^3 + A_w\cdot\left(\frac{h}{2} + t_{fc} - Y_{bar}\right)^2 = 170.7\cdot in^4$$

$$I_{fc} := \frac{1}{12}\cdot b_{fc}\cdot t_{fc}{}^3 + A_{fc}\cdot\left(Y_{bar} - \frac{t_{fc}}{2}\right)^2 = 730.7\cdot in^4$$

$$I_{ft} := \frac{1}{12}\cdot b_{ft}\cdot t_{ft}{}^3 + A_{ft}\cdot\left(d - Y_{bar} - \frac{t_{ft}}{2}\right)^2 = 715.2\cdot in^4$$

$$I_x := I_w + I_{fc} + I_{ft} = 1616.6\cdot in^4$$

Built-up member modulus of elasticity

$$S_{xt} := \frac{I_x}{d - Y_{bar}} = 185.7\cdot in^3$$

$$S_{xc} := \frac{I_x}{Y_{bar}} = 178.8\cdot in^3$$

Plastic Section Modulus of elasticity for composite shape

$$Z = A_{wt}\cdot d_1 + A_{wc}\cdot d_2 + A_{ft}\cdot d_3 + A_{fc}\cdot d_4$$

Find PNA Where Area Compression = Area Tension This is the center of the built up shape based on Area

Given

$x := 2\cdot in$

$$\frac{A_g}{2} = 14.148\cdot in^2$$

$$\frac{A_g}{2} - A_{fc} - t_w\cdot x = 0$$

$x := Find(x) = 8.296\cdot in$

$x = 8.296\cdot in$

$Y_{bar.pna} := x + t_{fc} = 9.296\cdot in$ *Distance from edge of compression flange to PNA*

$$d_1 := \frac{d_w - x}{2} = 3.852\cdot in$$

$$d_2 := \frac{x}{2} = 4.148\cdot in$$

$$d_3 := 2\cdot d_1 + \frac{t_{ft}}{2} = 8.079\cdot in$$

$$d_4 := 2\cdot d_2 + \frac{t_{fc}}{2} = 8.796\cdot in$$

$$A_{wt} := 2d_1 \cdot t_w = 3.852 \cdot in^2$$

$$A_{wc} := 2 \cdot d_2 \cdot t_w = 4.148 \cdot in^2$$

$$Z_{xpna} := A_{wt} \cdot d_1 + A_{wc} \cdot d_2 + A_{ft} \cdot d_3 + A_{fc} \cdot d_4 = 203.18 \cdot in^3$$

$$Z_x := Z_{xpna}$$

Check limiting Width- Thickness Ratios for compression members Table B4.1

$$K_c := \frac{4}{\sqrt{\frac{h}{t_w}}} \qquad K_c = 0.707 \qquad k_c := \begin{vmatrix} 0.35 & \text{if } K_c < 0.35 \\ 0.76 & \text{if } K_c > 0.76 \\ K_c & \text{otherwise} \end{vmatrix} \qquad k_c = 0.707$$

$$\boxed{\frac{S_{xt}}{S_{xc}} = 1.039}$$

$$F_L := 0.7 \cdot F_y \qquad F_L = 35 \cdot ksi$$

Reference foot note on AISC Table B4.1,
Major axis bending of slender-web built up I shaped members

Flange limiting thickness ratio,
unstiffened element

$$\lambda_{fc} := \frac{b_{fc}}{2t_{fc}} \qquad \lambda_{fc} = 5$$

$$\lambda_{ft} := \frac{b_{ft}}{2t_{ft}} \qquad \lambda_{ft} = 9.152$$

Table B4.1   Case 2

$$\lambda_{pf} := 0.38 \cdot \sqrt{\frac{E}{F_y}} \qquad \lambda_{pf} = 9.152$$ *compact*

$$\lambda_{rf} := 0.95 \cdot \sqrt{\frac{E \cdot k_c}{F_L}} \qquad \lambda_{rf} = 22.995$$ *noncompact*

Web limiting thickness ratio,
stiffened element

Table B4.1   Case 11

$$h_c := 2 \cdot \left(Y_{bar} - t_{fc}\right) \qquad h_c = 16.087 \cdot in$$

Twice the distance from the centroid to the inside face of the compression flange   Ref. B4.2(b)

$$h_p := 2\left(Y_{bar.pna} - t_{fc}\right) = 16.591 \cdot in$$

Twice the distance from the PNA to the inside face of the compression flange   Ref. B4.2(b)

$$M_p := \begin{vmatrix} Z_x \cdot F_y & \text{if } Z_x \cdot F_y \le 1.6 \cdot S_{xc} \cdot F_y \\ 1.6 \cdot S_{xc} \cdot F_y & \text{otherwise} \end{vmatrix} \qquad M_p = 846.6 \cdot kip \cdot ft$$

$$M_{yc} := F_y \cdot S_{xc} \qquad M_{yc} = 744.8 \cdot kip \cdot ft$$

$$\lambda_w := \frac{h_c}{t_w} \qquad \lambda_w = 32.173 \qquad \lambda_{rw} := 5.70 \cdot \sqrt{\frac{E}{F_y}} \qquad \lambda_{rw} = 137.3$$ *noncompact*

$$\lambda pw := \frac{\frac{h_c}{h_p} \cdot \sqrt{\frac{E}{F_y}}}{\left(0.54 \frac{M_p}{M_{yc}} - 0.09\right)^2} \qquad \lambda pw = 85.1$$ *compact*

$$\lambda_{pw} := \min\left(\lambda pw, \lambda_{rw}\right) \qquad \lambda_{pw} = 85.115$$

Check Compression Flange

$$\text{Compression\_Flange\_is\_} := \begin{cases} \text{"Compact"} & \text{if } \lambda_{fc} < \lambda_{pf} \\ \text{"Noncompact"} & \text{if } \lambda_{pf} < \lambda_{fc} \le \lambda_{rf} \\ \text{"Slender Elements"} & \text{otherwise} \end{cases} = \text{"Compact"}$$

$\text{Compression\_Flange\_is\_} = \text{"Compact"}$

Check Web

$$\text{Web\_is\_} := \begin{cases} \text{"Compact"} & \text{if } \lambda_{w} < \lambda_{pw} \\ \text{"Noncompact"} & \text{if } \lambda_{pw} < \lambda_{w} \le \lambda_{rw} \\ \text{"Slender Elements"} & \text{otherwise} \end{cases} = \text{"Compact"}$$

$\text{Web\_is\_} = \text{"Compact"}$

$\text{Web\_is\_} = \text{"Compact"}$

From Table F1.1 - AISE Section F4
Check:
1. (Y) Yielding (compression flange yielding) Section F4.1
2. (LTB) Lateral torsional buckling Section F4.2
3. (FLB) Flange Local Buckling Section F4.3
4. (TFY) tension flange yielding Section F4.4

Calculate the plastification factor corresponding to compression:

$Z_x \cdot F_y = 846.6 \cdot \text{kip} \cdot \text{ft} \qquad 1.6 \cdot S_{xc} \cdot F_y = 1191.7 \cdot \text{kip} \cdot \text{ft}$

$$M_p := \begin{cases} Z_x \cdot F_y & \text{if } Z_x \cdot F_y \le 1.6 \cdot S_{xc} \cdot F_y \\ 1.6 \cdot S_{xc} \cdot F_y & \text{otherwise} \end{cases} \qquad M_p = 846.6 \cdot \text{kip} \cdot \text{ft}$$

$M_{yc} := F_y \cdot S_{xc} \qquad M_{yc} = 744.8 \cdot \text{kip} \cdot \text{ft}$ *Eqn (F4-4)*

$$Rpc := \left[\frac{M_p}{M_{yc}} - \left(\frac{M_p}{M_{yc}} - 1 \right) \left(\frac{\lambda_w - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}} \right) \right] \qquad Rpc = 1.275$$ *Eqn (F4-9b)*

$$R_{pc} := \begin{cases} Rpc & \text{if } Rpc \le \dfrac{M_p}{M_{yc}} \\ \dfrac{M_p}{M_{yc}} & \text{otherwise} \end{cases} \qquad R_{pc} = 1.137$$

1. (Y) Yielding (compression flange yielding) Section F4.1

$M_{n.y} := R_{pc} \cdot F_y \cdot S_{xc} \qquad M_{n.y} = 846.6 \cdot \text{kip} \cdot \text{ft}$ *Eqn (F4-1)*

2. (LTB) Lateral torsional buckling Section F4.1

$$a_w := \frac{h_c \cdot t_w}{b_{fc} \cdot t_{fc}} = 0.804$$ *Eqn (F4-11)*

$$h_o := d - \frac{t_{fc}}{2} - \frac{t_{ft}}{2} = 16.875 \cdot in$$ *Distance between flange centroids*

$$r_t := \frac{b_{fc}}{\sqrt{12\left(\frac{h_o}{d} + \frac{1}{6} \cdot a_w \cdot \frac{h^2}{h_o \cdot d}\right)}} = 0.233\,ft$$ *Eqn (F4-10)*

$$L_p := 1.1 \cdot r_t \cdot \sqrt{\frac{E}{F_y}} = 6.175\,ft$$

$$r_{st} := \frac{b_{fc}}{\sqrt{12 \cdot \left(1 + \frac{1}{6} \cdot \frac{h\,t_w}{b_{fc} \cdot t_{fc}}\right)}} = 2.712 \cdot in$$

$$L_r := \pi \cdot r_{st} \cdot \sqrt{\frac{E}{0.7 \cdot F_y}} = 20.435 \cdot ft$$ *Section F4.2(b)*

$C_b := 1.0 \qquad L_b := L$

$$LTB := \left| \begin{array}{ll} \text{"Eqn F4-2"} & \text{if } L_p < L_b < L_r \\ \text{"Change"} & \text{otherwise} \end{array} \right. = \text{"Eqn F4-2"}$$

$$M_{n.LTB.F4.2} := C_b \cdot \left[R_{pc} \cdot M_{yc} - \left(R_{pc} \cdot M_{yc} - F_L \cdot S_{xc}\right) \cdot \left(\frac{L_b - L_p}{L_r - L_p}\right)\right] = 656.7 \cdot kip \cdot ft$$ *Eqn (F4-2)*

$$M_{n.LTB} := \min\left(M_{n.LTB.F4.2}, R_{pc} \cdot M_{yc}\right) = 656.7 \cdot kip \cdot ft$$

3. (FLB) Flange Local Buckling (compression flange local buckling) Section F4.1

$$F_L := \left| \begin{array}{ll} 0.7 \cdot F_y & \text{if } \frac{S_{xt}}{S_{xc}} \geq 0.7 \\ F_y \cdot \frac{S_{xt}}{S_{xc}} & \text{if } \frac{S_{xt}}{S_{xc}} < 0.7 \end{array} \right.$$ *Eqn (F4-6a)* *Eqn (F4-6b)*

$F_L = 35 \cdot ksi$

$$M_{n.FLB.F4.12} := \left[R_{pc} \cdot M_{yc} - \left(R_{pc} \cdot M_{yc} - F_L \cdot S_{xc}\right)\left(\frac{\lambda_{fc} - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right]$$ *Eqn (F4-12)*

$$M_{n.FLB.F4.13} := \frac{0.9 \cdot E \cdot k_c \cdot S_{xc}}{\lambda_{fc}^{\,2}}$$

$M_{n.FLB.F4.12} = 944.1 \cdot kip \cdot ft$

$M_{n.FLB.F4.13} = 10996.9 \cdot kip \cdot ft$ *Eqn (F4-12)*

Compression_Flange_is_ = "Compact"

$$M_{n.FLB} := \left| \begin{array}{l} \text{"Does not apply"} \quad \text{if Compression\_Flange\_is\_} = \text{"Compact"} \\ M_{n.FLB.F4.12} \quad \text{if Compression\_Flange\_is\_} = \text{"Noncompact"} \\ M_{n.FLB.F4.13} \quad \text{if Compression\_Flange\_is\_} = \text{"Slender Elements"} \end{array} \right. \qquad M_{n.FLB} = \text{"Does not apply"} \cdot kip \cdot ft$$

$M_{n.FLB} = \text{"Does not apply"} \cdot kip \cdot ft$

4. (TFY) tension flange yielding Section F4.4

Calculate the plastification factor corresponding to tension:

$M_{yt} := S_{xt} \cdot F_y \qquad M_{yt} = 773.6 \cdot kip \cdot ft$

$$Rpt := \left[\frac{M_p}{M_{yt}} - \left(\frac{M_p}{M_{yt}} - 1 \right) \left(\frac{\lambda_w - \lambda_{pw}}{\lambda_{rw} - \lambda_{pw}} \right) \right] \qquad Rpt = 1.19$$

Eqn (F4-15b)

$$R_{pt} := \left| \begin{array}{l} Rpc \quad \text{if } Rpc \le \frac{M_p}{M_{yt}} \\ \frac{M_p}{M_{yt}} \quad \text{otherwise} \end{array} \right. \qquad R_{pt} = 1.094$$

$$M_{n.TFY} := \left| \begin{array}{l} \text{"Does Not Apply"} \quad \text{if } S_{xt} \ge S_{xc} \\ R_{pt} \cdot M_{yt} \quad \text{if } S_{xt} < S_{xc} \end{array} \right.$$

$M_{n.TFY} = \text{"Does Not Apply"} \cdot kip \cdot ft$

Determine Mn, Lowest value for (Y, LTB,FLB,TFY)

$M_n := \min\left(M_{n.y}, M_{n.LTB}\right) = 656.72 \cdot kip \cdot ft$

$\boxed{M_n = 656.7 \cdot kip \cdot ft}$

ASD Design Capacity

$\Omega_c := 1.67$

LFRD design capacity

$\phi_c := 0.9$

$\boxed{\alpha \cdot \phi_c \cdot \frac{M_n}{1.4} = 358.9 \cdot kip \cdot ft}$ LRFD

$\boxed{0.87 \left(\frac{M_n}{\Omega_c} \right) = 342.1 \cdot kip \cdot ft}$ ASD

$M_u = 306.1 \cdot kip \cdot ft$

AWWA-M11

Table 7-1 Practical safe spans for simply supported pipe in 120° contact saddles*

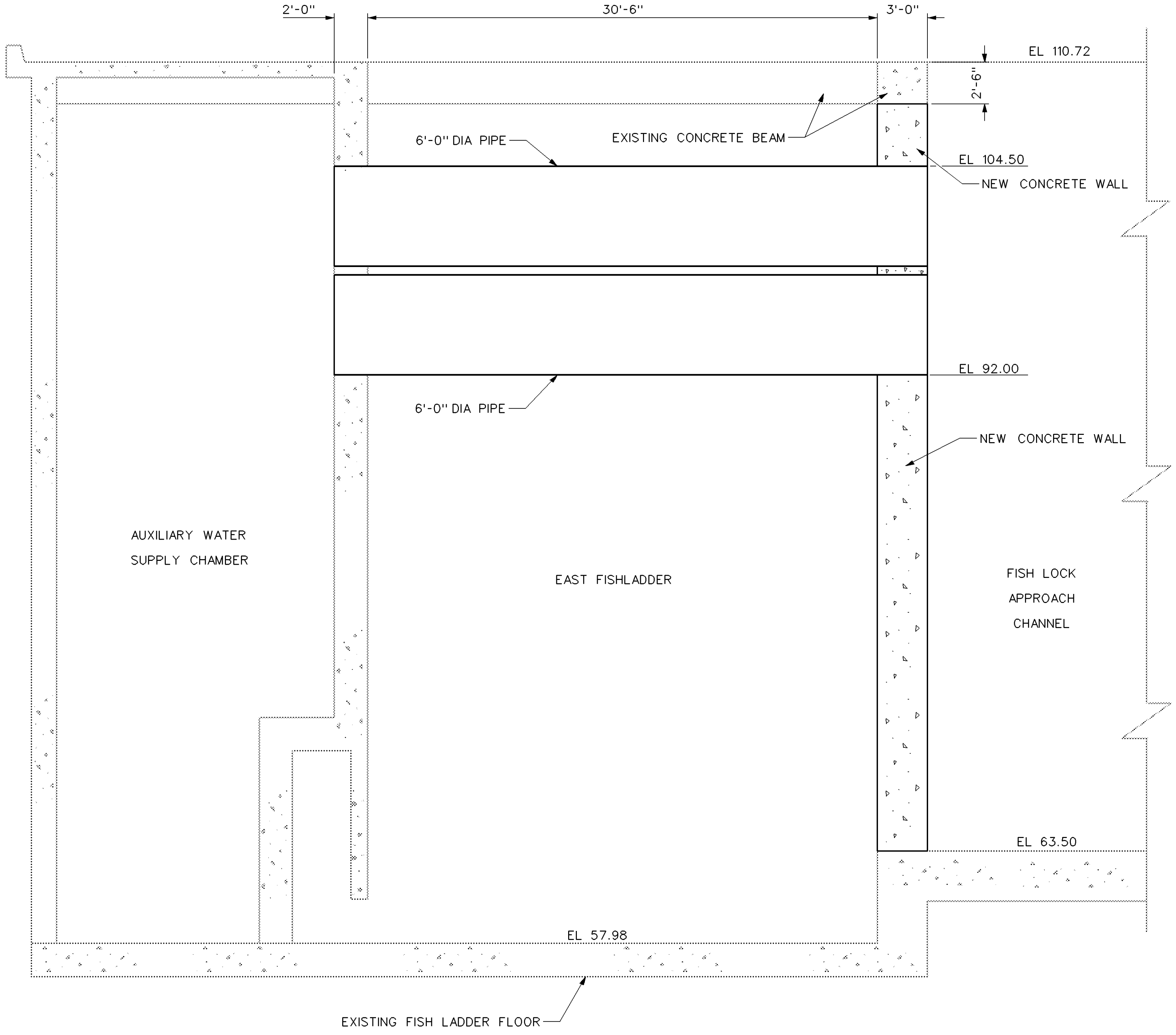
	Wall Thickness in.									
Nominal Size in.†	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1
	Span L ft									
6	36	40	44							
8	38	42	45							
10	39	43	46							
12	40	44	47							
14	40	44	47							
16	41	45	48							
18	41	46	49	52						
20	42	46	50	53						
22	42	46	51	54						
24	42	48	52	55	58	60				
26	43	48	52	56	59	61				
28	43	48	53	56	59	62				
30	43	49	53	57	60	63				
32	44	49	54	57	61	64				
34	44	49	54	58	61	64				
36	44	50	54	58	62	65	70			
38	44	50	55	59	62	65	70			
40	44	50	55	59	63	66	71			
42	44	50	55	59	63	66	72			
45		51	55	60	63	67	72			
48		51	56	60	64	67	73	78		
51		51	56	60	64	68	74	79		
54		51	56	61	65	68	74	79		
57		51	57	61	65	69	75	80		
60		51	57	61	65	69	75	80		
63		52	57	62	66	69	76	81		
66		52	57	62	66	70	76	81	86	90
72		52	58	62	66	70	77	82	87	92
78			58	62	67	71	77	83	88	93
84			58	63	67	71	78	84	89	94
90			58	63	67	71	78	84	90	94
96			58	63	68	72	79	85	90	95
102			58	63	68	72	79	85	91	96
108				64	68	72	80	86	91	96
114				64	68	73	80	86	92	97
120					69	73	80	87	92	98
126					69	73	81	87	93	98
132					69	73	81	87	93	98
138					69	73	81	88	94	99
144					69	74	81	88	94	99

1/4" will span over 30'
6- 6' DIA Steel pipes

NOTE: This table is based on bending stresses; localized stresses at supports must be analyzed.

* After Cates (1950): d and t are pipe diameter and thickness respectively in in. (mm), and L is in ft (m); fiber stress = 8,000 psi (55.16 MPa), loaded by dead weight of pipe plus container water.

† To convert nominal in. to nominal mm, multiply by 25.0; to convert in. to mm, multiply by 25.4; to convert ft to m, multiply by 0.3048.



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U.S. ARMY CORPS OF ENGINEERS
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U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

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SUBMITTED BY: SUBMITTER'S NAME		CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE	PLOT DATE: 30-MAY-2013	DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE	FILE NAME: FILE NAME	

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
ALTERNATIVE - DDR

SHEET TITLE LINE 1
SHEET TITLE LINE 2
SHEET TITLE LINE 3

SHEET IDENTIFICATION
S-301
SHEET OF

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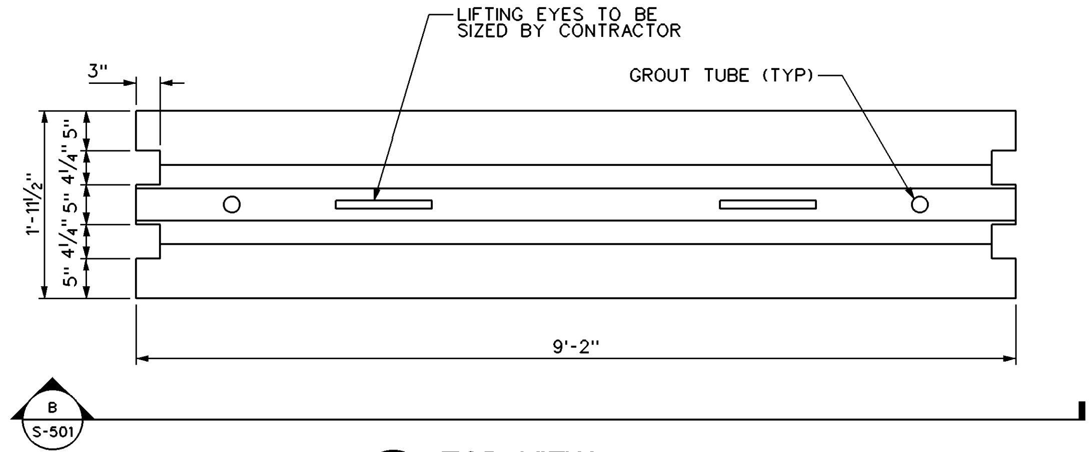
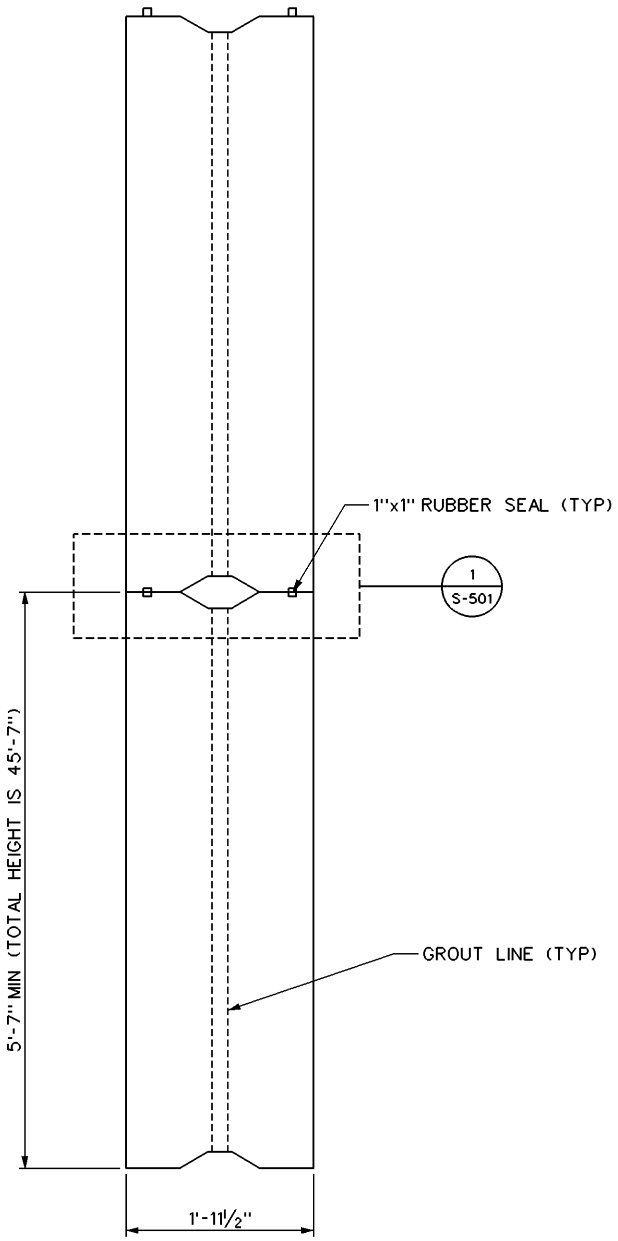


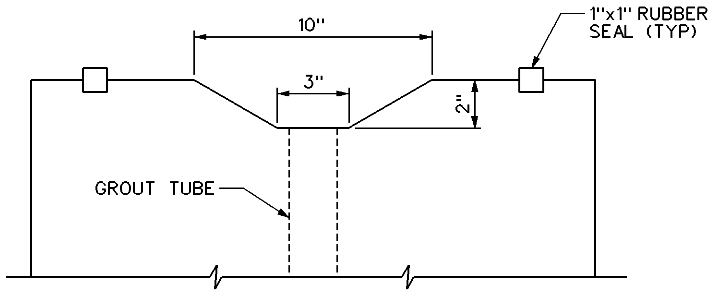
A TOP VIEW

0' 1' 2'



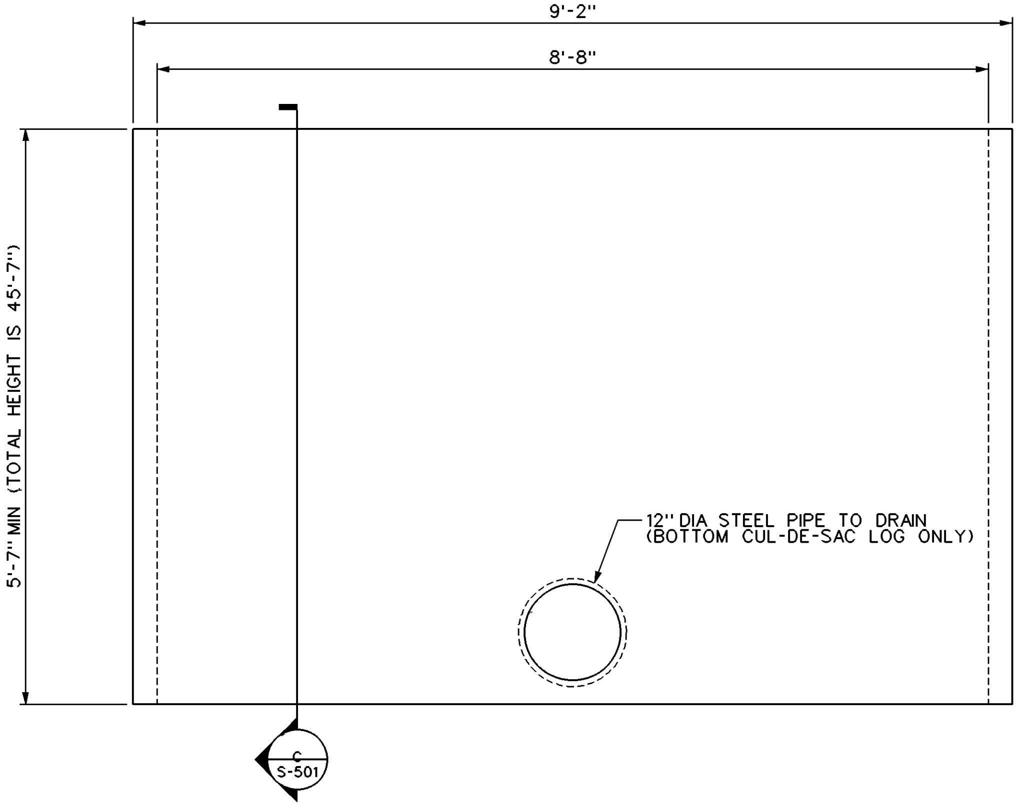
C SECTION

0' 1' 2'



1 DETAIL

0" 4" 8"



B SECTION

0' 1' 2'

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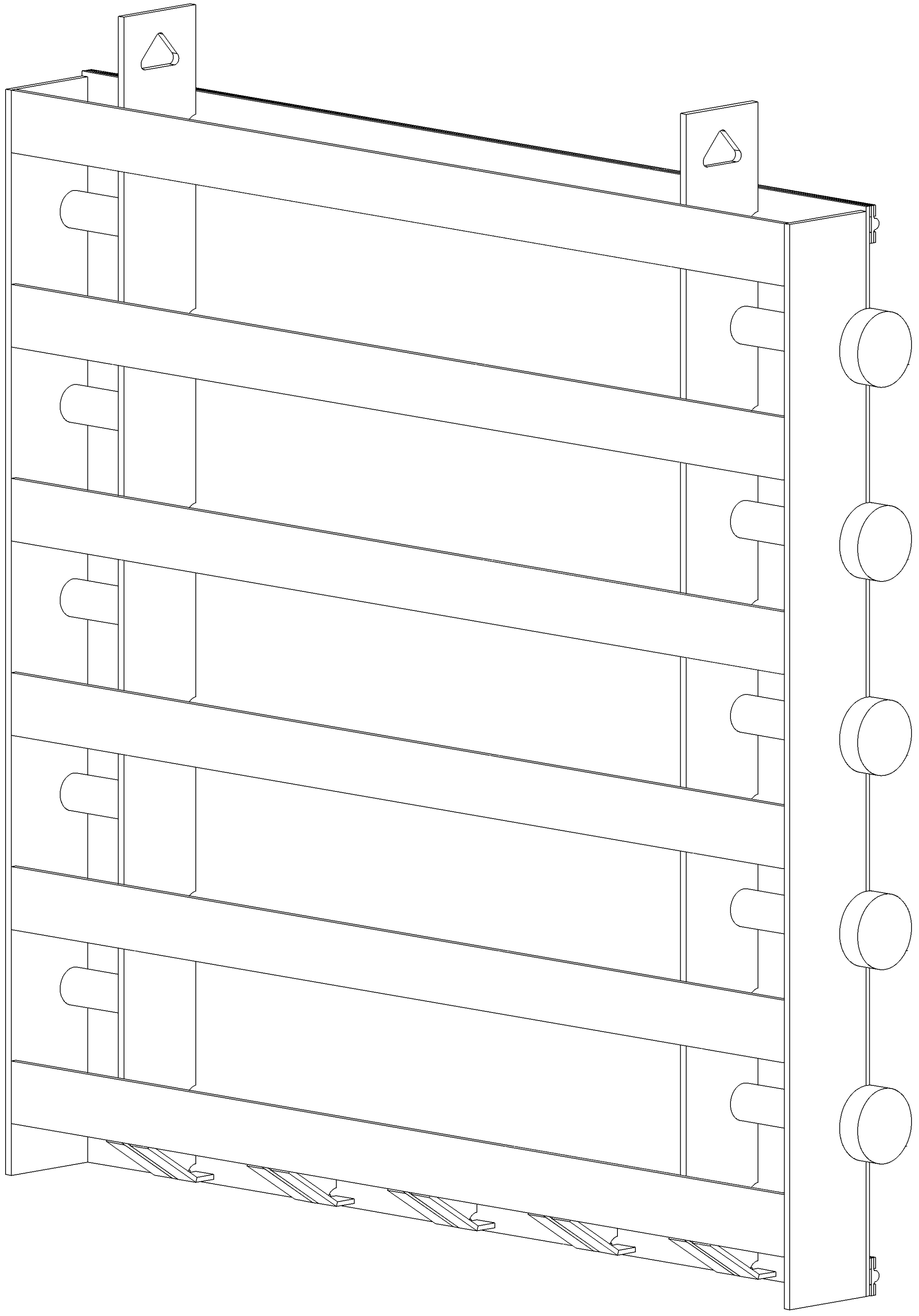
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
ALTERNATIVE - DDR

CUL-DE-SAC LOGS
DETAILS

SHEET
IDENTIFICATION
S-501
SHEET OF



NOTES:

1. OVERALL STRUCTURAL GATE SIZE IS 14.5' x 14.5'.

2. APPROXIMATE TOTAL WEIGHT OF GATE IS 20,500 lbs.

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THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
ALTERNATIVE - DDR

CLOSURE GATE
ISOMETRIC

SHEET
IDENTIFICATION
S-901
SHEET OF

DESIGN FILE: $PWDIR$

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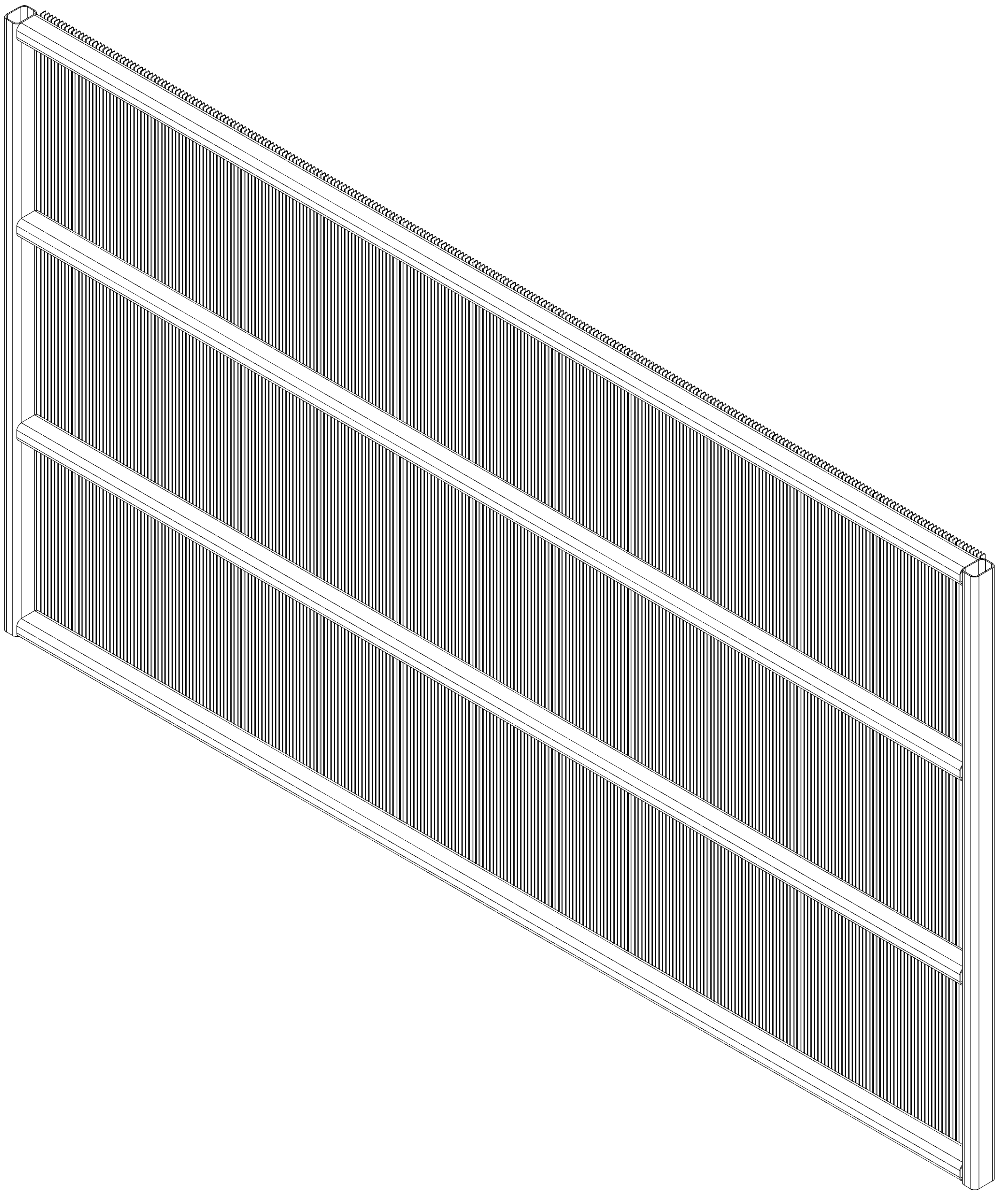

NOTES:

1. TRASHRACK DIMENSIONS ARE 12' x 22'.

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U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

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CONTRACT NO.: CONTRACT NUMBER
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DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE
FILE NAME: FILE NAME

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
ALTERNATIVE - DDR

TRASHRACK
ISOMETRIC

SHEET
IDENTIFICATION
S-902
SHEET OF

DESIGN FILE: $PWDIR$

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Dalles AWS

Trash Rack Design to 30% These cacls are for chekcing grating loaded oppisite than bar grating catalog. i.e. the compression side is not bracesed with cross braces every 4"
Will used SS. (1-1/4"-3/16) with bar spacing at 15/16" o.c. This provides a 3/4" clear opening between bars.
Use S.S. for reduced maintenance.

Bar Grating will be loaded opposite than design catalogs to allow for a trash rake to push debris off. This mean the unbraced length will be between supports.

Based on AISC 360-05 manual

Section F11 Rectangular Bars bent about the major axis

$E := 29000\text{ksi}$	*Modulus of elasticity of steel*
$F_y := 25\cdot\text{ksi}$	*Yield strength of S.S.*
$d := 1.25\cdot\text{in}$	*depth of bar*
$t := \frac{3}{16}\cdot\text{in}$	*thickness of bar*
$s := \frac{15}{16}\cdot\text{in}$	*bar spacing*
$L_b := 4\cdot\text{ft}$	*True unbraced length would be between inflection points*
$C_b := 1.0$	*lateral torsional buckling modification factor- assumed 1, conservative.*
$\Omega := 1.67$	*AISC 360-05 ASD reduction factor*

Section properties:

$$S_x := \frac{t\cdot d^2}{6} = 0.0488\cdot\text{in}^3$$

$$Z_x := \frac{t\cdot d^2}{4} = 0.0732\cdot\text{in}^3$$

$$F_{cr} := \frac{1.9\cdot E\cdot C_b}{\left(\frac{L_b\cdot d}{t^2}\right)} = 32.3\cdot\text{ksi}$$

eqn F11-4

$$M_y := S_x\cdot F_y = 0.1\cdot\text{kip}\cdot\text{ft}$$

Yield moment about the axis of bending, Salmon on Johnson 4ed page 373.

$$\text{Limit\_1} := \frac{L_b\cdot d}{t^2} = 1706.7$$

$$\text{Limit\_2} := \frac{0.08\cdot E}{F_y} = 92.8$$

$$\text{Limit\_3} := \frac{1.9\cdot E}{F_y} = 2204$$

$$M_{n.F11.1} := \min\left(F_y \cdot Z_x , 1.6 \cdot M_y\right) = 0.153 \cdot kip \cdot ft$$

eqn F11-1

$$M_{n.F11.2} := \min\left[C_b \cdot \left[1.52 - 0.274\left(\frac{L_b \cdot d}{t^2}\right) \cdot \frac{F_y}{E}\right] \cdot M_y , M_{n.F11.1}\right] = 0.114 \cdot kip \cdot ft$$

eqn F112

$$M_{n.F11.3} := \min\left(F_{cr} \cdot S_x , M_{n.F11.1}\right) = 0.131 \cdot kip \cdot ft$$

eqn F11-3

$$M_n := \begin{array}{|ll} M_{n.F11.1} & \text{if } Limit\_1 \le Limit\_2 \\ M_{n.F11.2} & \text{if } Limit\_2 < Limit\_1 \le Limit\_3 \\ M_{n.F11.3} & \text{if } Limit\_1 > Limit\_3 \end{array} = 0.114 \cdot kip \cdot ft$$

$$K := \frac{12 \cdot in}{s} = 12.8$$

Number of bars per foot

$$M_{nK} := M_n \cdot K = 1.5 \cdot kip \cdot ft$$

flexural capacity per foot.

$$\frac{M_n \cdot K}{\Omega} = 0.87 \cdot kip \cdot ft$$

allowable flexural capacity per foot.

Iteration 1. Loads from H.H.

load from H&H

$$P_d := 42.1 \cdot psf$$

pressure on bar grating with 75% open space (this assume 71% open for steel)

Load per foot of bar grating

$$w := P_d \cdot L_b = 0.17 \cdot \frac{kip}{ft}$$

$$M_u := \frac{w \cdot L_b^{\,2}}{8} = 0.34 \cdot kip \cdot ft$$

This is assuming simply supported ends, if continuous beams then moment will be less.

$$Flexure\_is\_ := \begin{array}{|ll} \text{"OK"} & \text{if } M_u \le M_n \cdot \frac{K}{\Omega} \\ \text{"NOT OK"} & \text{otherwise} \end{array} = \text{"OK"}$$

NBG 531-00 ANSI/NAAMM Metal Bar Grating Manual 6th ed.

304&316 S.S. bar grating loading @4' values are:
U=411psf
Du=0.274 in
C=822 lb per ft of grading
Dc=0.219 in

Note: these values are for grating with cross bars on compression side of members.

Shear is OK based on NBG 531-00 Catalog

Rectangular HSS in Flexure

AISC 360-05 Design Guidance

This is the calc for the frame that supports the SS grating for the Trashrack. The trashrack will span 22' and be in section of 12' tall. The frame will be built out of HSS ss tubes.

6x4x1/4 s.s.

$F_y := 25 \cdot ksi$

$E := 29000ksi$

$Z_x := 8.53 \cdot in^3$ *axis resisting water load*

$Z_y := 6.45 \cdot in^3$ *axis resisting dead load and grating weight*

$C := 10.1 \cdot in^3$

$d := 6 \cdot in$ $d_y := 4 \cdot in$ *y is weak axis*

$t_w := 0.233 \cdot in$

$W_b := 15.58 \cdot plf$ *Beam weight*

Applied Moment:

This assume 42.1psf applied load with 4ft span of grating applied from debris

$w := 168 \cdot \frac{lbf}{ft}$

$w_g := 7psf$

$W_g := w_g \cdot 6 \cdot ft = 42 \cdot plf$ *Weight of grating on beam*

$L_b := 22.5 \cdot ft$ *Unbraced length of beam- conservative for hydraulic loading-grating will brace compression face.*

$M_a := \frac{w \cdot L_b^2}{12} = 7.09 \cdot kip \cdot ft$ $M_{ay} := \frac{\left(W_g + W_b\right) \cdot L_b^2}{12} = 2.4 \cdot kip \cdot ft$

$M_r := M_a = 7.087 \cdot kip \cdot ft$ $M_{ry} := M_{ay}$

Applied Shear

$V_a := \frac{w \cdot L_b}{2} = 1.89 \cdot kip$ $V_{ay} := \frac{\left(W_g + W_b\right) \cdot L_b}{2} = 0.6 \cdot kip$

$V_r := V_a$ $V_{ry} := V_{ay}$

Applied Torsion

$e := \frac{d}{2} + \frac{1.25}{2} \cdot in = 3.625 \cdot in$ *Center of beam to center of grating*

$T_a := \frac{W_g \cdot L_b \cdot e}{2} = 0.143 \cdot kip \cdot ft$

$T_r := T_a$

Check Slenderness Ratio Table B4.1 Case 12 and 13

$\lambda_f := 14.2$

Check Flange Table B4.1 Case 12

$\lambda_{pf} := 1.12\sqrt{\dfrac{E}{F_y}} = 38.1$ *compact*

$\lambda_{rf} := 1.4\sqrt{\dfrac{E}{F_y}} = 47.7$ *noncompact*

$\lambda_w := 22.8$

Check Web Table B4.1 Case 13

$\lambda_{pw} := 2.42\sqrt{\dfrac{E}{F_y}} = 82.4$ *compact*

$\lambda_{rw} := 5.70\sqrt{\dfrac{E}{F_y}} = 194.1$ *noncompact*

$$\text{Flange\_is\_} := \left|\begin{array}{l} \text{"Compact"} \quad \text{if } \lambda_f < \lambda_{pf} \\ \text{"Non Compact"} \quad \text{if } \lambda_{pf} < \lambda_f \le \lambda_{rf} \\ \text{"Slender"} \quad \text{otherwise} \end{array}\right.$$

$\text{Flange\_is\_} = \text{"Compact"}$

$$\text{Web\_is\_} := \left|\begin{array}{l} \text{"Compact"} \quad \text{if } \lambda_w < \lambda_{rw} \\ \text{"Non Compact"} \quad \text{if } \lambda_{pf} < \lambda_f \le \lambda_{rf} \\ \text{"Slender"} \quad \text{otherwise} \end{array}\right.$$

$\text{Web\_is\_} = \text{"Compact"}$

For bending about the dead load axis (y-weak) the member will still be compact, λf and λw would be switched

Check Flexure Chapter F

From Table F1.1 use AISE Section F7- Square and Rectangular HSS and Box Shaped Members
Check:
1. (Y) Yielding Section F7-1
2. (FLB) Flange Local Buckling Section F7-2
3. (WLB) Web Local Buckling Section F7-3

Section F7-1 Yielding

$\Omega_b := 1.67$

$M_n := F_y \cdot Z_x = 17.77 \cdot \text{kip} \cdot \text{ft}$

$M_c := \dfrac{M_n}{\Omega_b} = 10.64 \cdot \text{kip} \cdot \text{ft}$

Dead load value

$M_{ny} := F_y \cdot Z_y = 13.4 \cdot \text{kip} \cdot \text{ft}$ *eqn F7-1*

$M_{cy} := \dfrac{M_{ny}}{\Omega_b} = 8 \cdot \text{kip} \cdot \text{ft}$

Section F7-2 Flange Local Buckling

Does not apply for compact sections

Section F7-3 Web Local Buckling

Does not apply for compact sections

$$\text{Flexure\_is} := \left|\begin{array}{l} \text{"OK"} \quad \text{if } M_r \le M_c \\ \text{"Not OK"} \quad \text{otherwise} \end{array}\right. = \text{"OK"}$$

Check Shear Chapter G

$\Omega_v := 1.67$

$h := d - 2\left(3 \cdot t_w\right) = 4.602 \cdot in$ *Height of web in shear minus radius*

$A_w := 2 \cdot h \cdot t_w = 2.145 \cdot in^2$ *Area of web minus radius*

$k_v := 5$

$$C_v := \begin{cases} 1 \quad \text{if } \lambda_w \le 1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} & \text{eqn G2-3} \\ \frac{1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}}}{\lambda_w} \quad \text{if } 1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} < \lambda_w \le 1.37 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} & \text{eqn G2-4} \\ \frac{1.51 \cdot E \cdot k_v}{\left(\lambda_w\right)^2 \cdot F_y} \quad \text{if } \lambda_w > 1.37 \cdot \sqrt{k_v \cdot \frac{E}{F_y}} & \text{eqn G2-5} \end{cases} = 1$$

$V_n := 0.6 \cdot F_y \cdot A_w \cdot C_v = 32.2 \cdot kip$ *eqn G2-1*

$$V_c := \frac{V_n}{\Omega_v} = 19.3 \cdot kip$$

$$\text{Shear\_is} := \begin{cases} \text{"OK"} \quad \text{if } V_r \le V_c \\ \text{"Not OK"} \quad \text{otherwise} \end{cases} = \text{"OK"}$$

$h_y := d_y - 2 \cdot 3 \cdot t_w = 2.602 \cdot in$ *Dead load value*

$A_{wy} := 2 \cdot h_y \cdot t_w = 1.213 \cdot in^2$

$V_{ny} := 0.6 \cdot F_y \cdot A_{wy} \cdot C_v = 18.188 \cdot kip$

$$V_{cy} := \frac{V_{ny}}{\Omega_v} = 10.891 \cdot kip$$

Design for member in Torsion and Flexure H3-6b

$$\frac{h}{t} = \lambda_w \qquad \Omega_t := 1.67$$

$$\left(0.6 \cdot F_y\right) = 15 \cdot \text{ksi}$$

$$F_{cr} := \begin{cases} \left(0.6 \cdot F_y\right) & \text{if } \lambda_w \le 2.45 \cdot \sqrt{\dfrac{E}{F_y}} \\ 0.6 \cdot F_y \cdot \dfrac{\left(2.45 \sqrt{\dfrac{E}{F_y}}\right)}{\lambda_w} & \text{if } 2.45 \cdot \sqrt{\dfrac{E}{F_y}} < \lambda_w \le 3.07 \cdot \sqrt{\dfrac{E}{F_y}} \\ 0.458 \cdot \pi^2 \cdot \dfrac{E}{\lambda_w^{\,2}} & \text{if } 3.07 \cdot \sqrt{\dfrac{E}{F_y}} < \lambda_w \le 260 \end{cases} = 15 \cdot \text{ksi}$$

eqn H3-3

eqn H3-4

eqn H3-5

$$T_n := F_{cr} \cdot C = 0.656\,\text{gal} \cdot \text{ksi}$$

eqn H3-1

$$T_c := \frac{T_n}{\Omega_t} = 0.393\,\text{gal} \cdot \text{ksi}$$

$$\text{Torsion\_is} := \begin{cases} \text{"OK"} & \text{if } T_r \le T_c \\ \text{"Not OK"} & \text{otherwise} \end{cases} = \text{"OK"}$$

$$\left(\frac{M_r}{M_c} + \frac{M_{ry}}{M_{cy}}\right) + \left(\frac{V_r}{V_c} + \frac{V_{ry}}{V_{cy}} + \frac{T_r}{T_c}\right)^2 = 0.999$$

eqn H3-6

If Less than or equal to 1-is OK,
Gravity loads will be less under water.

Walton, Eric D NWW

From: Negherbon, Logan L NWW
Sent: Wednesday, May 22, 2013 8:13 AM
To: Walton, Eric D NWW
Cc: Laughery, Ryan O NWW
Subject: Dalles EFL AWS - Trashrack (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Eric,

The updated calculation for a 50% cogging of open area on the trashrack shows a resultant pressure of 42.083 psf loading on the trashrack. Normal clean loading is 11.845 psf.

Logan Negherbon
Hydraulic Engineer, EIT
U.S. Army Corps of Engineers
Walla Walla District
Phone: (509) 527-7268
Email: logan.l.negherbon@usace.army.mil

Classification: UNCLASSIFIED
Caveats: NONE

The Dalles East Fish Ladder Auxiliary Water Backup System

60 Percent Design Documentation Report

APPENDIX D

Electrical

	FISH LADDER			**FCQ09**			*FISH AWS*	
CIR #	LOCATION/DESCRIPTION	CB AMPS	VOLT-AMPS OR WATTS	PH		CB AMPS	LOCATION/DESCRIPTION	#
1	HYDRAULIC POWER UNIT, PORTABLE	3P	3878	A	2105	3P	VALVE ACTUATOR, JET VALVE	2
3	" " " " (10 HP)	X	3878	B	2105	X	" " " " (5 HP, 1 EACH)	4
5	" " " "	25	3878	C	2105	15	" " " "	6
7	PANEL, LIGHTING (208/120V/3PH)	3P	5000	A	3P		spare	8
9	" " " "	X	5000	B	X		spare	10
11	" " " "	20	5000	C	20		spare	12
13	SPACE			A				14
15	SPACE			B				16
17	SPACE			C				18

PANEL DESCRIPTION:

3 PHASE, 4 WIRE WYE, 277Y/480V
100 AMPS, 18,000 AIC BUS ,100 AMP MAIN
BOLT-TO-BUS BREAKERS, 10,000 AIC
SURFACE MOUNT, NEMA 3R, DOOR-IN-DOOR STYLE REQUIRED
FED BY: (feeder circuit)

CONNECTED LOAD:

PHASE A	40	AMPS
PHASE B	40	AMPS
PHASE C	40	AMPS
ALL	33	KVA

Electrical Equipment near Fishlock

The Dalles East Fish Ladder Auxiliary Water Backup System

60 Percent Design Documentation Report

APPENDIX E

Mechanical

This calculation is to check the bending and shear capacity of the wheel axle for the Dalles EFL AWS emergency closure gate.

Variables

$W_{gate} := 14.5ft$	Width of the Gate
$H_{gate} := 14.5ft$	Height of theGate
$D_{water} := 50ft$	Depth of water at Gate invert.
$s1_{axle} := 3in$	Span between wheel and first reaction.
$s2_{axle} := 24in$	Span between first and second reaction in the wheel axle.
$d_{axle} := 6in$	Diamter of the wheel Axle.
$S_y := 50ksi$	Yield strength of the axle material.
$N_{axle} := 10$	Number of wheels per gate
$Density := 62.4\frac{lbf}{ft^3}$	Density of water

Calculations

$A_{gate} := W_{gate} \cdot H_{gate}$	$A_{gate} = 210.25\,ft^2$	Area of the gate
$F_{gate} := A_{gate} \cdot D_{water} \cdot Density$	$F_{gate} = 6.56 \times 10^5\,lbf$	Total water force on the gate
$P_{axle} := \frac{F_{gate}}{N_{axle}}$	$P_{axle} = 6.56 \times 10^4\,lbf$	Force acting on each wheel
$Ra := \frac{P_{axle} \cdot \left(s1_{axle} + s2_{axle}\right)}{s2_{axle}}$	$Ra = 7.38 \times 10^4\,lbf$	Reaction at plate nearest to the wheel.
$Rb := Ra - P_{axle}$	$Rb = 8.2 \times 10^3\,lbf$	Reaction at plate farthest from wheel.
$V_{max} := \max(Ra, Rb)$	$V_{max} = 7.38 \times 10^4\,lbf$	Maximum shear in axle
$M_{max} := Ra \cdot s1_{axle}$	$M_{max} = 221.393\,in \cdot kip$	Maximum moment in axle

$r_{axle} := \frac{d_{axle}}{2}$	$r_{axle} = 3\,in$	Radius of axle
$S_{axle} := \frac{\pi\, r_{axle}^{3}}{4}$	$S_{axle} = 21.206\,in^{3}$	Section modulus of axle
$fb_{axle} := \frac{M_{max}}{S_{axle}}$	$fb_{axle} = 10.44\,ksi$	Bending stress in axle.
$A_{axle} := \pi \cdot r_{axle}^{2}$	$A_{axle} = 28.274\,in^{2}$	Cross section area of axle
$fv_{axle} := \frac{V_{max}}{A_{axle}}$	$fv_{axle} = 2.61\,ksi$	Shear stress in axle.
$f_{vm} := \sqrt{\left(fb_{axle}^{2} + 3 \cdot fv_{axle}^{2}\right)}$	$f_{vm} = 11.377\,ksi$	Von Mises stress in axle
$FS := \frac{S_y}{f_{vm}}$	$FS = 4.395$	Factor of safety in axle

This calculation is to determine the size requirements for the cross beams for the trash rack rake

Variables

$P_w := 22.8 \frac{\mathrm{lbf}}{\mathrm{ft}^2}$	Pressure exterted by water flowing through the rake
$L_{rake} := 22\mathrm{ft}$	length of the rake
$S_{beam} := 1.75\mathrm{ft}$	Beam spacing for rake support
$S_y := 50\mathrm{ksi}$	Yield strength of beam material.

Calculations

$W_{beam} := P_w \cdot S_{beam}$	$W_{beam} = 39.9 \frac{\mathrm{lbf}}{\mathrm{ft}}$	Beam load
$F_{beam} := W_{beam} \cdot L_{rake}$	$F_{beam} = 877.8\,\mathrm{lbf}$	Total force on each beam
$V_{beam} := \frac{F_{beam}}{2}$	$V_{beam} = 438.9\,\mathrm{lbf}$	Maximum shear in beam
$M_{beam} := V_{beam} \cdot \frac{L_{rake}}{4}$	$M_{beam} = 28.967\,\mathrm{in} \cdot \mathrm{kip}$	Bending moment in beam
$F_{allow} := S_y \cdot .6$	$F_{allow} = 30\,\mathrm{ksi}$	Allowable Stress in beam
$S_{req} := \frac{M_{beam}}{F_{allow}}$	$S_{req} = 0.966\,\mathrm{in}^3$	Required Section modulus for the beam.

A section modulus this small calles for a beam that is smaller than required to support the wheel axles. As a result the trash rake beams are not stress controlled. The beam is geometry controlled and will result in a beam depth that is much stronger than necessary for the applied load.

This worksheet is to calculate the force required to rotate gate wheels against friction forces while the gate is under flow.

Variables

$H_1 := 50\text{ft}$	Depth of the bottom of the gate below water surface
$\text{Height}_g := 20\text{ft}$	Height of the gate
$\text{Width}_g := 20\text{ft}$	Width of the gate
$\text{Num}_w := 10$	Number of wheels
$\text{Wheel}_{od} := 12\text{in}$	Outside diameter of the wheel
$\text{Wheel}_{sp} := 9\text{in}$	Diameter of the spherical sliding surface of the wheel
$\text{mu}_s := .1$	Coefficient of sliding friction of the sliding surface.
$\text{rho}_{wat} := 62.4\dfrac{\text{lbf}}{\text{ft}^3}$	Density of water

Calculations

$A_{gate} := \text{Height}_g \cdot \text{Width}_g$	$A_{gate} = 400\,\text{ft}^2$	Area of the gate
$P0_{gate} := \left(H_1 - \text{Height}_g\right) \cdot \text{rho}_{wat}$	$P0_{gate} = 1.872 \times 10^3\,\text{psf}$	Pressure at the top of the gate
$Pb_{gate} := H_1 \cdot \text{rho}_{wat}$	$Pb_{gate} = 3.12 \times 10^3\,\text{psf}$	Pressure at the bottom of the gate.
$\text{Space}_{wh} := \dfrac{\text{Height}_g}{\left(\dfrac{\text{Num}_w}{2}\right)}$	$\text{Space}_{wh} = 4\,\text{ft}$	Wheel spacing
$\text{Force}_b := Pb_{gate} \cdot \text{Width}_g \cdot \text{Space}_{wh} \cdot .5$	$\text{Force}_b = 1.248 \times 10^5\,\text{lbf}$	Force on each of the bottom pair of wheels
$M_{frictm} := \text{Force}_b \cdot \text{mu}_s \cdot \dfrac{\text{Wheel}_{sp}}{2}$	$M_{frictm} = 5.616 \times 10^4\,\text{in} \cdot \text{lbf}$	Max Moment requred to turn each wheel under load

$$F_{wheelm} := \frac{M_{frictm}}{\left(\frac{Wheel_{od}}{2}\right)}$$

$$F_{wheelm} = 9.36 \times 10^{3}\ \mathrm{lbf}$$

Max Force applied to wheel OD required to turn wheel

$$F_{const} := P0_{gate} \cdot A_{gate}$$

$$F_{const} = 7.488 \times 10^{5}\ \mathrm{lbf}$$

Total constant force on gate

$$F_{grad} := A_{gate} \cdot \frac{\left(Pb_{gate} - P0_{gate}\right)}{2}$$

$$F_{grad} = 2.496 \times 10^{5}\ \mathrm{lbf}$$

Total force on gate due to gradient.

$$F_{tot} := F_{const} + F_{grad}$$

$$F_{tot} = 9.984 \times 10^{5}\ \mathrm{lbf}$$

Total force acting on gate due to water pressure.

$$F_{avg} := \frac{F_{tot}}{Num_{w}}$$

$$F_{avg} = 9.984 \times 10^{4}\ \mathrm{lbf}$$

Average force acting on each wheel

$$M_{fricta} := F_{avg} \cdot mu_{s} \cdot \frac{Wheel_{sp}}{2}$$

$$M_{fricta} = 4.493 \times 10^{4}\ \mathrm{in \cdot lbf}$$

Avg Moment requred to turr each wheel under load.

$$F_{wheela} := \frac{M_{fricta}}{\left(\frac{Wheel_{od}}{2}\right)}$$

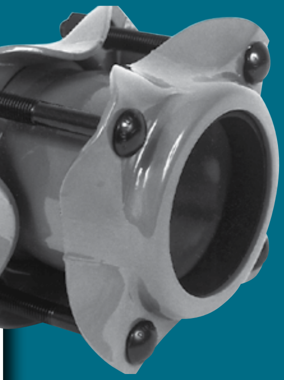
$$F_{wheela} = 7.488 \times 10^{3}\ \mathrm{lbf}$$

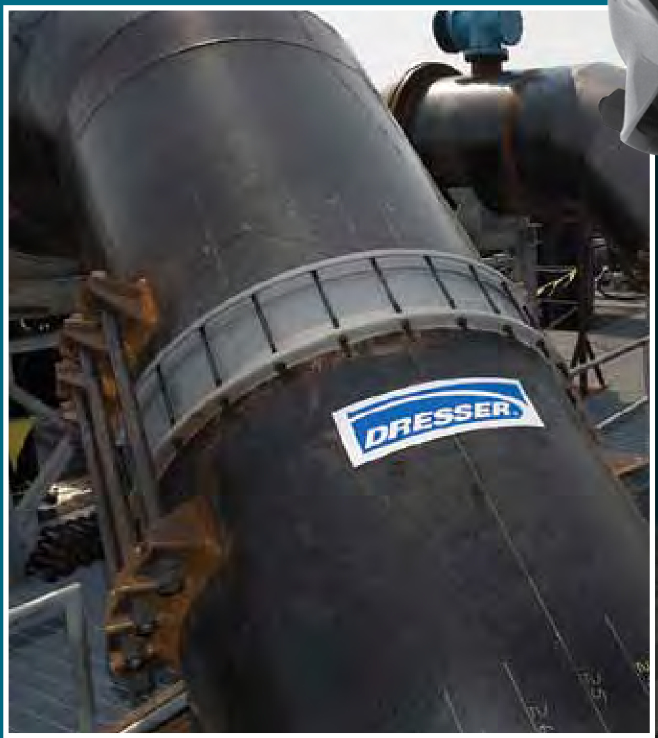
Avg Force applied to wheel OD required to turn wheel

$$F_{frict\_total} := F_{wheela} \cdot Num_{w}$$

$$F_{frict\_total} = 7.488 \times 10^{4}\ \mathrm{lbf}$$

Total downward force requried to turn wheels under load.

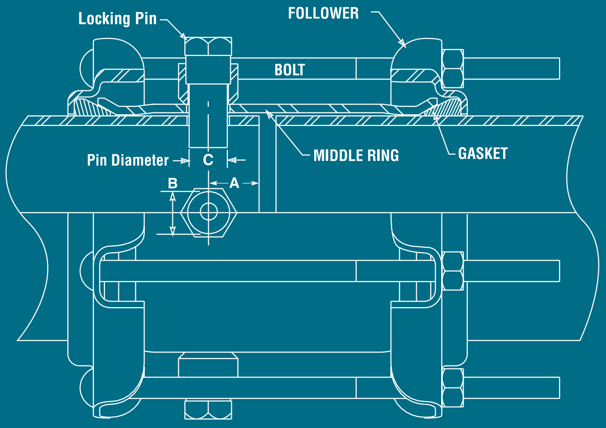




Steel Products

for Water, Wastewater and Industrial Piping Systems

- Couplings
- Flange Adapters
- Expansion Joints
- Dismantling Joints
- Joint Harnesses
- Custom Fabrication



Piping Specialties

Bradford, PA

Dresser water market products you'll find in this catalog…

Customer Service: 800-458-2398
Sales Fax: 800-362-9363
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AL-CLAD™ Coating offered as standard

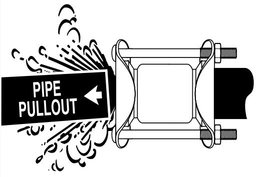
Dresser AL-CLAD fusion-bonded epoxy coating is offered as standard on the most common Dresser pipe joining products in the most popular sizes featured in this catalog.*

Tough, corrosion-resistant, factory-applied Dresser AL-CLAD coating has been developed through years of exhaustive testing and field application.

AL-CLAD epoxy coating is a fusion-bonded coating applied under rigidly controlled factory conditions and offers smoother flow in wetted waterways and provides protection against corrosive or aggressive conditions.

*Excludes Style 63 Expansion Joints where AL-CLAD coating is optional. Please consult factory for other products and sizes where AL-CLAD coating may be optional.

⚠WARNING



When pipe pullout could occur, pipe joint MUST be anchored. Failure to anchor pipe joint could result in escaping line content that could ignite and cause property damage, serious injury or death.

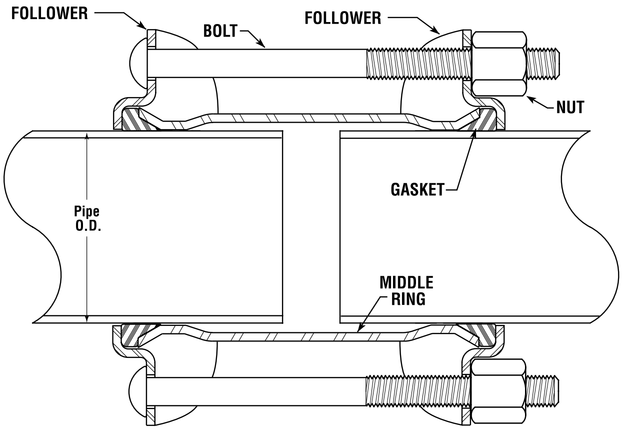
www.dresser.com

DRESSER

Steel Products for Water and Industrial Piping Systems

Why are DRESSER® couplings used more than any other coupling?

- Dresser offers the broadest line of couplings, including long body, insulating, reducing and transition types.
- Products feature Dresser AL-CLAD™ coating as standard in the most popular sizes. Our epoxy coating offers optimum protection against highly corrosive soil or aggressive water conditions and for handling brine, brackish water, most acids, alkalies, oil, chemical particulates and gases.
- Sizes range from 3/8” through 405” to cover every application including high temperature and abrasion.
- Dresser couplings are fast and easy to install with any size pipe or tubing.
- Wide temperature range from -20°F to +1200°F, with pressure ratings to 1500 psi.
- Available in rugged welded steel construction, stainless or carbon steel, titanium, monel or other alloys for special applications.
- Use a Dresser coupling and your pipeline joint is non-rigid, accepting expansion, contraction, vibration and line deflection.
- Special elastomer formulations are provided custom-matched to specific fluid process or application requirements.



Cutaway view shows components of a basic Dresser Style 38 Coupling

The Basic Working Principle of Dresser Couplings…

The **Dresser** coupling consists of one cylindrical middle ring, two follower rings, two resilient gaskets of special Dresser compound, and a set of steel trackhead bolts. The middle ring has a conical flare at each end to receive the wedge portion of the gaskets. The follower rings confine the outer ends of the gaskets. As the nuts are tightened, the bolts draw the follower rings toward each other, compressing the gaskets in the spaces formed by follower rings, middle ring flares and pipe surface thus producing a flexible, leak-proof seal on the pipe joint.

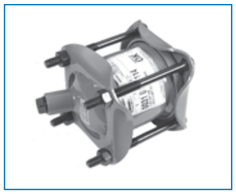
Style 38, 38 Stainless & 138 Couplings
Page 5-8

Style 39 Insulating Couplings
Page 9

Style 40 Long Couplings
Page 10-11

Style 62 Reducing & Transition Couplings
Page 12-13

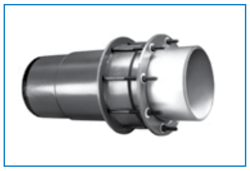
Style 31 Line Caps
Page 14



Style 167 Lock Coupling
Page 15

Style 128-W Flange Adapter
Page 16

Style 63 Expansion Joints
Page 17



Style 131 Dismantling Joint
Page 18

Style 440 Joint Harness - Pg.19
Style 253 Cast Coupling - Pg.20

How to Specify Dresser Products

DRESSER®

For those who may wish to draw up specifications of a general nature covering Dresser Style 38 couplings, this suggested form is offered:

1.) The pipe coupling shall be of a gasketed, sleeve-type design with diameter to properly fit the pipe. Each coupling shall consist of one (1) steel middle ring, of thickness and length specified, two (2) steel followers, two (2) rubber-compounded wedge section gaskets and sufficient track-head steel bolts to properly compress the gaskets.

The middle ring and followers of the coupling shall be true circular sections free from irregularities, flat spots or surface defects. They shall be formed from mill sections with the follower-ring section of such design as to provide confinement of the gasket. After welding, they shall be tested by cold expanding a minimum of 1% beyond the yield point. The middle ring, inside and out, and followers shall be coated with AL-CLAD™ thermosetting, fusion-bonded epoxy coating material that provides disbondment resistance in cathodically-protected systems and resistance to soil stresses and fungi. All constituents of the cured film are FDA and NSF-61 approved for exposure to fluids for human consumption and potable water.

The coupling bolts shall be of the elliptic-neck, track-head design with rolled threads. The manufacturer shall supply information as to the recommended torque to which the bolts shall be tightened. All bolt holes in the followers shall be oval for greater strength.

The coupling gaskets shall be composed of a crude or synthetic rubber base compounded with other products to produce a material that will not deteriorate from age, heat, or exposure to air under normal storage conditions. It shall also possess the quality of resilience and ability to resist cold flow of the material so that the joint will remain sealed and tight indefinitely when subjected to shock, vibration, pulsation and temperature or other adjustments of the pipeline.

2.) The couplings shall be assembled on the job in a manner to ensure permanently tight joints under all reasonable conditions of expansion, contraction, shifting and settlement, unavoidable variations in trench gradient, etc. The coupling shall be Dresser Style 38, as manufactured by Dresser Piping Specialties, Bradford, PA, and the necessary quantity shall be furnished.

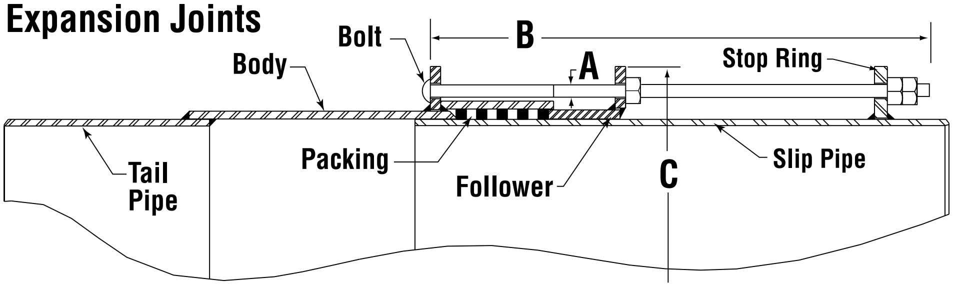
When Ordering Dresser Expansion Joints

Inquiries or orders for Dresser Style 63 Expansion Joints should contain the following information:

(1) Quantity
(2) Type of pipe: ductile iron, steel, etc.
(3) Style number and type
(4) Service: Water, Industrial, etc.
(5) Maximum working pressure
(6) Amount of movement to be taken care of by each joint
(7) Temperature limitations and ranges
(8) Frequency of cycling;
(9) End preparation of slip or tail pipe—beveled for welding, flanged, other
(10) Remarks, unusual installations, and list support methods of line and joint

The proper type of expansion joint to use and the method of anchoring and connecting it into a line depend upon the conditions of service and type of installation, as well as other joints in the line. The most effective use of Style 63 expansion joints usually requires an engineering recommendation. For that reason, a complete description of the installation should be submitted, with sketches or working drawings, if possible. Special joints may also be made for unusual conditions.

Expansion Joints



How to Specify Pipe Ends for Dresser Couplings

How to Specify Ends* on Steel Pipe

On orders and in specifications, the ends on steel pipe to be used with Dresser couplings may be specified briefly as follows:

- The pipe shall be furnished with plain ends for Dresser couplings in accordance with **A.W.W.A.** (American Water Works Association) Steel Water Pipe Specifications;

OR:

- The pipe shall be furnished with plain ends for Dresser couplings in accordance with A.P.I. (American Petroleum Institute) Line Pipe Specifications.

If specifications are to be detailed, the following may be used:

For Pipe Above 5” OD to 10-3/4” OD inclusive:

- The pipe shall be sufficiently free from indentations, projections or roll marks for a distance of 8” from the end of the pipe to make a tight joint with the rubber-gasket type of coupling. The outside diameter of the pipe shall not be more than 1/64” smaller than the nominal outside diameter for a distance of 8” from the end of the pipe and shall permit the passing for a distance of 8” of a ring gauge which has a bore 1/16” larger than the nominal outside diameter of the pipe. The minimum outside pipe diameter shall be determined by the use of a steel tape circumferentially applied to prevent the shipment of undersize, out-of-round pipe which, if measured diametrically through the maximum diameter or checked with a No-Go ring gauge, might appear within the specified tolerance.

For Pipe Larger than 10-3/4” OD:

- The pipe shall be sufficiently free from indentations, projections or roll marks for a distance of 8” from the end of the pipe to make a tight joint with the rubber-gasket type of coupling. The outside diameter of the pipe shall not be more than 1/32” smaller than the nominal outside diameter for a distance of 8” from the end of the pipe and shall permit the passing for a distance of 8” of a ring gauge which has a bore 3/32” larger than the nominal outside diameter of the pipe. The minimum outside pipe diameter shall be determined by the use of a steel tape circumferentially applied to prevent the shipment of undersize, out-of-round pipe which, if measured diametrically through the maximum diameter or checked with a No-Go ring gauge, might appear within the specified tolerance.

How to Specify Ends on Cast/Ductile Iron Pipe

On orders and in specifications, the ends on cast or ductile iron pipe to be used with Dresser couplings may be specified briefly as follows:

- The pipe shall be furnished with plain ends for Dresser couplings in accordance with **A.W.W.A.** (American Water Works Association) specifications on tolerances;

OR:

- The pipe shall be furnished with plain ends for Dresser couplings in accordance with A.G.A. (American Gas Association) specifications on tolerances.

If further specifications are desired, the following may be added:

- The pipe shall be smooth and round for a distance of 8” from each end. The maximum plus or minus variation from nominal outside diameters for each size shall not exceed dimensions as shown in chart shown below.
- The maximum outside pipe diameter shall be such as to permit the passing of a ring gauge having an internal bore not greater than .01” larger than the maximum allowable outside diameter of the pipe. This ring gauge shall go over the end of the pipe for a distance of 8” for all sizes up to and including 24” and for a distance of 12” on sizes above 24”.
- The minimum outside diameter shall be determined by use of a steel tape circumferentially applied to prevent the shipment of undersized, out-of-round pipe which, if measured diametrically through the maximum diameter or checked with a No-Go ring gauge, might appear within the specified tolerance.

Size	Maximum Variation
3” - 16”	.06”
18”- 24”	.08”
30”- 42”	.10”
48”	.12”
54”- 60”	.15”

---

*While Dresser couplings require only plain-end pipe, other kinds of pipe ends (such as threaded, beveled or grooved) can be used if such pipe is already on hand.

Coupling Deflection, Movement, Expansion and Contraction

Laying out curves with standard Dresser couplings and straight sections of pipe

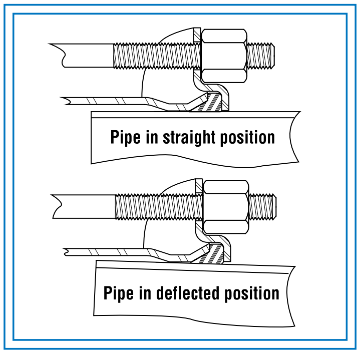
Presented in tabular form in the table at right entitled “Radius of Curve and Deflection of Pipe in Feet”, this chart indicates (1) radius of circle for any given degrees of deflection and pipe length, (2) length of pipe for any given radius and deflection or (3) degrees deflection necessary for any given pipe length and radius. This information is worked out for the more commonly used pipe lengths and degrees deflection.

Expansion & Contraction

Each coupling 10” ID and larger will safely accommodate up to 3/8” longitudinal pipe movement. This is equivalent to the amount of movement resulting from a 120° temperature variation in a 40-foot length of steel pipe. If pipe is not buried, anchorage should be provided to prevent excessive accumulation of movement. For repeated movements such as on a bridge or above ground, or if expansion exceeds 3/8” per joint, a Dresser Style 63 expansion joint should be used.

RADIUS OF CURVE AND DEFLECTION OF PIPE IN FEET

Length of Pipe Sec. (feet)	Radius of Curve (Feet) Varying degrees deflection in each coupling						Deflection of Pipe (Feet/Inches) Varying degrees deflection in each coupling					
	1°	2°	3°	4°	5°	6°	1°	2°	3°	4°	5°	6°
6	344	172	115	84	66	57	1/4”	2-1/2”	3-3/4”	5”	6-1/4”	7-1/2”
12	687	344	229	172	138	114	2-1/2	5	7-1/2	10	1’ 5/8	1’ 3
16	916	458	306	229	183	153	3-3/8	6-3/4	10	1’ 1-1/2	1’ 4-3/4	1’ 8
18	1031	516	344	258	206	172	3-3/8	7-1/2	1’1-1/4	1’ 3-1/8	1’ 6-7/8	1’10-1/2
20	1145	573	382	286	229	191	4-1/4	8-3/8	1’ 5/8	1’ 4-3/4	1’ 8-7/8	2’ 1
30	1718	860	573	430	344	286	6-1/4	1’ 5/8	1’ 6-7/8	2’ 1	2’ 7-7/8	3’ 1-5/8
40	2291	1146	764	573	458	382	8-3/8	1’ 4-3/4	2’ 1	2’ 9-1/2	3’ 5-7/8	4’ 2-1/8



Maximum Recommended Laying Deflection Dresser Style 38 Couplings

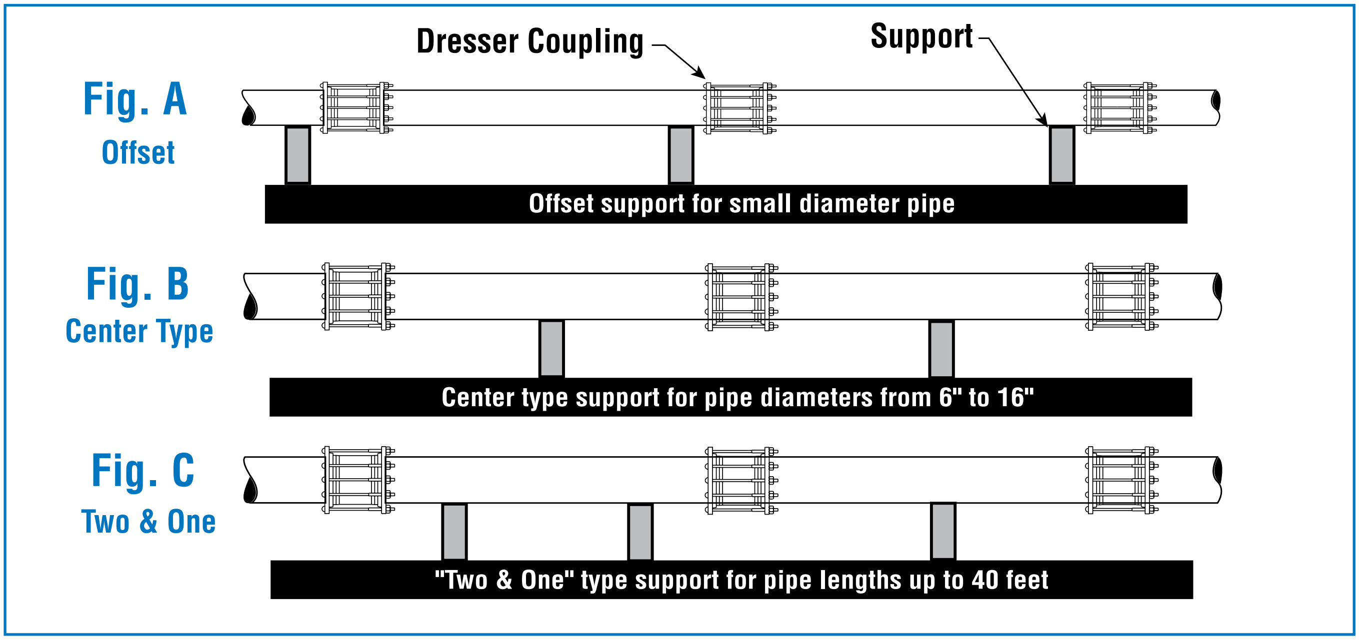
From 3/8” ID to 2” ID Inclusive..................6°
From 2” ID to 14” OD Inclusive..................4°

With Middle Ring Lengths:	5”	7”	10”
14” OD - 20” OD Inclusive	2-1/2°	4°	4°
20” OD - 30” OD Inclusive	2°	4°	4°
30” OD - 37” OD Inclusive	1-1/2°	3°	3-1/2°
37” OD - 42” OD Inclusive		2-1/2°	3-1/2°
42” OD - 49” OD Inclusive		2°	3°
49” OD - 54” OD Inclusive		2°	3°
54” OD - 66” OD Inclusive		2°	2-1/2°
66” OD - 78” OD Inclusive			2°
78” OD - 90” OD Inclusive			1-1/2°

Methods of Supporting Coupled Lines

Shown below are three options for supporting pipeline connections when using Dresser couplings. **Figure A** shows the offset method near the pipe joint for diameters 6” and smaller with pipe lengths up to 20 feet. Suitable for any pressure providing pipe is anchored to support for high pressure. **Figure B** indicates the center-type support for diameters from 6” to 16” and lengths not over 20 feet. This method is suitable for pressures up to 25 lb. maximum with pipe fully anchored to supports.

Figure C shows the “Two & One” method for all sizes and any length of pipe up to 40 feet. Suitable for any pressure providing pipe is adequately anchored. When utilizing this method each length of pipe must be anchored to one (and ONLY one) support.



Style 63 Expansion Joints

For absorbing concentrated pipe movement

NOTE:
See Page 2 for Style 63 ordering information

Dresser offers the broadest line of **Style 63 Expansion Joints** including single-end (Type 1 and Type 3 shown below), and double-end (Type 2 & 4), limited-movement types, flanged, lock coupled, or weld ends. Aggressive wear and pipe wall failure caused by fatigue of the convoluted surfaces present in rubber accordion or metal bellows types is eliminated with Dresser expansion joints. There is no need for expensive pipe loop systems.

Dresser expansion joints are built to order and are available up to 120" in diameter. Provided with rugged welded steel construction, the Style 63 is available in stainless or carbon steel, monel or other alloys for special applications. Single-end expansion joints permit up to 10" of concentrated pipe movement. Larger amounts of movement are available per application.

Special packing and lubrication requirements are custom-matched to specific fluid processes or application requirements. Temperature ratings to 800°F and pressure ratings to 1200 psi.

Available with Dresser AL-CLAD™ coating for optimum protection against aggressive water conditions and for handling brine, brackish water, coke oven gas, petroleum and other line content.

Materials of Construction

Body: AISI C1006, C1010, C1015, C1025 or ASTM A513 Carbon Steel

Follower: AISI C1012, C1021, ASTM A20 or A36 Carbon Steel

Slip Pipe: Chrome plated

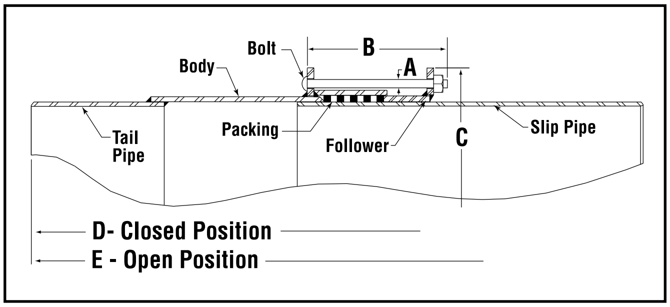
Tail Pipe: AISI C1006, C1010, C1015, C1025 or ASTM A513 Carbon Steel

Bolts & Nuts: ANSI/AWWA C111/ANSI A21.11

Packing: Standard packing is alternate rings of Buna-S and lubricating split jute

Style 63 Type 1 Sizes and Specifications

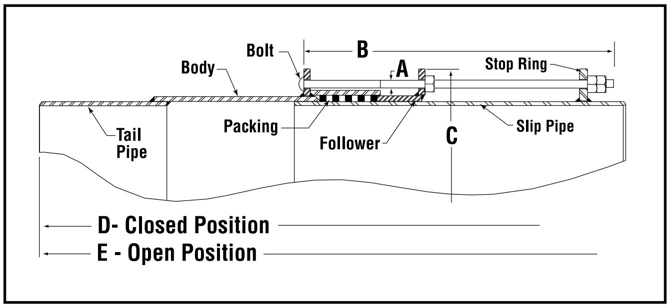
Pipe Nominal Size (In)	Outside Diameter (OD)	Bolts No./Diam. x Length (A&B)	Overall Dimensions		Weight Per Joint (Lbs)
			Diam. (C)	Length (D) (E)	
3	3.500	4–5/8 x 11	8-1/2	CONSULT FACTORY PER ORDER	65
4	4.500	4–5/8 x 11	9-1/2		75
5	5.563	4–5/8 x 11	10-5/8		110
6	6.625	6–5/8 x 11	11-3/4		130
8	8.625	6–5/8 x 11	13-3/4		180
10	10.750	8–5/8 x 11	15-7/8		250
12	12.750	8–5/8 x 11	17-7/8		315
	14.000	8–5/8 x 11	19-1/2		340
	16.000	10–5/8 x 11	21-1/2		380
	18.000	10–5/8 x 11	23-1/2		415
	20.000	12–5/8 x 11	25-1/2		470
	22.000	14–5/8 x 11	27-1/2		525
	24.000	14–5/8 x 11	29-1/2		565



Type 1 is a single-end expansion joint permitting up to 10" of concentrated pipe movement. Standard packing consists of alternate layers of split resilient sealing rings and jute lubricating rings. Other packing for special conditions can be supplied.

Style 63 Type 3 Sizes and Specifications

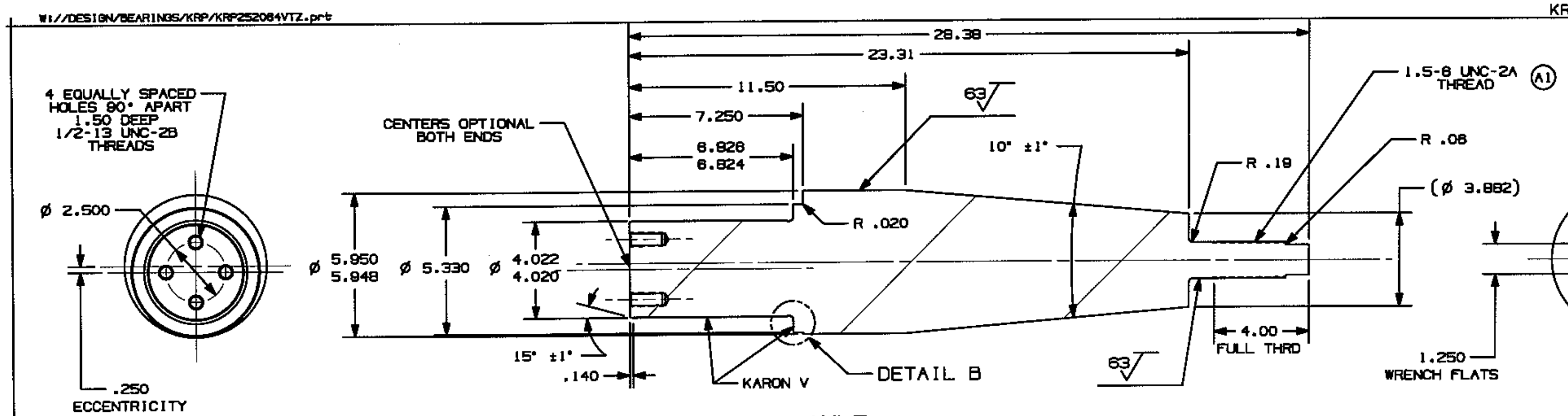
Pipe Nominal Size (In)	Outside Diameter (OD)	Bolts No./Diam. x Length (A&B)	Overall Dimensions		Weight Per Joint (Lbs)
			Diam. (C)	Length (D) (E)	
3	3.500	4–5/8 x 24	8-1/2	CONSULT FACTORY PER ORDER	80
4	4.500	4–5/8 x 24	9-1/2		90
5	5.563	4–5/8 x 24	10-5/8		125
6	6.625	6–5/8 x 24	11-3/4		155
8	8.625	6–5/8 x 24	13-3/4		205
10	10.750	8–5/8 x 24	15-7/8		285
12	12.750	8–5/8 x 24	17-7/8		350
	14.000	8–5/8 x 24	19-1/2		385
	16.000	10–5/8 x 24	21-1/2		430
	18.000	10–5/8 x 24	23-1/2		470
	20.000	12–5/8 x 24	25-1/2		530
	22.000	14–5/8 x 24	27-1/2		590
	24.000	14–5/8 x 24	29-1/2		635



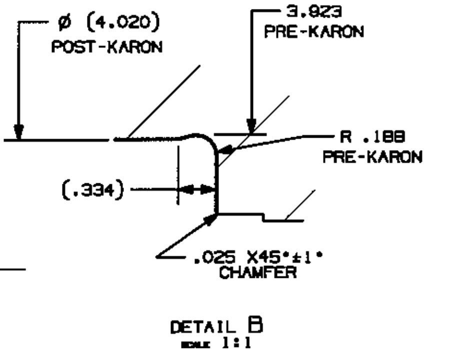
Type 3 is a single-end expansion joint equipped with a limited movement feature to limit the maximum amount of pipe withdrawal. Slip pipes are regularly furnished for Type 3 expansion joints.

KRP252064VTZ REV A

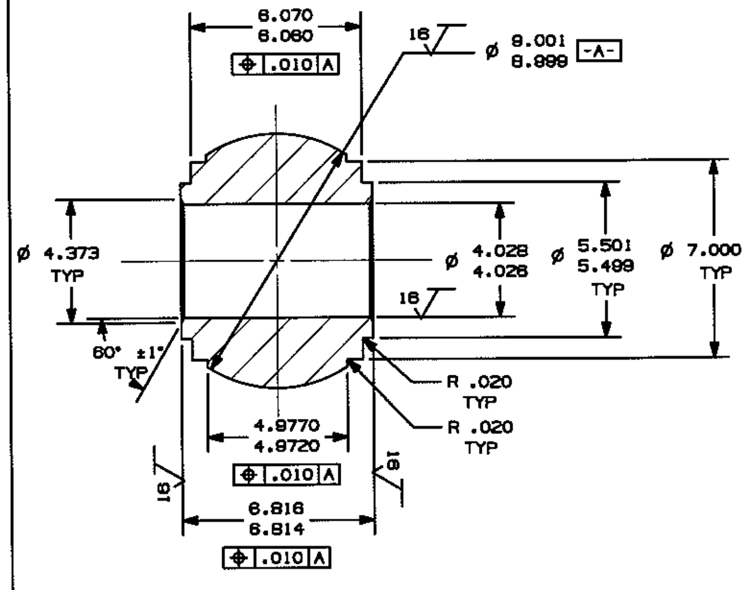
W://DESIGN/BEARINGS/KRP/KRP252064VTZ.prt



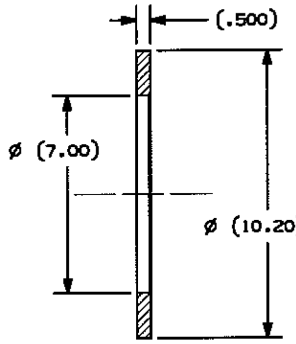
AXLE



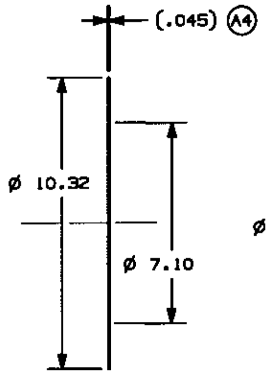
DETAIL B
SCALE 1:1



BALL

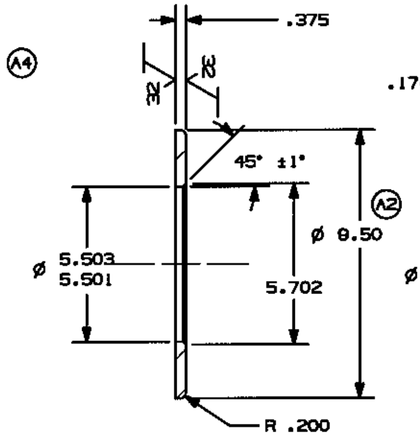


2X SNUBBER

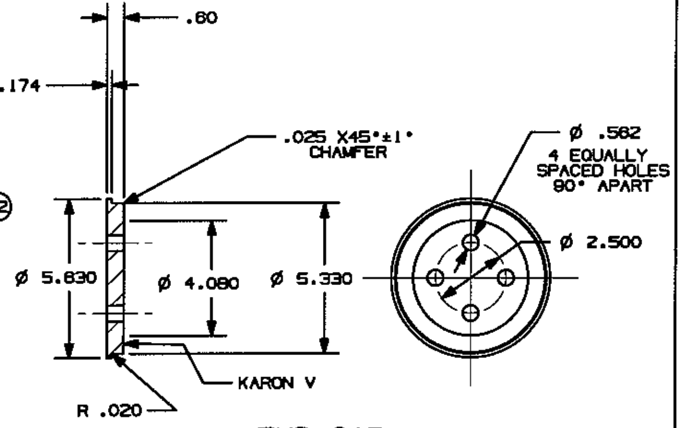


(A6)

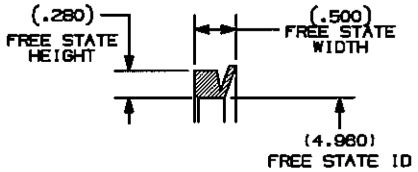
2X SNUBBER GUARD



2X THRUST WASHER



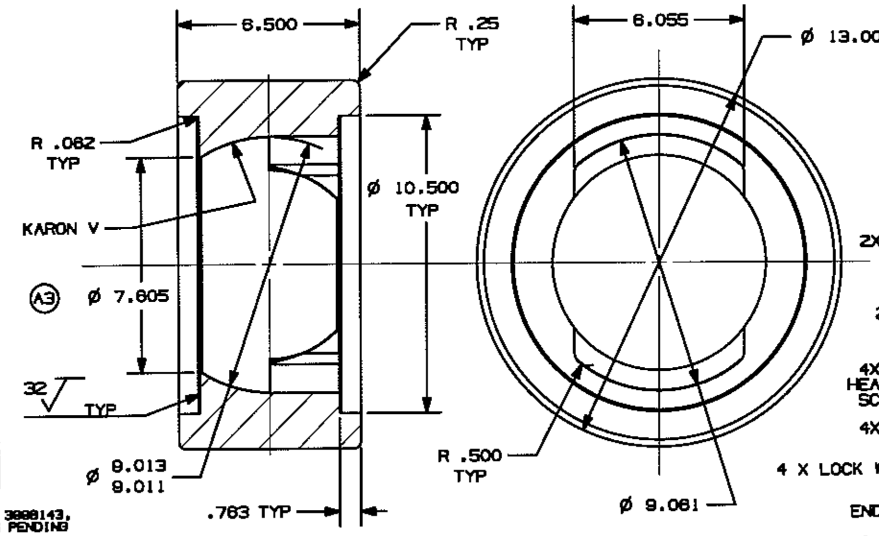
END CAP



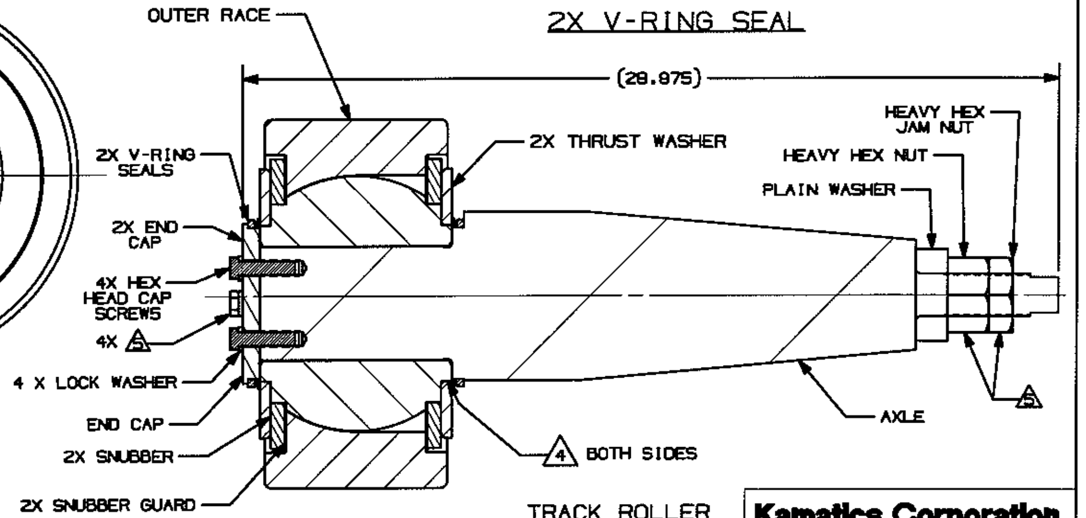
2X V-RING SEAL

MATERAIALS	
OUTER RACE	17-4 CRES (UNS S17400), RC 38 MIN
BALL	17-4 CRES (UNS S17400), RC 40 MIN
THRUST WASHERS	17-4 CRES (UNS S17400), RC 40 MIN
AXLE	CRES PER ASTM A 564, UNS S17400, TYPE 630, CONDITION H1150
(A7) SNUBBER	ELASTOMER (NITRILE/BUNA N OR EQ.)
(A5) SNUBBER GUARD	P54 WEAR STRIP
V-RING SEALS	NITRILE (GENERAL PURPOSE SEAL)
END CAP	17-4 STAINLESS STEEL (UNS S17400) HEAT TREATED TO RC 30 MIN
HEX HEAD CAP SCREWS	18-8 OR 300 SERIES STAINLESS STEEL (2-INCH LONG)
LOCK WASHER	18-8 OR 300 SERIES STAINLESS STEEL
HEAVY HEX NUT	410 STAINLESS STEEL
(A9) HEAVY HEX JAM NUT	410 STAINLESS STEEL
PLAIN WASHER	18-8 OR 300 SERIES STAINLESS STEEL
LINER	KARON V (.010/.015 THK)

U.S. PATENT NO. 3806218, 3904731, 3929398, 3998143, 4033019, 4048370, 4053665, 4080287, OTHERS PENDING



OUTER RACE



TRACK ROLLER ASSEMBLY

NOTES:
1. RADIAL STATIC LIMIT LOAD = 1,000,000 LB (BASED ON KARON COMPONENT ONLY, AXLE BENDING NOT CONSIDERED
2. RADIAL DYNAMIC LOAD RATING = 365,500 LB (BASED ON KARON COMPONENT ONLY, AXLE BENDING NOT CONSIDERED)
3. BEARING MISALIGNMENT = ±2.5°
4. WELD THRUST WASHER TO BALL BOTH SIDES AROUND ENTIRE CIRC (.060 MIN DEEP)
5. ALL MECHANICAL FASTENERS SHALL BE INSTALLED WITH ANTI SEIZE COMPOUND (A8) (SCREWS, NUTS, THREADS, ETC...)

NOTICE OF PROPRIETARY RIGHTS

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REVISIONS	
A	1. ADDED THREAD CALL OUT 2. WAS 9.75 IS 9.50 3. ADDED SPHERICAL "WINDOW" DIA - 7.605 4. ADDED REF SNUBBER GUARD THK 5. ADDED SNUBBER GUARD TO BOM 6. RENAMED P54 WASHER TO SNUBBER GUARD 7. ADDED ELASTOMER CALLOUT TO SNUBBER 8. ADDED NOTE 5 "ANTI SEIZE COMPOUND REQ" 9. ADDED LOCK WASHER, HEAVY HEX NUT, HEAVY HEX JAM NUT, AND PLAIN WASHER TO BOM TPR 07/13/07 7/19/07

TOLERANCE
UNLESS OTHERWISE SPECIFIED
All dimensions in inches
Break sharp edges; .015 max.
Single place decimals ± .125
Two place decimals ± .030
Three place decimals ± .010
Angles ± 2° (degrees)
Surface roughness; 125 per MIL-STD-10

Sheet 1 OF 1		
PLOT SCALE: NA		
DWN	TPR	7/02/07
APPVD		

Kamatics Corporation
KAMAN
MANUFACTURING ENGINEERING
TOOLING DRAWING

JOHN DAY TEMPORARY
SPILLWAY WEIR
GATE ROLLER

KRP252064VTZ
REV. A

CORPS OF ENGINEERS 02-03

32.5427.01

The New Timken® Spherical Roller Bearing

TIMKEN

Where You Turn

Timken's spherical roller bearings are available with stamped steel or machined brass cages.

Designs: *EJ/EM/EMB*

Common Applications:

- *Casters (metal mills)*
- *Conveyors*
- *Felt and Wire Rolls (paper)*
- *Gear Drives*
- *Shaker Screens*

Top Performance, Longer Life and Cooler Running

For the new Timken® spherical roller bearing top performance is in the details. With our one-of-a-kind slotted-cage, unique internal geometries and enhanced surface textures, our spherical roller bearing line reaches the highest performance levels in the industry.

In fact, this product offers an 18 percent increase in capacity resulting in a 75 percent design life improvement over our former spherical roller bearing offering. Engineered for enhanced durability, the new spherical roller bearing from Timken also runs cooler and has a longer design life – for greater reliability.

Innovative Design

Advanced Internal Geometries

- Optimized internal geometries balance the need for increasing load-carrying capability while lowering operating temperatures.
- Axial roller guidance improves lubricant distribution and positive roller guidance, which translates into lower operating temperatures and improved performance.
- Circumferential roller guidance generates positive hydrodynamic contact, contributing to better roller/cage interaction.

Surface Finishes

- Improved surface finishes help lower operating temperatures and increase speed capabilities.

Cage Options

Stamped Steel Cage (EJ)

- Two-piece land riding
- Surface hardened
- Slotted for more efficient lubrication distribution
- Ideal for increased speeds

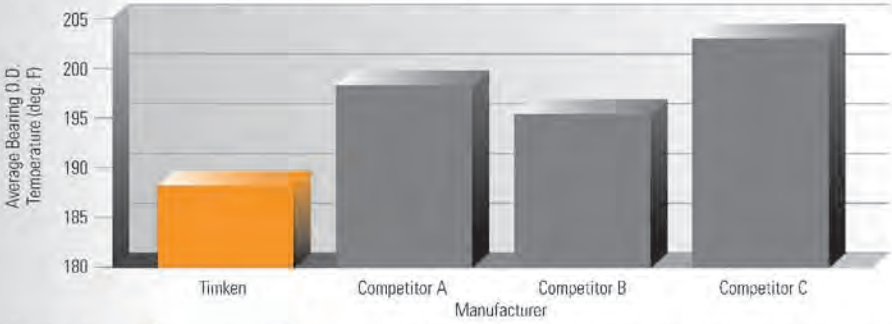
Machined Brass Cage (EM/EMB)

- Type EM is roller riding
- Type EMB is land riding
- Ideal for extreme operating environments

Cooler Than the Competition

Timken spherical roller bearings are designed to run cooler in heavy-duty applications subject to high temperatures. These bearings are engineered for maximum load capacity and are able to support combinations of radial and axial loading, even under significant misalignment conditions.

Actual Average Bearing O.D. Temperature Comparison: 22322 Spherical Roller Bearings



The bearing outside diameter (O.D.) temperature shown here is an average of the temperatures measured at the bearing O.D. of four competing bearings included in the test. Timken spherical roller bearings ran up to 14°F cooler than the competition.

From Design to Maintenance

Timken spherical roller bearings allow manufacturers and end-users to build and operate leaner, more reliable equipment while reducing their total cost of operation. Our power-dense bearings allow original equipment manufacturers to downsize their designs and still improve customer satisfaction. For operators, high bearing quality and reliability means less maintenance, while cooler operating temperatures help lengthen service life. It all adds up to greater uptime and a positive impact on your bottom line.

The Timken Difference

The Timken brand stands for high quality and outstanding performance. Using our capabilities in bearing technology, manufacturing, application knowledge and engineering, we provide our customers with smart, cost-effective friction management and power transmission solutions that improve total system performance and help outperform the competition. We also strive to deliver and excel in the moments that build your trust and confidence in our products.

Designed to Last

Our global engineering team collects performance requirements from around the world and designs bearings to meet the specifications our customers demand.

High Material Quality

Timken is the only premium bearing manufacturer in the world to produce clean, high-alloy steel. Our steel manufacturing knowledge helps ensure quality materials are used in our bearings.

Manufacturing Excellence

Timken worldwide quality standards are implemented in every manufacturing facility, so each Timken® bearing meets the same performance standards – no matter where in the world it is manufactured.

Timken Experts are Your Experts

Every Timken bearing is backed by our team of experts, providing you with the industry's best design, application and 24/7 field-engineering support.

A Full Range of Products

Timken continues to expand its line of spherical bearings to meet customer size and configuration demands. With our wide range of tapered, cylindrical and spherical bearings, you can make Timken your single-source bearing provider.

Timken Spherical Bearing Nomenclature

2	23	40	K	EJ	W507	C08	C3

EJ → Cage Type

TIMKEN
Where You Turn

Bearings • Steel •
Power Transmission Systems •
Precision Components • Seals •
Lubrication • Industrial Services •
Remanufacture and Repair

www.timken.com

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Printed in U.S.A.
20M 06-10: 29 Order No. 10376

The Dalles East Fish Ladder Auxiliary Water Backup System

60 Percent Design Documentation Report

APPENDIX F

Cost Estimates

Estimated by	Royal Mortier
Designed by	30% DDR by Walla Walla District
Prepared by	Royal Mortier
Preparation Date	2/28/2013
Effective Date of Pricing	2/28/2013
Estimated Construction Time	Days

Designed by
30% DDR by Walla Walla District

Estimated by
Royal Mortier

Prepared by
Royal Mortier

Design Document	The Dalles EFL AWS 30% DDR
Document Date	10/1/2014
District	Walla Walla District
Contact	Royal Mortier
Budget Year	2012
UOM System	Original

Direct Costs

LaborCost
EQCost
MatlCost
SubBidCost

Timeline/Currency

Preparation Date	2/28/2013
Escalation Date	2/28/2013
Eff. Pricing Date	2/28/2013
Estimated Duration	0 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB10EB: MII English Cost Book 2010

Labor NLS2010: National Labor Library - Seattle 2010

Note: http://www.wdol.gov is the website for current Davis Bacon & Service Labor Rates. Fringes paid to the laborers are taxable. In a non-union job the whole fringes are taxa
vaca

Labor Rates

LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP11R08: MII Equipment 2011 Region 08

08 NORTHWEST

Sales Tax	5.40
Working Hours per Year	1,540
Labor Adjustment Factor	1.05
Cost of Money	2.50
Cost of Money Discount	25.00
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel

Electricity	0.072
Gas	3.670
Diesel Off-Road	3.450
Diesel On-Road	3.990

Shipping Rates

Over 0 CWT	28.32
Over 240 CWT	26.60
Over 300 CWT	24.23
Over 400 CWT	22.06
Over 500 CWT	11.26
Over 700 CWT	9.51
Over 800 CWT	6.48

Date	**Author**	**Note**

Project Notes

Description	Quantity	UOM	ProjectCost
Project Cost Summary Report			**10,911,725**
The Dalles EFL AWS	**1.00**	**EA**	*10,911,724.63* **10,911,725**
Mob/Demob	**1.00**	**EA**	*206,685.85* **206,686**
Cofferdam	**1.00**	**EA**	*1,859,769.26* **1,859,769**
Steel Pipe Through Dam	**1.00**	**EA**	*1,499,848.42* **1,499,848**
E-11.3.4 Furnish and Install Steel Pipe	**570.50**	**LF**	*1,522.29* **868,469**
E-11.3.4.7 Pipe Welding Including Inspection	**480.00**	**LF**	*41.81* **20,067**
Welding Crew	**1.00**	**EA**	*20,067.14* **20,067**
E-11.3.4.1 Furnish and Install Steel Rails	**240.00**	**LF**	*67.32* **16,156**
E-11.3.5 Pressure Grout & Inlet Transition	**479.00**	**CY**	*620.28* **297,113**
E-11.3.5.1 Pressure Grout Around Conduits	**479.00**	**CY**	*620.28* **297,113**
E-11.3.6 Surface Prep & Paint Inside Area of Conduit Pipe	**21,510.00**	**SF**	*15.54* **334,266**
E-11.3.6.1 Surface Prep Interior of Steel Pipe	**21,510.00**	**SF**	*10.60* **228,079**
E-11.3.6.2 Paint Inside Area of Steel Pipes	**21,510.00**	**SF**	*4.94* **106,188**
MC-ZINC 100 (First Coat)	**1.00**	**EA**	*35,012.75* **35,013**
MC-TAR 100 (Second Coat)	**1.00**	**EA**	*35,587.45* **35,587**
MC-TAR 100 (Top Coat)	**1.00**	**EA**	*35,587.45* **35,587**
Piping from Dam to Channel	**1.00**	**EA**	*1,966,196.68* **1,966,197**
Concrete Mining	**1.00**	**EA**	*947,310.13* **947,310**
Approach Channel & Fish Lock Mod	**1.00**	**LS**	**2,063,583**

Description	Quantity	UOM	ProjectCost
Demolish Control House	**1.00**	**LS**	**41,323**
Demolish Fishlock Equipment	**1.00**	**LS**	**36,035**
			43,031.20
Demolition at Fishlock Approach Channel	**1.00**	**EA**	**43,031**
			1,943,193.97
Modification of Fishlock Approach Channel	**1.00**	**EA**	**1,943,194**
			1,810,295.14
Trash Rack	**1.00**	**EA**	**1,810,295**
			1,167,657.81
Intake Screen	**1.00**	**EA**	**1,167,658**
			558,035.98
Trash Rake	**1.00**	**EA**	**558,036**

Description	Quantity	UOM	Contractor	Duration	CrewHours	ManHours	ProjectCost
Contract Cost Summary Report				**1,939.50**	**2,215.50**	**18,480.78**	**10,911,725**
				1,939.50	*2,215.50*	*18,480.78*	*10,911,724.63*
The Dalles EFL AWS	**1.00**	**EA**		**1,939.50**	**2,215.50**	**18,480.78**	**10,911,725**
				0.00	*48.00*	*576.00*	*206,685.85*
Mob/Demob	**1.00**	**EA**	**Prime Contractor**	**0.00**	**48.00**	**576.00**	**206,686**
				46.00	*54.00*	*464.00*	*1,859,769.26*
Cofferdam	**1.00**	**EA**	**Prime Contractor**	**46.00**	**54.00**	**464.00**	**1,859,769**
				887.20	*887.20*	*3,944.56*	*1,499,848.42*
Steel Pipe Through Dam	**1.00**	**EA**	**Prime Contractor**	**887.20**	**887.20**	**3,944.56**	**1,499,848**
				0.53	*0.53*	*3.17*	*1,522.29*
E-11.3.4 Furnish and Install Steel Pipe	**570.50**	**LF**	**Prime Contractor**	**302.80**	**302.80**	**1,808.96**	**868,469**
(Note: Welded steel pipe liner will have to be installed in possibly five to six sections (combining individual lengths of pipe) by sliding in from the outlet side. The sections will have to be welded together with full penetration welds after installation.)							
				0.06	*0.06*	*0.24*	*41.81*
E-11.3.4.7 Pipe Welding Including Inspection	**480.00**	**LF**	**Prime Contractor**	**28.24**	**28.24**	**112.94**	**20,067**
(Note: Pipe welding will occur at the entry outside of the concrete conduit and then the new steel conduit will be pushed into place.)							
				28.24	*28.24*	*112.94*	*20,067.14*
Welding Crew	**1.00**	**EA**	**Prime Contractor**	**28.24**	**28.24**	**112.94**	**20,067**
				0.17	*0.17*	*0.49*	*67.32*
E-11.3.4.1 Furnish and Install Steel Rails	**240.00**	**LF**	**Prime Contractor**	**39.68**	**39.68**	**116.48**	**16,156**
(Note: Assume installation steel rails to support and guide the new conduit through the concrete conduit. The total length of the concrete conduit is 60 LF x 4 rails each conduit = 240 LF total.)							
				0.00	*0.00*	*0.00*	*620.28*
E-11.3.5 Pressure Grout & Inlet Transition	**479.00**	**CY**	**Prime Contractor**	**0.00**	**0.00**	**0.00**	**297,113**
(Note: Fill Voids with Non Shrink Grout Typical of 5000PSI.)							
				0.00	*0.00*	*0.00*	*620.28*
E-11.3.5.1 Pressure Grout Around Conduits	**479.00**	**CY**	**Prime Contractor**	**0.00**	**0.00**	**0.00**	**297,113**
(Note: See Item detail for information regarding quantity calculations. This work is assumed to be subcontracted out and the markups are reflected in the quote eventhough the prime contractor is assigned.)							
				0.03	*0.03*	*0.10*	*15.54*
E-11.3.6 Surface Prep & Paint Inside Area of Conduit Pipe	**21,510.00**	**SF**	**Prime Contractor**	**584.40**	**584.40**	**2,135.60**	**334,266**
(Note: Total surface area (ID) = pi x diam x length = 3.14... x 12' x 570.5 LF = 21,507 SF (rouding up = 21,510 SF))							
				0.02	*0.02*	*0.07*	*10.60*
E-11.3.6.1 Surface Prep Interior of Steel Pipe	**21,510.00**	**SF**	**Prime Contractor**	**382.40**	**382.40**	**1,529.60**	**228,079**
(Note: Assume on site surface preparation at staging area. Check item detail for quantity information.)							
				0.01	*0.01*	*0.03*	*4.94*
E-11.3.6.2 Paint Inside Area of Steel Pipes	**21,510.00**	**SF**	**Prime Contractor**	**202.00**	**202.00**	**606.00**	**106,188**
(Note: Assume 70 percent of painting done on-site at staging area. Remaing 30 percent done after installation due to selding. Check item detail for quantity information.)							
				54.00	*54.00*	*162.00*	*35,012.75*
MC-ZINC 100 (First Coat)	**1.00**	**EA**	**Prime Contractor**	**54.00**	**54.00**	**162.00**	**35,013**
				74.00	*74.00*	*222.00*	*35,587.45*

Description	Quantity	UOM	Contractor	Duration	CrewHours	ManHours	ProjectCost
MC-TAR 100 (Second Coat)	**1.00**	**EA**	**Prime Contractor**	**74.00**	**74.00**	**222.00**	**35,587**
				74.00	*74.00*	*222.00*	*35,587.45*
MC-TAR 100 (Top Coat)	**1.00**	**EA**	**Prime Contractor**	**74.00**	**74.00**	**222.00**	**35,587**
				382.06	*382.06*	*4,408.22*	*1,966,196.68*
Piping from Dam to Channel	**1.00**	**EA**	**Prime Contractor**	**382.06**	**382.06**	**4,408.22**	**1,966,197**
				0.00	*220.00*	*2,640.00*	*947,310.13*
Concrete Mining	**1.00**	**EA**	**Prime Contractor**	**0.00**	**220.00**	**2,640.00**	**947,310**
Approach Channel & Fish Lock Mod	**1.00**	**LS**	**Prime Contractor**	**491.25**	**491.25**	**5,895.00**	**2,063,583**
Demolish Control House	**1.00**	**LS**	**Prime Contractor**	**0.00**	**0.00**	**0.00**	**41,323**
Demolish Fishlock Equipment	**1.00**	**LS**	**Prime Contractor**	**0.00**	**0.00**	**0.00**	**36,035**
				10.00	*10.00*	*120.00*	*43,031.20*
Demolition at Fishlock Approach Channel	**1.00**	**EA**	**Prime Contractor**	**10.00**	**10.00**	**120.00**	**43,031**
				481.25	*481.25*	*5,775.00*	*1,943,193.97*
Modification of Fishlock Approach Channel	**1.00**	**EA**	**Prime Contractor**	**481.25**	**481.25**	**5,775.00**	**1,943,194**
(Note: 30% DDR will require ~4200 CY of new conrete for walls and reinforcing of the fishlock approach channel)							
				117.00	*117.00*	*521.00*	*1,810,295.14*
Trash Rack	**1.00**	**EA**	**Prime Contractor**	**117.00**	**117.00**	**521.00**	**1,810,295**
				45.00	*45.00*	*225.00*	*1,167,657.81*
Intake Screen	**1.00**	**EA**	**Prime Contractor**	**45.00**	**45.00**	**225.00**	**1,167,658**
				16.00	*16.00*	*32.00*	*558,035.98*
Trash Rake	**1.00**	**EA**	**Prime Contractor**	**16.00**	**16.00**	**32.00**	**558,036**

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
Crews (Bare Costs) by Contractor, Report		**2,215.50**			**18,280.78**	**855,126.52**	**28,675.20**	**1,157,118.80**	**2,012,245.33**
Prime Contractor	**LaborCost1**	**2,215.50**		**0.00**	**18,280.78**	**855,126.52**	**28,675.20**	**1,157,118.80**	**2,012,245.33**
					2.00	*88.50*	*1.00*	*9.05*	*97.55*
RSM B89A B89A	LaborCost1	16.00			32.00	1,416.00	16.00	144.76	1,560.76
MIL B-SKILLWKR Skilled Workers			Journeyman	48.47	1.00	48.47			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	1.00	40.03			
GEN D20Z2800 DRILL, CORE, COLUMN MOUNTED, 9"-36" (229-914 MM) DIA, W/STAND AND HYDRAULIC POWER PACK (ADD COST FOR DRILL STEEL AND BIT WEAR)			EP / Average	9.05			1.00	9.05	
					1.00	*48.47*	*0.00*	*0.00*	*48.47*
RSM CARP CARP	LaborCost1	26.88			26.88	1,302.87	0.00	0.00	1,302.87
MIL B-CARPNTER Carpenters			Journeyman	48.47	1.00	48.47			
					4.00	*146.03*	*3.00*	*29.08*	*175.11*
RSM E11 E11	LaborCost1	382.40			1,529.60	55,841.87	1,147.20	11,121.85	66,963.72
MIL B-PAINTSS Painters, Structural Steel			Journeyman	28.26	2.00	56.52			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	1.00	40.03			
MIL B-EQOPRLT Equip. Operators, Light			Journeyman	49.48	1.00	49.48			
GEN A15Z0140 AIR COMPRESSOR, 250 CFM (7 CMM), 100 PSI (689 KPA) (ADD HOSE)			EP / Average	18.12			1.00	18.12	
GEN A20Z0220 SANDBLASTER, 600 LB (272 KG) CAPACITY, W/HOSE (ADD 250 CFM (7 CMM) COMPRESSOR & NOZZLE COST)			EP / Average	2.97			1.00	2.97	
GEN A20Z0240 SANDBLASTER, ABRASIVE STORAGE HOPPER, 35 TON (31.7 MT), 700 CF (20 M3) (ADD SAND BLASTER & ACCESSORIES)			EP / Average	7.99			1.00	7.99	
					7.00	*363.26*	*1.00*	*129.05*	*492.31*
RSM E2 E2	LaborCost1	12.80			89.60	4,649.73	12.80	1,651.88	6,301.61
MIL B-STRSTEEL Structural Steel Workers			Foreman	56.02	1.00	56.02			
MIL B-EQOPRCRN Equip. Operators, Heavy			Journeyman	50.39	1.00	50.39			
MIL B-EQOPROIL Equip. Operators, Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	4.00	216.08			
GEN C80Z2300 CRANE, HYDRAULIC, TRUCK MOUNTED, 90 TON (81.6 MT), 114' (34.7 M) BOOM, 8X4			EP / Average	129.05			1.00	129.05	
					4.00	*218.08*	*1.00*	*10.64*	*228.72*
RSM E4 E4	LaborCost1	14.88			59.53	3,245.84	14.88	158.36	3,404.20

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	3.00	162.06			
MIL B-STRSTEEL Structural Steel Workers			Foreman	56.02	1.00	56.02			
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED			EP / Average	10.64			1.00	10.64	
					3.00	*136.97*	*0.00*	*0.00*	*136.97*
RSM L4 L4	LaborCost1	32.00			96.00	4,383.04	0.00	0.00	4,383.04
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	1.00	40.03			
MIL B-SKILLWKR Skilled Workers			Journeyman	48.47	2.00	96.94			
					4.00	*171.22*	*2.00*	*203.55*	*374.77*
USR 150 Ton Crane and Operator	LaborCost1	6.00			24.00	1,027.32	12.00	1,221.30	2,248.62
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
					12.00	*567.85*	*35.00*	*1,484.55*	*2,052.40*
USR Boring Crew and Equipment	LaborCost1	48.00			576.00	27,256.80	1,680.00	71,258.41	98,515.21
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Foreman	51.39	1.00	51.39			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
					12.00	*566.85*	*35.00*	*1,484.55*	*2,051.40*
USR Boring Crew and Equipment	LaborCost1	10.00			120.00	5,668.50	350.00	14,845.50	20,514.00
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
					12.00	*567.85*	*35.00*	*1,484.55*	*2,052.40*
USR Boring Crew and Equipment	LaborCost1	220.00			2,640.00	124,927.00	7,700.00	326,601.03	451,528.03
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Foreman	51.39	1.00	51.39			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100',			EP / Average	6.18			2.00	12.36	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
HARDROCK									
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
					5.00	*238.49*	*2.00*	*203.55*	*442.04*

Description	**LaborRate**	**CrewHours**	**MemberType**	**MemberRate**	**ManHours**	**LaborCost**	**EQHours**	**EQCost**	**CrewCost**
USR Bulkhead Install Crew	LaborCost1	40.00			200.00	9,539.60	80.00	8,141.98	17,681.58
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
					5.00	*238.49*	*2.00*	*203.55*	*442.04*
USR Bulkhead Install Crew	LaborCost1	20.00			100.00	4,769.80	40.00	4,070.99	8,840.79
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
					5.00	*238.49*	*2.00*	*203.55*	*442.04*
USR Bulkhead Install Crew	LaborCost1	25.00			125.00	5,962.25	50.00	5,088.74	11,050.99
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
					12.00	*566.85*	*35.00*	*1,484.55*	*2,051.40*
USR Piping Install Crew	LaborCost1	220.00			2,640.00	124,707.00	7,700.00	326,601.03	451,308.03
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
					12.00	*566.85*	*35.00*	*1,484.55*	*2,051.40*
USR Piping Install Crew	LaborCost1	40.00			480.00	22,674.00	1,400.00	59,382.01	82,056.01
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
					12.00	*566.85*	*35.00*	*1,484.55*	*2,051.40*
USR Piping Install Crew	LaborCost1	100.00			1,200.00	56,685.00	3,500.00	148,455.02	205,140.02
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000			EP / Average	96.49			1.00	96.49	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)									
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
					12.00	*566.85*	*35.00*	*1,484.55*	*2,051.40*
USR Piping Install Crew	LaborCost1	60.00			720.00	34,011.00	2,100.00	89,073.01	123,084.01
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
					4.00	*203.09*	*5.00*	*45.94*	*249.03*
USR Welding Crew	LaborCost1	80.00			320.00	16,247.20	400.00	3,675.58	19,922.78
MIL B-WELDERS Welders, Structural Steel			Journeyman	54.02	3.00	162.06			
MIL B-LABORER Laborers, (Semi-Skilled)			Foreman	41.03	1.00	41.03			
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			1.00	10.64	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			1.00	1.85	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
					4.00	*203.09*	*5.00*	*45.94*	*249.03*
USR Welding Crew	LaborCost1	28.24			112.94	5,734.31	141.18	1,297.26	7,031.57
MIL B-WELDERS Welders, Structural Steel			Journeyman	54.02	3.00	162.06			
MIL B-LABORER Laborers, (Semi-Skilled)			Foreman	41.03	1.00	41.03			
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			1.00	10.64	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			1.00	1.85	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
					3.00	*96.55*	*2.00*	*23.67*	*120.22*
USR 2pnt + 1lbr + 1trk 2 Painters + 1 Truck	LaborCost1	202.00			606.00	19,503.10	404.00	4,780.47	24,283.57
MIL B-PAINTSS Painters, Structural Steel			Journeyman	28.26	2.00	56.52			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	1.00	40.03			
GEN T50Z7310 TRUCK, HIGHWAY, CONVENTIONAL, 8,600 LB (3,901 KG) GVW, 4X2, 2 AXLE, 3/4 TON (0.68 MT) - PICKUP			EP / Average	11.83			2.00	23.67	
					6.00	*251.28*	*1.00*	*37.45*	*288.73*
USR 4 Laborers + 1 Operator + 1 Oiler + 1 Crane 18 Ton 4 Laborers + 1 Operator + 1 Oiler + 1 Crane 18 Tons	LaborCost1	80.00			480.00	20,102.40	80.00	2,996.02	23,098.42
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	4.00	160.12			
MIL B-EQOPROIL Equip. Operators, Oilers /			Journeyman	40.77	1.00	40.77			

Description	**LaborRate**	**CrewHours**	**MemberType**	**MemberRate**	**ManHours**	**LaborCost**	**EQHours**	**EQCost**	**CrewCost**
Grade Checker									
MIL X-EQOPRHVY Outside Equip. Operators, Heavy			Journeyman	50.39	1.00	50.39			
EP C75BD010 CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 18.0 TON, 50' BOOM, 4X4			EP / Average	37.45			1.00	37.45	
					4.00	*169.99*	*5.00*	*112.21*	*282.20*
USR B10Y B10Y	LaborCost1	4.00			16.00	679.96	20.00	448.84	1,128.80
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	3.00	120.09			
MIL B-EQOPRMED Equip. Operators, Medium			Journeyman	49.90	1.00	49.90			
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
GEN R45Z5675 ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 6.6 TON (6.0 MT), 56" (4.5 M) WIDE, ASPHALT COMPACTOR			EP / Average	45.34			1.00	45.34	
					4.00	*170.48*	*6.00*	*236.51*	*406.99*
USR B13F B13F	LaborCost1	9.36			37.44	1,595.69	56.16	2,213.74	3,809.43
MIL B-EQOPRCRN Equip. Operators, Heavy			Journeyman	50.39	1.00	50.39			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	3.00	120.09			
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
GEN H25Z3210 HYDRAULIC EXCAVATOR, CRAWLER, 140,000 LB (63,503 KG), 3.50 CY (2.7 M3) BUCKET, 31.4' (9.6 M) MAX DIGGING DEPTH			EP / Average	154.64			1.00	154.64	
GEN XMEZ9685 8 x 24 STEEL TRENCH BOX			Non-EP / Average	15.00			1.00	15.00	
					12.00	*579.57*	*2.00*	*128.44*	*708.01*
USR C14D C14D	LaborCost1	393.75			4,725.00	228,205.69	787.50	50,572.52	278,778.21
MIL B-CARPNTER Carpenters			Foreman	50.07	1.00	50.07			

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MIL B-EQOPRMED Equip. Operators, Medium			Journeyman	49.90	1.00	49.90			
MIL B-CARPNTER Carpenters			Journeyman	48.47	5.00	242.35			
MIL B-CEMTFINR Cement Finishers			Journeyman	49.15	1.00	49.15			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-RODMAN Rodmen, (Reinforcing)			Journeyman	54.02	2.00	108.04			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	0.00			0.00	0.00	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	0.00			0.00	0.00	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	0.00			0.00	0.00	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	0.00			0.00	0.00	
GEN XMEZ9520 CONCRETE VIBRATOR, 2.5" (63.5 MM) DIA, W/7.5 HP (5.6 KW) GENERATOR			Non-EP / Average	3.02			1.00	3.02	
GEN C55Z1960 CONCRETE PUMP, PUMP & BOOM, 117 CY/HR (89 M3/HR), 75' (23 M) BOOM, TRUCK MOUNTED			EP / Average	125.42			1.00	125.42	
					12.00	*579.57*	*8.00*	*229.74*	*809.31*
USR C14E C14E	LaborCost1	87.50			1,050.00	50,712.38	700.00	20,102.03	70,814.41
MIL B-RODMAN Rodmen, (Reinforcing)			Journeyman	54.02	2.00	108.04			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-CARPNTER Carpenters			Journeyman	48.47	5.00	242.35			
MIL B-CEMTFINR Cement Finishers			Journeyman	49.15	1.00	49.15			
MIL B-EQOPRMED Equip. Operators, Medium			Journeyman	49.90	1.00	49.90			
MIL B-CARPNTER Carpenters			Foreman	50.07	1.00	50.07			
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			3.00	32.04	
GEN XMEZ9520 CONCRETE VIBRATOR, 2.5"			Non-EP / Average	3.02			1.00	3.02	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
(63.5 MM) DIA, W/7.5 HP (5.6 KW) GENERATOR									
GEN C55Z1960 CONCRETE PUMP, PUMP & BOOM, 117 CY/HR (89 M3/HR), 75' (23 M) BOOM, TRUCK MOUNTED			EP / Average	125.42			1.00	125.42	
					4.00	*169.99*	*5.00*	*122.51*	*292.50*
USR CODFB10T 1 eqoprmed + 1 loader, F/E, wheel, 4WD, 3.25 CY	LaborCost1	8.70			34.78	1,478.17	43.48	1,065.27	2,543.45
MIL B-EQOPRMED Equip. Operators, Medium			Journeyman	49.90	1.00	49.90			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	3.00	120.09			
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
GEN L40Z4397 LOADER, FRONT END, WHEEL, ARTICULATED, 3.25 CY (2.5 M3) BUCKET, 4X4			EP / Average	55.63			1.00	55.63	
Diving Contractor	**LaborCost1**	**48.00**		**0.00**	**240.00**	**22,800.00**	**240.00**	**2,151.21**	**24,951.21**
					5.00	*475.00*	*5.00*	*44.82*	*519.82*
USR Dive Crew	LaborCost1	24.00			120.00	11,400.00	120.00	1,075.60	12,475.60
USR DIVER Diver			Journeyman	95.00	5.00	475.00			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
EP M10MZ007 MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 40' X 12' X 5', 51 TON			EP / Average	2.18			1.00	2.18	
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED			EP / Average	10.64			2.00	21.28	
					5.00	*475.00*	*5.00*	*44.82*	*519.82*
USR Dive Crew	LaborCost1	24.00			120.00	11,400.00	120.00	1,075.60	12,475.60
USR DIVER Diver			Journeyman	95.00	5.00	475.00			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
EP M10MZ007 MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 40' X 12' X 5', 51 TON			EP / Average	2.18			1.00	2.18	
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED			EP / Average	10.64			2.00	21.28	

Description	CostType	ConditionType	Manufacturer	EQHours	Ownership	Operating	Total
Equipment by Contractor, Report				**28,865**	**342,232**	**809,175**	**1,151,407**
Prime Contractor				**28,865**	**342,232**	**809,175**	**1,151,407**
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)	EP	Average	XX NO SPECIFIC MANUFACTURER	698	*1.52* 1,060	*21.64* 15,103	*23.16* 16,163
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK	EP	Average	XX NO SPECIFIC MANUFACTURER	1,396	*2.17* 3,029	*3.98* 5,563	*6.15* 8,592
EP C75BD010 CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 18.0 TON, 50' BOOM, 4X4	EP	Average	BD BRODERSON MANUFACTURING CORPORATION	80	*12.32* 986	*24.62* 1,969	*36.94* 2,955
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8	EP	Average	TD TADANO AMERICA CORPORATION	789	*52.31* 41,274	*137.61* 108,575	*189.92* 149,849
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)	EP	Average	SU SULLIVAN-PALATEK, INC.	698	*13.80* 9,636	*19.19* 13,392	*32.99* 23,028
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW	EP	Average	XX NO SPECIFIC MANUFACTURER	806	*1.86* 1,499	*10.19* 8,212	*12.04* 9,711
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW	EP	Average	XX NO SPECIFIC MANUFACTURER	698	*5.09* 3,551	*54.92* 38,336	*60.01* 41,886
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)	EP	Average	NP NPK CONSTRUCTION EQUIPMENT	698	*40.58* 28,327	*55.02* 38,404	*95.60* 66,731
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)	EP	Average	KN KENT DEMOLITION TOOLS	698	*8.73* 6,095	*11.43* 7,977	*20.16* 14,071
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH	EP	Average	AB ALLMAND BROTHERS INC.	1,396	*1.96* 2,729	*6.15* 8,588	*8.11* 11,317
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET	EP	Average	KM Komatsu America International Company	698	*40.71* 28,414	*83.50* 58,283	*124.21* 86,698
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)	EP	Average	MY MIDLAND MANUFACTURING INC.	1,396	*1.52* 2,128	*1.25* 1,749	*2.78* 3,877

Description	**CostType**	**ConditionType**	**Manufacturer**	**EQHours**	**Ownership**	**Operating**	**Total**
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4	EP	Average	XX NO SPECIFIC MANUFACTURER	3,406	*3.23* 11,014	*7.35* 25,047	*10.59* 36,062
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)	EP	Average	WG ATLAS COPCO WAGNER	698	*113.29* 79,076	*143.12* 99,899	*256.41* 178,975
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP	EP	Average	NL NLB CORPORATION	1,396	*15.72* 21,946	*45.08* 62,930	*60.80* 84,877
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE	EP	Average	SO SOUTHWEST CONSTRUCTION EQUIPMENT CO.	698	*3.01* 2,102	*1.89* 1,321	*4.90* 3,424
GEN A15Z0140 AIR COMPRESSOR, 250 CFM (7 CMM), 100 PSI (689 KPA) (ADD HOSE)	EP	Average	ZZ GENERIC EQUIPMENT	382	*2.96* 1,133	*15.06* 5,759	*18.02* 6,892
GEN A20Z0220 SANDBLASTER, 600 LB (272 KG) CAPACITY, W/HOSE (ADD 250 CFM (7 CMM) COMPRESSOR & NOZZLE COST)	EP	Average	ZZ GENERIC EQUIPMENT	382	*0.97* 371	*1.98* 758	*2.95* 1,129
GEN A20Z0240 SANDBLASTER, ABRASIVE STORAGE HOPPER, 35 TON (31.7 MT), 700 CF (20 M3) (ADD SAND BLASTER & ACCESSORIES)	EP	Average	ZZ GENERIC EQUIPMENT	382	*2.63* 1,004	*5.32* 2,033	*7.94* 3,037
GEN C55Z1960 CONCRETE PUMP, PUMP & BOOM, 117 CY/HR (89 M3/HR), 75' (23 M) BOOM, TRUCK MOUNTED	EP	Average	ZZ GENERIC EQUIPMENT	481	*42.57* 20,486	*81.84* 39,388	*124.41* 59,874
GEN C80Z2300 CRANE, HYDRAULIC, TRUCK MOUNTED, 90 TON (81.6 MT), 114' (34.7 M) BOOM, 8X4	EP	Average	ZZ GENERIC EQUIPMENT	13	*47.95* 614	*78.63* 1,006	*126.58* 1,620
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST	EP	Average	ZZ GENERIC EQUIPMENT	698	*11.71* 8,176	*26.66* 18,605	*38.37* 26,781
GEN D20Z2800 DRILL, CORE, COLUMN MOUNTED, 9"-36" (229-914 MM) DIA, W/STAND AND HYDRAULIC POWER PACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	EP	Average	ZZ GENERIC EQUIPMENT	16	*1.39* 22	*7.62* 122	*9.01* 144
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST	EP	Average	ZZ GENERIC EQUIPMENT	786	*6.86* 5,387	*16.65* 13,080	*23.51* 18,467
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH	EP	Average	ZZ GENERIC EQUIPMENT	698	*27.21* 18,994	*69.80* 48,721	*97.01* 67,714
GEN H25Z3210 HYDRAULIC EXCAVATOR, CRAWLER, 140,000 LB (63,503	EP	Average	ZZ GENERIC EQUIPMENT	9	*47.78* 447	*104.25* 976	*152.04* 1,423

Description	CostType	ConditionType	Manufacturer	EQHours	Ownership	Operating	Total
KG), 3.50 CY (2.7 M3) BUCKET, 31.4' (9.6 M) MAX DIGGING DEPTH							
GEN L40Z4397 LOADER, FRONT END, WHEEL, ARTICULATED, 3.25 CY (2.5 M3) BUCKET, 4X4	EP	Average	ZZ GENERIC EQUIPMENT	9	*13.87* 121	*41.26* 359	*55.12* 479
GEN R45Z5675 ROLLER, VIBRATORY, SELF-PROPELLED, DOUBLE DRUM, SMOOTH, 6.6 TON (6.0 MT), 56" (4.5 M) WIDE, ASPHALT COMPACTOR	EP	Average	ZZ GENERIC EQUIPMENT	4	*13.76* 55	*31.19* 125	*44.96* 180
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)	EP	Average	ZZ GENERIC EQUIPMENT	808	*3.01* 2,428	*2.45* 1,975	*5.45* 4,403
GEN T50Z7310 TRUCK, HIGHWAY, CONVENTIONAL, 8,600 LB (3,901 KG) GVW, 4X2, 2 AXLE, 3/4 TON (0.68 MT) - PICKUP	EP	Average	ZZ GENERIC EQUIPMENT	404	*2.07* 837	*9.70* 3,919	*11.77* 4,756
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)	EP	Average	ZZ GENERIC EQUIPMENT	808	*7.62* 6,153	*32.05* 25,878	*39.66* 32,031
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED	EP	Average	ZZ GENERIC EQUIPMENT	15	*1.76* 26	*8.83* 131	*10.59* 158
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES	Non-EP	Average	ZZ GENERIC EQUIPMENT	1,504	*0.14* 206	*1.71* 2,572	*1.85* 2,778
GEN XMEZ9520 CONCRETE VIBRATOR, 2.5" (63.5 MM) DIA, W/7.5 HP (5.6 KW) GENERATOR	Non-EP	Average	ZZ GENERIC EQUIPMENT	481	*0.82* 395	*2.18* 1,049	*3.00* 1,444
GEN XMEZ9685 8 x 24 STEEL TRENCH BOX	Non-EP	Average	ZZ GENERIC EQUIPMENT	9	*15.00* 140	*0.00* 0	*15.00* 140
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)	EP	Average	SR SULLAIR CORPORATION	698	*12.06* 8,418	*74.55* 52,037	*86.61* 60,455
MAP B10KB001 BATCH PLANT, PUGMILL, CONTINUOUS MIXER, 48" DIA TWIN SHAFT X 6' LONG, W/9 CY FEEDER HOPPER/ 36" X 11.5' BELT FEEDER/ 30" X 27' CONVEYOR/ WATER OR ASPHALT PUMP & METER (ADD 95 KW GENERATOR & ANY MATERIAL FEEDS)	EP	Average	KB KOLBERG - PIONEER, INC	150	*15.65* 2,347	*27.36* 4,104	*43.01* 6,452
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET	EP	Average	CA CATERPILLAR INC. (MACHINE DIVISION)	698	*11.25* 7,850	*27.58* 19,248	*38.82* 27,097
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)	EP	Average	XX NO SPECIFIC MANUFACTURER	1,396	*7.50* 10,469	*40.81* 56,973	*48.31* 67,442
					1.76	*8.83*	*10.59*

Description	CostType	ConditionType	Manufacturer	EQHours	Ownership	Operating	Total
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD	EP	Average	XX NO SPECIFIC MANUFACTURER	1,504	2,645	13,279	15,924
Diving Contractor				**280**	**643**	**1,729**	**2,372**
					1.26	*0.82*	*2.09*
EP M10MZ007 MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 40' X 12' X 5', 51 TON	EP	Average	MZ MARINE INLAND FABRICATORS	48	61	40	100
					3.23	*7.35*	*10.59*
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4	EP	Average	XX NO SPECIFIC MANUFACTURER	96	310	706	1,016
					1.76	*8.83*	*10.59*
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED	EP	Average	ZZ GENERIC EQUIPMENT	96	169	847	1,016
					2.59	*3.39*	*5.98*
MAP XX0XX700 WORK BARGE, FLAT DECK, 500 TON	Non-EP	Average	ZZ GENERIC EQUIPMENT	40	103	136	239

COE Standard Report Selections

Title Page

Estimated by USACE and HDR
Designed by USACE, Portland District
Prepared by Royal Mortier
Preparation Date 4/15/2013
Effective Date of Pricing 4/15/2013
Estimated Construction Time Days

Designed by
USACE, Portland District

Estimated by
USACE and HDR

Prepared by
Royal Mortier

Design Document	The Dalles EFL AWS - 90% EDR Alt 2
Document Date	4/15/2013
District	Walla Walla District
Contact	Royal Mortier
Budget Year	2013
UOM System	Original

Direct Costs

LaborCost
EQCost
MatlCost
SubBidCost

Timeline/Currency

Preparation Date	4/15/2013
Escalation Date	4/15/2013
Eff. Pricing Date	4/15/2013
Estimated Duration	0 Day(s)
Currency	US dollars
Exchange Rate	1.000000

Costbook CB10EB: MII English Cost Book 2010

Labor NLS2010: National Labor Library - Seattle 2010

Note: http://www.wdol.gov is the website for current Davis Bacon & Service Labor Rates. Fringes paid to the laborers are taxable. In a non-union job the whole fringes are taxa
vaca

Labor Rates

LaborCost1
LaborCost2
LaborCost3
LaborCost4

Equipment EP11R08: MII Equipment 2011 Region 08

08 NORTHWEST	
Sales Tax	5.40
Working Hours per Year	1,540
Labor Adjustment Factor	1.05
Cost of Money	2.50
Cost of Money Discount	25.00
Tire Recap Cost Factor	1.50
Tire Recap Wear Factor	1.80
Tire Repair Factor	0.15
Equipment Cost Factor	1.00
Standby Depreciation Factor	0.50

Fuel	
Electricity	0.072
Gas	3.670
Diesel Off-Road	3.450
Diesel On-Road	3.990

Shipping Rates	
Over 0 CWT	28.32
Over 240 CWT	26.60
Over 300 CWT	24.23
Over 400 CWT	22.06
Over 500 CWT	11.26
Over 700 CWT	9.51
Over 800 CWT	6.48

Date	**Author**	**Note**

Project Notes

Description	Quantity	UOM	ProjectCost
Project Cost Summary Report			**15,997,107**
The Dalles EFL AWS_EDR Alt 2	**1.00**	**EA**	*15,997,106.51* **15,997,107**
Mob/Demob	**1.00**	**EA**	*282,958.23* **282,958**
Cofferdam	**1.00**	**EA**	*1,832,411.79* **1,832,412**
Trash Rack	**1.00**	**EA**	*2,238,899.59* **2,238,900**
Intake Screen	**1.00**	**EA**	*1,701,474.19* **1,701,474**
Trash Rake	**1.00**	**EA**	*557,538.58* **557,539**
Concrete Mining	**1.00**	**EA**	*1,399,949.40* **1,399,949**
72" Pipe	**1.00**	**EA**	*2,658,886.92* **2,658,887**
Thrust Blocking and Supports	**500.00**	**CY**	*226.27* **113,137**
72" Pipe Installation Setup Through Dam	**1.00**	**EA**	*151,310.43* **151,310**
E-11.3.4.1 Furnish and Install Steel Rails	**240.00**	**LF**	*65.75* **15,780**
Welding Crew	**1.00**	**EA**	*19,445.67* **19,446**
72" Valves	**2.00**	**EA**	*784,541.45* **1,569,083**
Valve Room Modification	**1.00**	**EA**	*3,279,119.86* **3,279,120**
Demo Valve Room Piping	**1.00**	**EA**	*86,695.67* **86,696**
Field Fabricate & Install 48" Diameter Bend	**1.00**	**EA**	*42,791.18* **42,791**
Field Fabricate & Install Valve Vault Piping	**1.00**	**EA**	*313,500.85* **313,501**
Install Valve Vault Valves	**1.00**	**LS**	**2,836,132**
Approach Channel & Fish Lock Mod	**1.00**	**LS**	**1,547,712**
Demolish Control House	**1.00**	**LS**	**56,572**

Description	Quantity	UOM	ProjectCost
Demolish Fishlock Equipment	**1.00**	**LS**	**49,333**
			74,455.77
7' x 7' x 9' Deep Cutout to Fishlock Approach Channel Base Slab	**1.00**	**EA**	**74,456**
			110,853.85
Demolition at Fishlock Approach Channel	**1.00**	**EA**	**110,854**
			3,346.04
15" Thick CIP Wall Height	**25.00**	**EA**	**83,651**
Seal 8' x 8' Culvert Joints	**1.00**	**LS**	**240,346**
Stop Logs	**1.00**	**LS**	**932,501**
Electrical	**1.00**	**LS**	**479,237**
Power From Existing Unit	**1.00**	**LS**	**188,937**
Power for Valve Operators	**1.00**	**LS**	**74,582**
Power for Trash Rake	**1.00**	**LS**	**55,662**
Power for Hydraulic Power Units	**1.00**	**LS**	**55,887**
Power for Bulkhead Crane	**1.00**	**LS**	**52,646**
Relocate Electrical Panel at Fence	**1.00**	**LS**	**24,375**
Modify Electrical Security System at Fence	**1.00**	**LS**	**14,580**
Demo Existing Electrical at Existing FCQ7 - MCC	**1.00**	**LS**	**10,929**
Disconnect/Demo Electrical Circuits to Control House	**1.00**	**LS**	**1,639**

Description	Quantity	UOM	Contractor	Duration	CrewHours	ManHours	ProjectCost
Contract Cost Summary Report				**1,242.68**	**1,628.68**	**14,034.07**	**15,997,107**
				1,242.68	*1,628.68*	*14,034.07*	*15,997,106.51*
The Dalles EFL AWS_EDR Alt 2	**1.00**	**EA**		**1,242.68**	**1,628.68**	**14,034.07**	**15,997,107**
				0.00	*48.00*	*576.00*	*282,958.23*
Mob/Demob	**1.00**	**EA**	**Diving Contractor**	**0.00**	**48.00**	**576.00**	**282,958**
				46.00	*54.00*	*464.00*	*1,832,411.79*
Cofferdam	**1.00**	**EA**	**Steel Workers**	**46.00**	**54.00**	**464.00**	**1,832,412**
				117.00	*117.00*	*521.00*	*2,238,899.59*
Trash Rack	**1.00**	**EA**	**Prime Contractor**	**117.00**	**117.00**	**521.00**	**2,238,900**
				45.00	*45.00*	*225.00*	*1,701,474.19*
Intake Screen	**1.00**	**EA**	**Prime Contractor**	**45.00**	**45.00**	**225.00**	**1,701,474**
				16.00	*16.00*	*32.00*	*557,538.58*
Trash Rake	**1.00**	**EA**	**Prime Contractor**	**16.00**	**16.00**	**32.00**	**557,539**
				0.00	*330.00*	*3,960.00*	*1,399,949.40*
Concrete Mining	**1.00**	**EA**	**Prime Contractor**	**0.00**	**330.00**	**3,960.00**	**1,399,949**
				514.29	*514.29*	*6,085.71*	*2,658,886.92*
72" Pipe	**1.00**	**EA**	**Prime Contractor**	**514.29**	**514.29**	**6,085.71**	**2,658,887**
				0.03	*0.03*	*0.17*	*226.27*
Thrust Blocking and Supports	**500.00**	**CY**	**Prime Contractor**	**14.29**	**14.29**	**85.71**	**113,137**
				202.80	*202.80*	*1,008.96*	*151,310.43*
72" Pipe Installation Setup Through Dam	**1.00**	**EA**	**Prime Contractor**	**202.80**	**202.80**	**1,008.96**	**151,310**
				0.17	*0.17*	*0.49*	*65.75*
E-11.3.4.1 Furnish and Install Steel Rails	**240.00**	**LF**	**Prime Contractor**	**39.68**	**39.68**	**116.48**	**15,780**
(Note: Assume installation steel rails to support and guide the new conduit through the concrete conduit. The total length of the concrete conduit is 60 LF x 4 rails each conduit = 240 LF total.)							
				28.24	*28.24*	*112.94*	*19,445.67*
Welding Crew	**1.00**	**EA**	**Prime Contractor**	**28.24**	**28.24**	**112.94**	**19,446**
				2.00	*2.00*	*8.00*	*784,541.45*
72" Valves	**2.00**	**EA**	**Prime Contractor**	**4.00**	**4.00**	**16.00**	**1,569,083**
				342.60	*342.60*	*1,370.40*	*3,279,119.86*
Valve Room Modification	**1.00**	**EA**	**Steel Workers**	**342.60**	**342.60**	**1,370.40**	**3,279,120**
				100.55	*100.55*	*402.20*	*86,695.67*
Demo Valve Room Piping	**1.00**	**EA**	**Steel Workers**	**100.55**	**100.55**	**402.20**	**86,696**
				42.05	*42.05*	*168.20*	*42,791.18*
Field Fabricate & Install 48" Diameter Bend	**1.00**	**EA**	**Steel Workers**	**42.05**	**42.05**	**168.20**	**42,791**
				200.00	*200.00*	*800.00*	*313,500.85*
Field Fabricate & Install Valve Vault Piping	**1.00**	**EA**	**Steel Workers**	**200.00**	**200.00**	**800.00**	**313,501**
Install Valve Vault Valves	**1.00**	**LS**	**Steel Workers**	**0.00**	**0.00**	**0.00**	**2,836,132**
Approach Channel & Fish Lock Mod	**1.00**	**LS**	**Demolition Sub**	**0.00**	**0.00**	**0.00**	**1,547,712**

Description	Quantity	UOM	Contractor	Duration	CrewHours	ManHours	ProjectCost
Demolish Control House	**1.00**	**LS**	**Demolition Sub**	**0.00**	**0.00**	**0.00**	**56,572**
Demolish Fishlock Equipment	**1.00**	**LS**	**Demolition Sub**	**0.00**	**0.00**	**0.00**	**49,333**
				0.00	*0.00*	*0.00*	*74,455.77*
7' x 7' x 9' Deep Cutout to Fishlock Approach Channel Base Slab	**1.00**	**EA**	**Demolition Sub**	**0.00**	**0.00**	**0.00**	**74,456**
				0.00	*0.00*	*0.00*	*110,853.85*
Demolition at Fishlock Approach Channel	**1.00**	**EA**	**Demolition Sub**	**0.00**	**0.00**	**0.00**	**110,854**
				0.00	*0.00*	*0.00*	*3,346.04*
15" Thick CIP Wall Height	**25.00**	**EA**	**Demolition Sub**	**0.00**	**0.00**	**0.00**	**83,651**
Seal 8' x 8' Culvert Joints	**1.00**	**LS**	**Prime Contractor**	**0.00**	**0.00**	**0.00**	**240,346**
Stop Logs	**1.00**	**LS**	**Prime Contractor**	**0.00**	**0.00**	**0.00**	**932,501**
Electrical	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**479,237**
Power From Existing Unit	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**188,937**
Power for Valve Operators	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**74,582**
Power for Trash Rake	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**55,662**
Power for Hydraulic Power Units	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**55,887**
Power for Bulkhead Crane	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**52,646**
Relocate Electrical Panel at Fence	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**24,375**
Modify Electrical Security System at Fence	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**14,580**
Demo Existing Electrical at Existing FCQ7 - MCC	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**10,929**
Disconnect/Demo Electrical Circuits to Control House	**1.00**	**LS**	**Electrical Contractor**	**0.00**	**0.00**	**0.00**	**1,639**

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
Crews (Bare Costs) by Contractor, Report		**1,628.68**			**13,834.07**	**672,031.46**	**32,699.26**	**1,343,379.20**	**2,015,410.66**
Prime Contractor	**LaborCost1**	**1,628.68**		**0.00**	**13,834.07**	**672,031.46**	**32,699.26**	**1,343,379.20**	**2,015,410.66**
RSM B89A B89A	LaborCost1	16.00			*2.00* 32.00	*88.50* 1,416.00	*1.00* 16.00	*9.05* 144.76	*97.55* 1,560.76
MIL B-SKILLWKR Skilled Workers			Journeyman	48.47	1.00	48.47			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	1.00	40.03			
GEN D20Z2800 DRILL, CORE, COLUMN MOUNTED, 9"-36" (229-914 MM) DIA, W/STAND AND HYDRAULIC POWER PACK (ADD COST FOR DRILL STEEL AND BIT WEAR)			EP / Average	9.05			1.00	9.05	
RSM CARP CARP	LaborCost1	26.88			*1.00* 26.88	*48.47* 1,302.87	*0.00* 0.00	*0.00* 0.00	*48.47* 1,302.87
MIL B-CARPNTER Carpenters			Journeyman	48.47	1.00	48.47			
RSM E2 E2	LaborCost1	12.80			*7.00* 89.60	*363.26* 4,649.73	*1.00* 12.80	*126.00* 1,612.79	*489.26* 6,262.52
MIL B-STRSTEEL Structural Steel Workers			Foreman	56.02	1.00	56.02			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	4.00	216.08			
MIL B-EQOPRCRN Equip. Operators, Heavy			Journeyman	50.39	1.00	50.39			
MIL B-EQOPROIL Equip. Operators, Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
GEN C80Z2300 CRANE, HYDRAULIC, TRUCK MOUNTED, 90 TON (81.6 MT), 114' (34.7 M) BOOM, 8X4			EP / Average	126.00			1.00	126.00	
RSM E4 E4	LaborCost1	14.88			*4.00* 59.53	*218.08* 3,245.84	*1.00* 14.88	*10.64* 158.36	*228.72* 3,404.20
MIL B-STRSTEEL Structural Steel Workers			Foreman	56.02	1.00	56.02			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	3.00	162.06			
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED			EP / Average	10.64			1.00	10.64	
RSM L4 L4	LaborCost1	32.00			*3.00* 96.00	*136.97* 4,383.04	*0.00* 0.00	*0.00* 0.00	*136.97* 4,383.04
MIL B-SKILLWKR Skilled Workers			Journeyman	48.47	2.00	96.94			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	1.00	40.03			
USR 150 Ton Crane and Operator	LaborCost1	6.00			*4.00* 24.00	*171.22* 1,027.32	*2.00* 12.00	*203.55* 1,221.30	*374.77* 2,248.62
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
					12.00	*567.85*	*35.00*	*1,484.55*	*2,052.40*
USR Boring Crew and Equipment	LaborCost1	330.00			3,960.00	187,390.50	11,550.00	489,901.55	677,292.05
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Foreman	51.39	1.00	51.39			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM			EP / Average	33.66			1.00	33.66	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
COMPRESSOR)									
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
					5.00	*238.49*	*2.00*	*203.55*	*442.04*
USR Bulkhead Install Crew	LaborCost1	40.00			200.00	9,539.60	80.00	8,141.98	17,681.58
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
					5.00	*238.49*	*2.00*	*203.55*	*442.04*
USR Bulkhead Install Crew	LaborCost1	20.00			100.00	4,769.80	40.00	4,070.99	8,840.79
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
					5.00	*238.49*	*2.00*	*203.55*	*442.04*
USR Bulkhead Install Crew	LaborCost1	25.00			125.00	5,962.25	50.00	5,088.74	11,050.99
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			1.00	10.68	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
					12.00	*566.85*	*35.00*	*1,484.55*	*2,051.40*
USR Piping Install Crew	LaborCost1	500.00			6,000.00	283,425.00	17,500.00	742,275.08	1,025,700.08
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL X-EQOPRMED Outside Equip. Operators,			Journeyman	49.90	2.00	99.80			

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
Medium									
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD,			EP / Average	12.10			1.00	12.10	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
25 KW									
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
					4.00	*171.22*	*3.00*	*214.23*	*385.45*
USR Valve Install Crew	LaborCost1	4.00			16.00	684.88	12.00	856.92	1,541.80
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Journeyman	50.39	1.00	50.39			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
					4.00	*203.09*	*5.00*	*45.94*	*249.03*
USR Welding Crew	LaborCost1	28.24			112.94	5,734.31	141.18	1,297.26	7,031.57

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
MIL B-WELDERS Welders, Structural Steel			Journeyman	54.02	3.00	162.06			
MIL B-LABORER Laborers, (Semi-Skilled)			Foreman	41.03	1.00	41.03			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			1.00	10.64	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			1.00	1.85	
					6.00	*251.28*	*1.00*	*37.45*	*288.73*
USR 4 Laborers + 1 Operator + 1 Oiler + 1 Crane 18 Ton 4 Laborers + 1 Operator + 1 Oiler + 1 Crane 18 Tons	LaborCost1	120.00			720.00	30,153.60	120.00	4,494.03	34,647.63
MIL B-EQOPROIL Equip. Operators, Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL X-EQOPRHVY Outside Equip. Operators, Heavy			Journeyman	50.39	1.00	50.39			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	4.00	160.12			
EP C75BD010 CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 18.0 TON, 50' BOOM, 4X4			EP / Average	37.45			1.00	37.45	
					6.00	*250.30*	*7.00*	*96.66*	*346.96*
USR C6 C6	LaborCost1	14.29			85.71	3,575.71	100.00	1,380.86	4,956.57
MIL B-LABORER Laborers, (Semi-Skilled)			Foreman	41.03	1.00	41.03			
MIL B-LABORER Laborers, (Semi-Skilled)			Journeyman	40.03	4.00	160.12			
MIL B-CEMTFINR Cement Finishers			Journeyman	49.15	1.00	49.15			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
GEN XMEZ9520 CONCRETE VIBRATOR, 2.5" (63.5 MM) DIA, W/7.5 HP (5.6 KW) GENERATOR			Non-EP / Average	3.02			2.00	6.04	
Diving Contractor	**LaborCost1**	**96.00**		**0.00**	**816.00**	**50,056.80**	**1,680.00**	**71,258.41**	**121,315.21**

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
					12.00	*567.85*	*35.00*	*1,484.55*	*2,052.40*
USR Boring Crew and Equipment	LaborCost1	48.00			576.00	27,256.80	1,680.00	71,258.41	98,515.21
MIL X-EQOPRMED Outside Equip. Operators, Medium			Journeyman	49.90	2.00	99.80			
MIL X-EQOPRMED Outside Equip. Operators, Medium			Foreman	50.90	1.00	50.90			
MIL B-EQOPRCRB Equip. Operators Crane with Boom Pay			Foreman	51.39	1.00	51.39			
MIL B-TRKDVRLT Truck Drivers, Light			Journeyman	45.63	3.00	136.89			
MIL X-LABORER Outside Laborers, (Semi-Skilled)			Journeyman	40.03	2.00	80.06			
MIL X-EQOPROIL Outside Equip. Oilers / Grade Checker			Journeyman	40.77	1.00	40.77			
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	2.00	108.04			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			4.00	42.72	
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST			EP / Average	23.75			1.00	23.75	
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)			EP / Average	261.05			1.00	261.05	
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW			EP / Average	60.15			1.00	60.15	
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST			EP / Average	38.80			1.00	38.80	
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)			EP / Average	96.49			1.00	96.49	
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET			EP / Average	39.20			1.00	39.20	
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)			EP / Average	33.66			1.00	33.66	
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)			EP / Average	87.02			1.00	87.02	
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK			EP / Average	6.18			2.00	12.36	
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH			EP / Average	8.16			2.00	16.32	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH			EP / Average	98.49			1.00	98.49	
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET			EP / Average	125.57			1.00	125.57	
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)			EP / Average	23.21			1.00	23.21	
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW			EP / Average	12.10			1.00	12.10	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			2.00	21.28	
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP			EP / Average	61.05			2.00	122.10	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			2.00	3.70	
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)			EP / Average	20.33			1.00	20.33	
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)			EP / Average	5.54			1.00	5.54	
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)			EP / Average	39.97			1.00	39.97	
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)			EP / Average	2.81			2.00	5.63	
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)			EP / Average	48.61			2.00	97.23	
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8			EP / Average	192.87			1.00	192.87	
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE			EP / Average	5.02			1.00	5.02	
					5.00	*475.00*	*0.00*	*0.00*	*475.00*
USR Dive Crew	LaborCost1	24.00			120.00	11,400.00	0.00	0.00	11,400.00
USR DIVER Diver			Journeyman	95.00	5.00	475.00			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	0.00			0.00	0.00	
EP M10MZ007 MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 40' X			EP / Average	0.00			0.00	0.00	

Description	LaborRate	CrewHours	MemberType	MemberRate	ManHours	LaborCost	EQHours	EQCost	CrewCost
12' X 5', 51 TON									
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED			EP / Average	0.00			0.00	0.00	
					5.00	*475.00*	*0.00*	*0.00*	*475.00*
USR Dive Crew	LaborCost1	24.00			120.00	11,400.00	0.00	0.00	11,400.00
USR DIVER Diver			Journeyman	95.00	5.00	475.00			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	0.00			0.00	0.00	
EP M10MZ007 MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 40' X 12' X 5', 51 TON			EP / Average	0.00			0.00	0.00	
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED			EP / Average	0.00			0.00	0.00	
Steel Workers	**LaborCost1**	**342.60**		**0.00**	**1,370.40**	**74,714.21**	**1,370.40**	**11,476.17**	**86,190.38**
					4.00	*218.08*	*4.00*	*33.85*	*251.93*
USR E25 Structural Steel Crew	LaborCost1	277.60			1,110.40	60,539.01	1,110.40	9,396.28	69,935.29
MIL B-WELDERS Welders, Structural Steel			Journeyman	54.02	3.00	162.06			
MIL B-WELDERS Welders, Structural Steel			Foreman	56.02	1.00	56.02			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD			EP / Average	10.64			1.00	10.64	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Average	1.85			1.00	1.85	
					4.00	*218.08*	*4.00*	*32.00*	*250.08*
USR SIWSE4 4 strsteels + 1 welder, 300 amp, trailer mtd	LaborCost1	65.00			260.00	14,175.20	260.00	2,079.89	16,255.09
MIL B-STRSTEEL Structural Steel Workers			Journeyman	54.02	3.00	162.06			
MIL B-STRSTEEL Structural Steel Workers			Foreman	56.02	1.00	56.02			
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4			EP / Average	10.68			2.00	21.36	
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED			EP / Average	10.64			1.00	10.64	
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES			Non-EP / Standby	0.00			1.00	0.00	

Description	CostType	ConditionType	Manufacturer	EQHours	Ownership	Operating	Total
Equipment by Contractor, Report				**32,899**	**393,379**	**937,081**	**1,330,460**
Prime Contractor				**32,899**	**393,379**	**937,081**	**1,330,460**
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)	EP	Average	XX NO SPECIFIC MANUFACTURER	830	*1.52* 1,260	*21.64* 17,960	*23.16* 19,220
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK	EP	Average	XX NO SPECIFIC MANUFACTURER	1,660	*2.17* 3,602	*3.98* 6,614	*6.15* 10,217
EP C75BD010 CRANES, HYDRAULIC, SELF-PROPELLED, YARD, 18.0 TON, 50' BOOM, 4X4	EP	Average	BD BRODERSON MANUFACTURING CORPORATION	120	*12.32* 1,479	*24.62* 2,954	*36.94* 4,433
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8	EP	Average	TD TADANO AMERICA CORPORATION	925	*52.31* 48,389	*137.61* 127,290	*189.92* 175,679
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)	EP	Average	SU SULLIVAN-PALATEK, INC.	830	*13.80* 11,458	*19.19* 15,924	*32.99* 27,382
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW	EP	Average	XX NO SPECIFIC MANUFACTURER	858	*1.86* 1,596	*10.19* 8,741	*12.04* 10,337
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW	EP	Average	XX NO SPECIFIC MANUFACTURER	830	*5.09* 4,222	*54.92* 45,585	*60.01* 49,808
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)	EP	Average	NP NPK CONSTRUCTION EQUIPMENT	830	*40.58* 33,684	*55.02* 45,666	*95.60* 79,350
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)	EP	Average	KN KENT DEMOLITION TOOLS	830	*8.73* 7,247	*11.43* 9,485	*20.16* 16,732
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN, ELECTRIC MAST WINCH	EP	Average	AB ALLMAND BROTHERS INC.	1,660	*1.96* 3,245	*6.15* 10,212	*8.11* 13,457
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET	EP	Average	KM Komatsu America International Company	830	*40.71* 33,788	*83.50* 69,305	*124.21* 103,093
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)	EP	Average	MY MIDLAND MANUFACTURING INC.	1,660	*1.52* 2,530	*1.25* 2,079	*2.78* 4,610

Description	CostType	ConditionType	Manufacturer	EQHours	Ownership	Operating	Total
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4	EP	Average	XX NO SPECIFIC MANUFACTURER	3,504	*3.23* 11,331	*7.35* 25,768	*10.59* 37,099
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)	EP	Average	WG ATLAS COPCO WAGNER	830	*113.29* 94,030	*143.12* 118,791	*256.41* 212,821
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP	EP	Average	NL NLB CORPORATION	1,660	*15.72* 26,096	*45.08* 74,831	*60.80* 100,928
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE	EP	Average	SO SOUTHWEST CONSTRUCTION EQUIPMENT CO.	830	*3.01* 2,500	*1.89* 1,571	*4.90* 4,071
GEN C80Z2300 CRANE, HYDRAULIC, TRUCK MOUNTED, 90 TON (81.6 MT), 114' (34.7 M) BOOM, 8X4	EP	Average	ZZ GENERIC EQUIPMENT	13	*46.80* 599	*76.79* 983	*123.59* 1,582
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST	EP	Average	ZZ GENERIC EQUIPMENT	830	*11.71* 9,722	*26.66* 22,124	*38.37* 31,846
GEN D20Z2800 DRILL, CORE, COLUMN MOUNTED, 9"-36" (229-914 MM) DIA, W/STAND AND HYDRAULIC POWER PACK (ADD COST FOR DRILL STEEL AND BIT WEAR)	EP	Average	ZZ GENERIC EQUIPMENT	16	*1.39* 22	*7.62* 122	*9.01* 144
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST	EP	Average	ZZ GENERIC EQUIPMENT	844	*6.86* 5,790	*16.65* 14,059	*23.51* 19,849
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH	EP	Average	ZZ GENERIC EQUIPMENT	830	*27.21* 22,585	*69.80* 57,934	*97.01* 80,520
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)	EP	Average	ZZ GENERIC EQUIPMENT	844	*3.01* 2,539	*2.45* 2,064	*5.45* 4,603
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)	EP	Average	ZZ GENERIC EQUIPMENT	844	*7.62* 6,432	*32.05* 27,055	*39.66* 33,488
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED	EP	Average	ZZ GENERIC EQUIPMENT	15	*1.76* 26	*8.83* 131	*10.59* 158
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES	Non-EP	Average	ZZ GENERIC EQUIPMENT	1,688	*0.14* 231	*1.71* 2,887	*1.85* 3,118
GEN XMEZ9520 CONCRETE VIBRATOR, 2.5" (63.5 MM) DIA, W/7.5 HP (5.6 KW) GENERATOR	Non-EP	Average	ZZ GENERIC EQUIPMENT	29	*0.82* 23	*2.18* 62	*3.00* 86

Description	CostType	ConditionType	Manufacturer	EQHours	Ownership	Operating	Total
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)	EP	Average	SR SULLAIR CORPORATION	830	*12.06* 10,010	*74.55* 61,878	*86.61* 71,888
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET	EP	Average	CA CATERPILLAR INC. (MACHINE DIVISION)	830	*11.25* 9,334	*27.58* 22,888	*38.82* 32,222
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)	EP	Average	XX NO SPECIFIC MANUFACTURER	1,660	*7.50* 12,449	*40.81* 67,748	*48.31* 80,196
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD	EP	Average	XX NO SPECIFIC MANUFACTURER	1,688	*1.76* 2,968	*8.83* 14,904	*10.59* 17,872
Diving Contractor				**1,880**	**21,334**	**50,925**	**72,259**
EP A15XX029 AIR COMPRESSOR, 185 CFM, 125 PSI (ADD HOSE)	EP	Average	XX NO SPECIFIC MANUFACTURER	48	*1.52* 73	*21.64* 1,039	*23.16* 1,112
EP A20XX008 AIR HOSE, 4.00", 100', HARDROCK	EP	Average	XX NO SPECIFIC MANUFACTURER	96	*2.17* 208	*3.98* 383	*6.15* 591
EP C80TD005 CRANES, HYDRAULIC, TRUCK MTD, ALL TERRAIN, 150 TON, 162' BOOM, 10X8	EP	Average	TD TADANO AMERICA CORPORATION	48	*52.31* 2,511	*137.61* 6,605	*189.92* 9,116
EP D10SU003 DRILL, AIR TRACK, CRAWLER, 3.0-4.0" DIA, 12' FEED (ADD COST FOR DRILL STEEL AND BIT WEAR, ADD 900 CFM COMPRESSOR)	EP	Average	SU SULLIVAN-PALATEK, INC.	48	*13.80* 663	*19.19* 921	*32.99* 1,584
EP G10XX005 GENERATOR SET, SKID MTD, 25 KW	EP	Average	XX NO SPECIFIC MANUFACTURER	48	*1.86* 89	*10.19* 489	*12.04* 578
EP G10XX012 GENERATOR SET, SKID MTD, 300 KW	EP	Average	XX NO SPECIFIC MANUFACTURER	48	*5.09* 244	*54.92* 2,636	*60.01* 2,880
EP H10NP018 HAMMERS, HYDRAULIC, 20,000 FT-LBS, IMPACT FREQUENCY 330 BPM (ADD 80-130 TON HYDRAULIC EXCAVATOR H25)(ADD COST FOR POINT WEAR)	EP	Average	NP NPK CONSTRUCTION EQUIPMENT	48	*40.58* 1,948	*55.02* 2,641	*95.60* 4,589
EP H25KN004 HYDRAULIC EXCAVATOR, ATTACHMENT, CONCRETE BREAKER, 5,000 FT-LB, W/5.51" DIA. POINT (ADD 50,000-64,000 LB HYDRAULIC EXCAVATOR)	EP	Average	KN KENT DEMOLITION TOOLS	48	*8.73* 419	*11.43* 549	*20.16* 968
EP L20AB019 LITE SET, TRAILER MTD., 6/1,000W, W/8 KW GEN,	EP	Average	AB ALLMAND	96	*1.96* 188	*6.15* 591	*8.11* 778

Description	**CostType**	**ConditionType**	**Manufacturer**	**EQHours**	**Ownership**	**Operating**	**Total**
ELECTRIC MAST WINCH			BROTHERS INC.				
EP L35KM006 LOADER, FRONT END, CRAWLER, 3.30 CY BUCKET	EP	Average	KM Komatsu America International Company	48	*40.71* 1,954	*83.50* 4,008	*124.21* 5,962
EP M10MZ007 MARINE EQUIPMENT, WORK BARGE, SECTIONAL, MEDIUM DUTY, 40' X 12' X 5', 51 TON	EP	Average	MZ MARINE INLAND FABRICATORS	40	*1.26* 51	*0.82* 33	*2.09* 84
EP T40MY006 TRUCK OPTIONS, DUMP BODY, REAR, 20.0 CY, AIR GATE (W/HOIST) (ADD 50,000 GVW TRUCK)	EP	Average	MY MIDLAND MANUFACTURING INC.	96	*1.52* 146	*1.25* 120	*2.78* 267
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4	EP	Average	XX NO SPECIFIC MANUFACTURER	272	*3.23* 880	*7.35* 2,000	*10.59* 2,880
EP T65WG012 TUNNELING DRILL, 2 BOOM, 560-1,120 SF CROSS SECTION, RUBBER TIRED (ADD DRILL BITS AND DRILL STEEL COST)	EP	Average	WG ATLAS COPCO WAGNER	48	*113.29* 5,438	*143.12* 6,870	*256.41* 12,308
EP W25NL001 WATER BLASTER, HIGH PRESSURE, 6,000 PSI, 50 GPM, SKID MTD, W/MODEL 10200 PUMP	EP	Average	NL NLB CORPORATION	96	*15.72* 1,509	*45.08* 4,328	*60.80* 5,837
EP W30SO005 WATER TANK, PORTABLE, SKID MTD, 10,000 GAL, 10" PIPE	EP	Average	SO SOUTHWEST CONSTRUCTION EQUIPMENT CO.	48	*3.01* 145	*1.89* 91	*4.90* 235
GEN D15Z0100 HORIZ DIR DRILL 20,000 LB THRUST	EP	Average	ZZ GENERIC EQUIPMENT	48	*11.71* 562	*26.66* 1,279	*38.37* 1,842
GEN F10Z3040 FORK LIFT, ROUGH TERRAIN, 8,000 LB (3629 KG), 16.0' (4.9 M) HIGH, TELESCOPING MAST	EP	Average	ZZ GENERIC EQUIPMENT	48	*6.86* 329	*16.65* 799	*23.51* 1,128
GEN H25Z3205 HYDRAULIC EXCAVATOR, CRAWLER, 110,000 LB (49,895 KG), 3.00 CY (2.3 M3) BUCKET, 27.5' (8.4 M) MAX DIGGING DEPTH	EP	Average	ZZ GENERIC EQUIPMENT	48	*27.21* 1,306	*69.80* 3,350	*97.01* 4,657
GEN T40Z7055 TRUCK OPTION, WATER TANK, 3,000 GAL (11,356 L) (ADD 45,000 LB (20,412 KG) GVW TRUCK)	EP	Average	ZZ GENERIC EQUIPMENT	48	*3.01* 144	*2.45* 117	*5.45* 262
GEN T50Z7420 TRUCK, HIGHWAY, 45,000 LB (20,412 KG) GVW, 6X4, 3 AXLE (ADD ACCESSORIES)	EP	Average	ZZ GENERIC EQUIPMENT	48	*7.62* 366	*32.05* 1,538	*39.66* 1,904
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED	EP	Average	ZZ GENERIC EQUIPMENT	80	*1.76* 141	*8.83* 706	*10.59* 847
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES	Non-EP	Average	ZZ GENERIC EQUIPMENT	96	*0.14* 13	*1.71* 164	*1.85* 177

Description	CostType	ConditionType	Manufacturer	EQHours	Ownership	Operating	Total
MAP A15SR002 AIR COMPRESSOR, 900 CFM, 350 PSI (ADD HOSE)	EP	Average	SR SULLAIR CORPORATION	48	*12.06* 579	*74.55* 3,579	*86.61* 4,157
MAP L35CA013 LOADER, FRONT END, CRAWLER, 1.50 CY BUCKET	EP	Average	CA CATERPILLAR INC. (MACHINE DIVISION)	48	*11.25* 540	*27.58* 1,324	*38.82* 1,863
MAP T50XX029 TRUCK, HIGHWAY, 50,000 LBS GVW, 3 AXLE, 6X4 (CHASSIS ONLY-ADD OPTIONS)	EP	Average	XX NO SPECIFIC MANUFACTURER	96	*7.50* 720	*40.81* 3,918	*48.31* 4,638
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD	EP	Average	XX NO SPECIFIC MANUFACTURER	96	*1.76* 169	*8.83* 847	*10.59* 1,016
Steel Workers				**1,370**	**2,856**	**8,538**	**11,394**
EP T50XX018 TRUCK, HIGHWAY, CONVENTIONAL, 1 TON PICKUP, 4X4	EP	Average	XX NO SPECIFIC MANUFACTURER	685	*3.23* 2,216	*7.35* 5,039	*10.59* 7,254
GEN W35Z8640 WELDER, ENGINE DRIVEN, DIESEL, 300 AMP, TRAILER MOUNTED	EP	Average	ZZ GENERIC EQUIPMENT	65	*1.76* 114	*8.83* 574	*10.59* 688
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES	Non-EP	Average	ZZ GENERIC EQUIPMENT	278	*0.14* 38	*1.71* 475	*1.85* 513
GEN XMEZ9480 TORCH, OXYGEN/ACETYLENE, W/TANKS & HOSES	Non-EP	Standby	ZZ GENERIC EQUIPMENT	65	*0.00* 0	*0.00* 0	*0.00* 0
MAP W35XX024 WELDER, ENGINE DRIVEN, DIESEL, DC-CC/CV, 400 AMP, 2-10 KW, TRAILER MTD	EP	Average	XX NO SPECIFIC MANUFACTURER	278	*1.76* 488	*8.83* 2,451	*10.59* 2,939

The Dalles East Fish Ladder Auxiliary Water Backup System

60 Percent Design Documentation Report

APPENDIX G

Plates

US Army Corps
of Engineers
Portland District

THE DALLES LOCK AND DAM
NORTH-EAST FISH LADDER
BACKUP AUXILIARY WATER SUPPLY

THIS PROJECT WAS DESIGNED BY THE PORTLAND DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS OR SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER 1110-1-8152 AND INDICATE OFFICIAL RECOMMENDATION AND APPROVAL OF ALL THE DRAWINGS IN THIS SET.

BRIAN S. KAMISATO, P.E.
CHIEF, DESIGN BRANCH

LANCE A. HELWIG, P.E.
CHIEF, ENGINEERING & CONSTRUCTION DIVISION

JOHN W. EISENHAUER, P.E.
COLONEL, CORPS OF ENGINEERS
DISTRICT COMMANDER

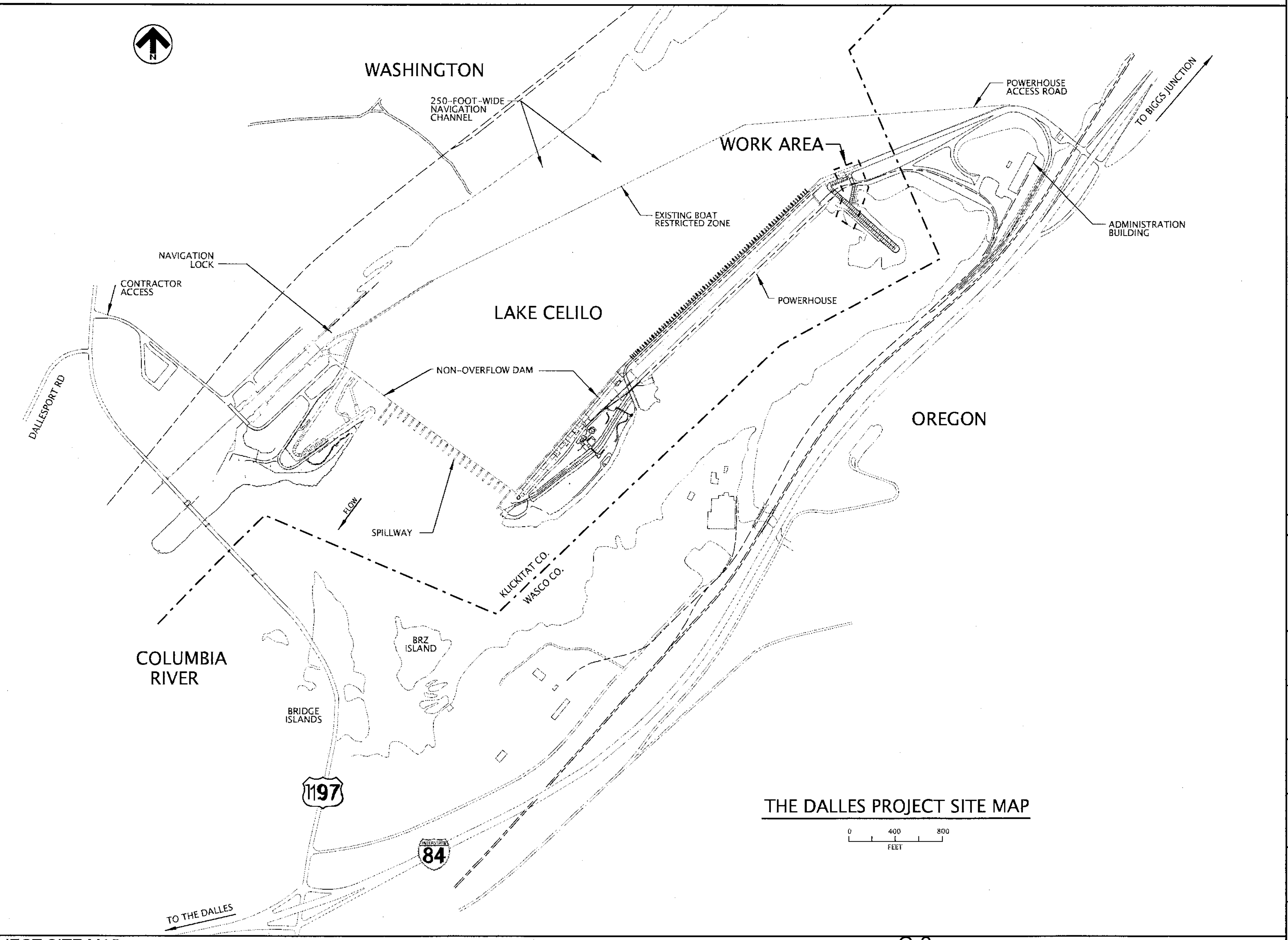
DATE: ____________________

SOLICITATION NUMBER:

US ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT

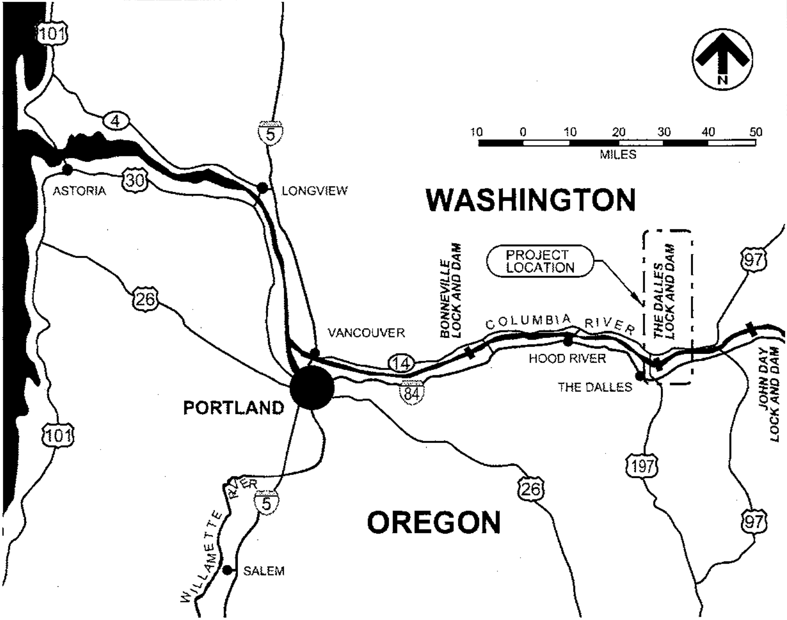
THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
DDR - BACKUP AUXILLARY WATER SUPPLY

SOLICITATION NUMBER:
DATE:

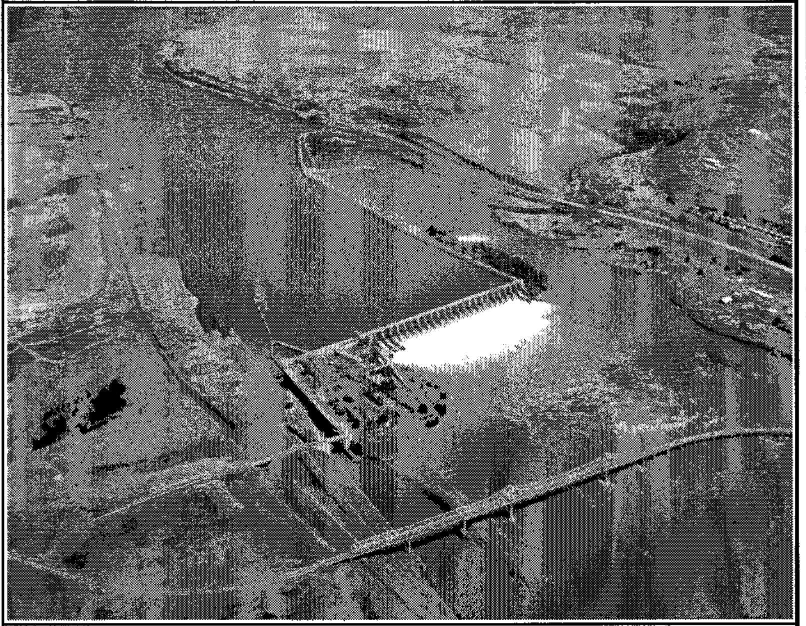


THE DALLES PROJECT SITE MAP

PROJECT SITE MAP



LOCAL VICINITY MAP



PROJECT PHOTO

THIS PROJECT WAS DESIGNED BY THE PORTLAND DISTRICT OF THE U.S. ARMY CORPS OF ENGINEERS. THE INITIALS OR SIGNATURES AND REGISTRATION DESIGNATIONS OF INDIVIDUALS APPEAR ON THESE PROJECT DOCUMENTS WITHIN THE SCOPE OF THEIR EMPLOYMENT AS REQUIRED BY ER 1110-1-8152 AND INDICATE OFFICIAL RECOMMENDATION AND APPROVAL OF ALL THE DRAWINGS IN THIS SET.

SUBMITTED

X
CHIEF, DESIGN BRANCH

SUBMITTED

X
CHIEF, ENGINEERING & CONSTRUCTION DIVISION

APPROVED

X
COLONEL, CORPS OF ENGINEERS
DISTRICT COMMANDER

US Army Corps of Engineers®
PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OR

DESIGNED BY:
DWN BY:
CKD BY:
SUBMITTED BY:
PLOT SCALE:
PLOT DATE: 6/3/2013
SIZE:
FILE NAME: DDF1.102_G-002XXX.dgn
DATE:
SOLICITATION NO.:
CONTRACT NO.:
DRAWING NUMBER:

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
VICINITY MAP
LOCATION MAP

SHEET IDENTIFICATION
G-002
SHEET 0 OF 0

DESIGN FILE: L:\wfo\cad\TDEA01\DDF1.102_G-001XXX.dgn

DRAWING PLOT SIZE: $BORDER$
DATE AND TIME PLOTTED: 6/3/2013 1:29:34 PM
BY USERNAME: $USER$
SHEET NAME: $SHEETN$

INDEX TO DRAWINGS

CONTRACT DRAWINGS

SHEET NO.	SHEET ID.	CADD FILE NAME	TITLE
1		DDF1.102_G-000CSD.dgn	COVER SHEET
2	G-001	DDF1.102_G-002XXX.dgn	GENERAL - VICINITY MAP - LOCATION MAP
3	G-002	DDF1.102_G-003XXX.dgn	GENERAL - INDEX TO DRAWINGS
4	G-101	TDEA01G-101---.dgn	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - PROJECT PLAN VIEW
5	G-102	TDEA01G-102---.dgn	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - INTAKE
6	G-103	TDEA01G-103---.dgn	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - SECTION - START OF CONDUIT
7	G-104	TDEA01G-104---.dgn	GENERAL - MAIN AUXILLARY WATER SUPPLY PIPE - SECTION - FISH LOCK APPROACH CHANNEL
8	S-301	TDEA01S-301---.dgn	STRUCTURAL - FAC TO AWSC CONDUITS
9	S-501	TDEA01S-501---.dgn	STRUCTURAL - CUL-DE-SAC LOGS - DETAILS
10	S-901	TDEA01S-901---.dgn	STRUCTURAL - CLOSURE GATE - ISOMETRIC
11	S-902	TDEA01S-902---.dgn	STRUCTURAL - TRASHRACK - ISOMETRIC
12	M-401	DFF1.XXX_M-401XXX.dgn	MECHANICAL - INTAKE - TRASH RAKE
13	M-402	DFF1.XXX_M-402XXX.dgn	MECHANICAL - INTAKE - GATE WHEEL
14	MD101	DFF1.XXX_MD101XXX.dgn	MECHANICAL - DEMOLITION - SITE PLAN
15	MD901	DFF1.XXX_MD901XXX.dgn	MECHANICAL - DEMOLITION - PHOTOS 1
16	MD902	DFF1.XXX_MD902XXX.dgn	MECHANICAL - DEMOLITION - PHOTOS 2

US Army Corps
of Engineers®
PORTLAND DISTRICT

MARK	DESCRIPTION	DATE	APPR.

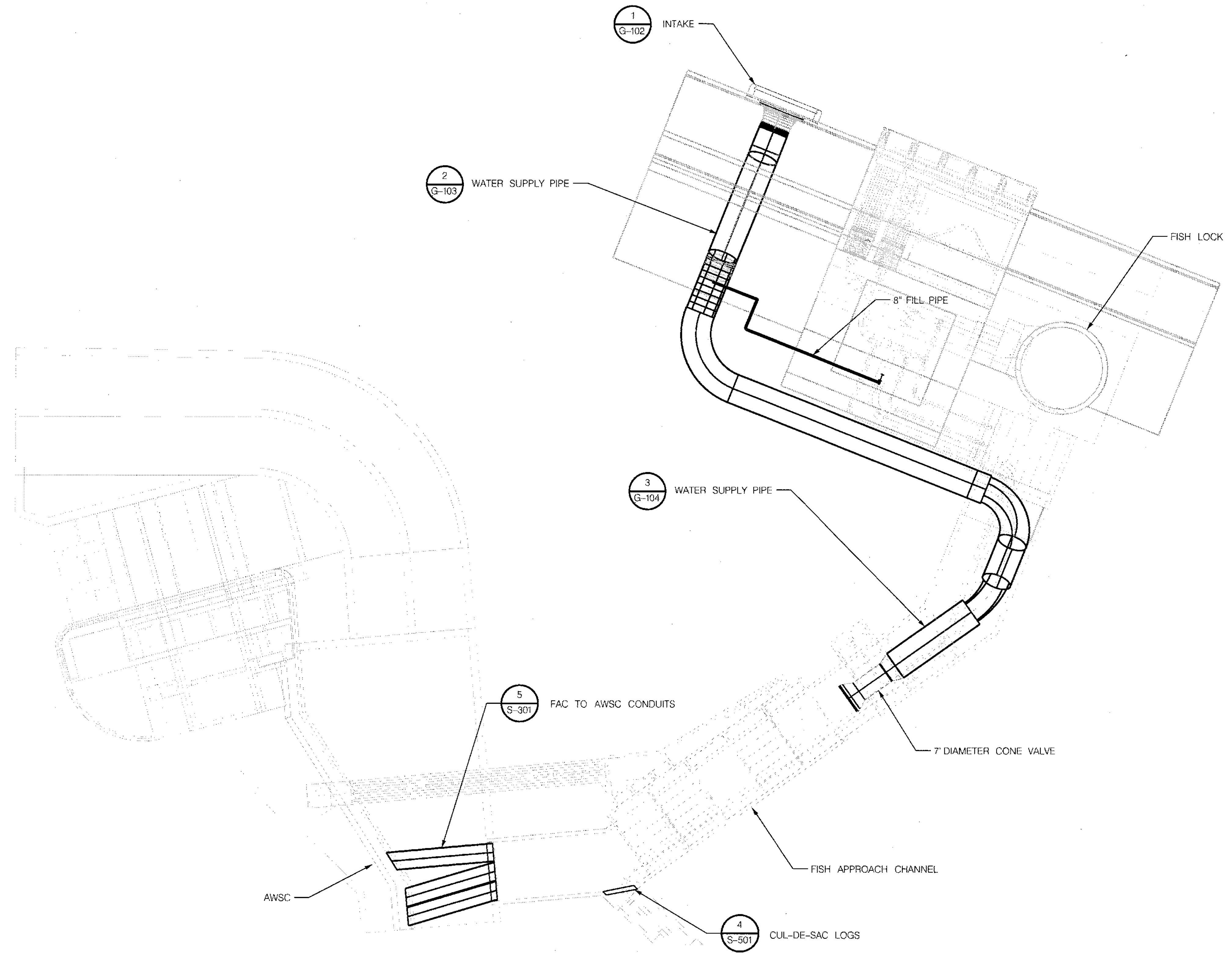
U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

DESIGNED BY:		DATE: 05/02/2013
DWN BY:	CKD BY:	SOLICITATION NO.: X
SUBMITTED BY:		CONTRACT NO.:
PLOT SCALE: 1:1	PLOT DATE: 6/3/2013	DRAWING NUMBER:
SIZE: ANSI D	FILE NAME: DDF1.102_G-003XXX.dgn	

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
INDEX TO DRAWINGS

SHEET
IDENTIFICATION
G-003
SHEET 0 OF 0



5 PLAN VIEW

0' 20' 40'

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDLLN
DWN BY: G4EDDJAH
CKD BY: CKD BY
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTER'S NAME
CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE
FILE NAME: FILE NAME

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
PROJECT PLAN VIEW

SHEET IDENTIFICATION
G-101
SHEET OF

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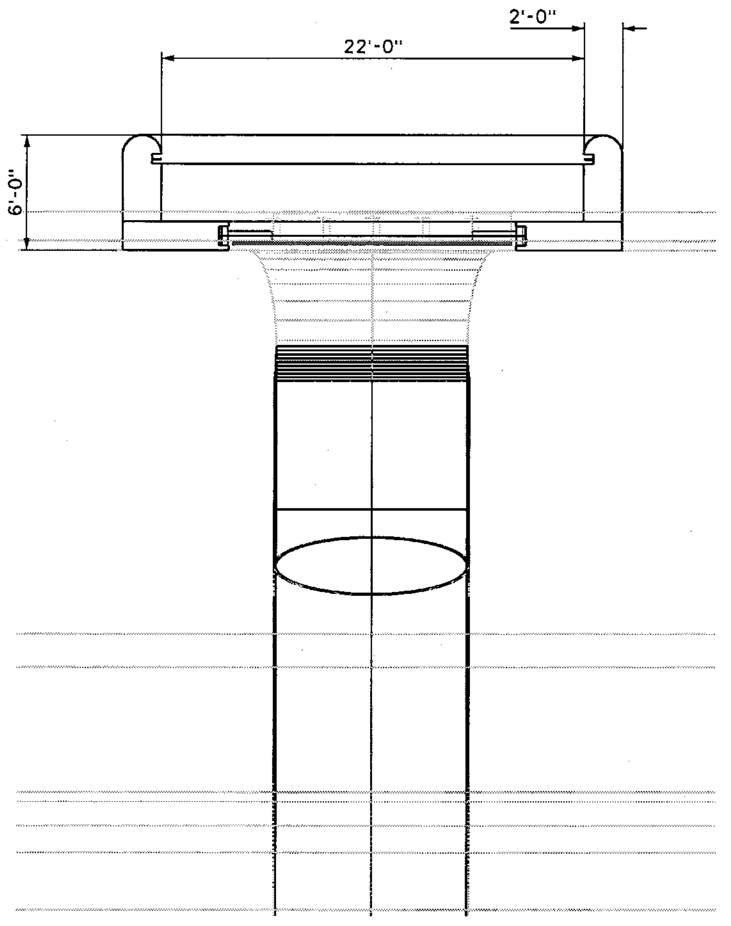
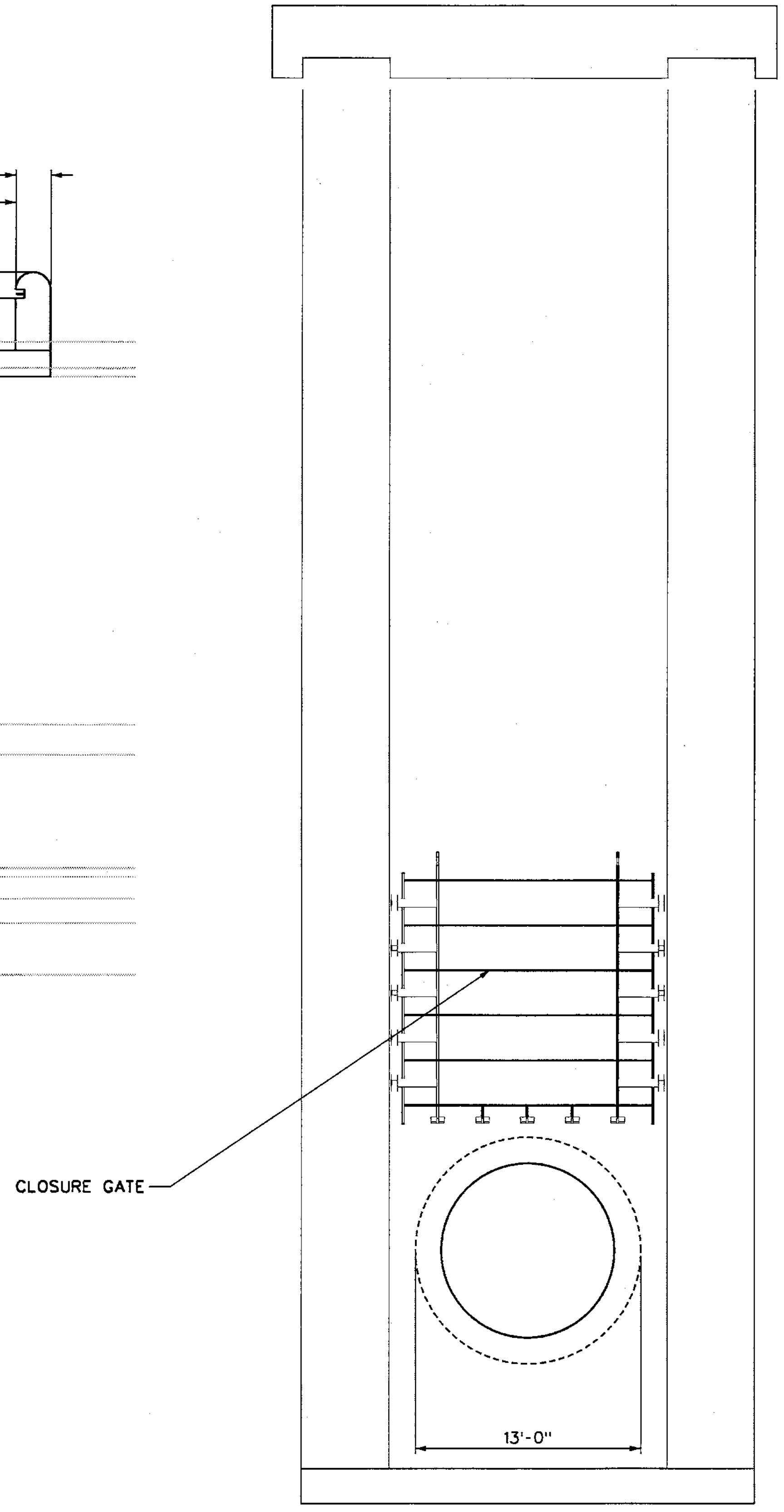
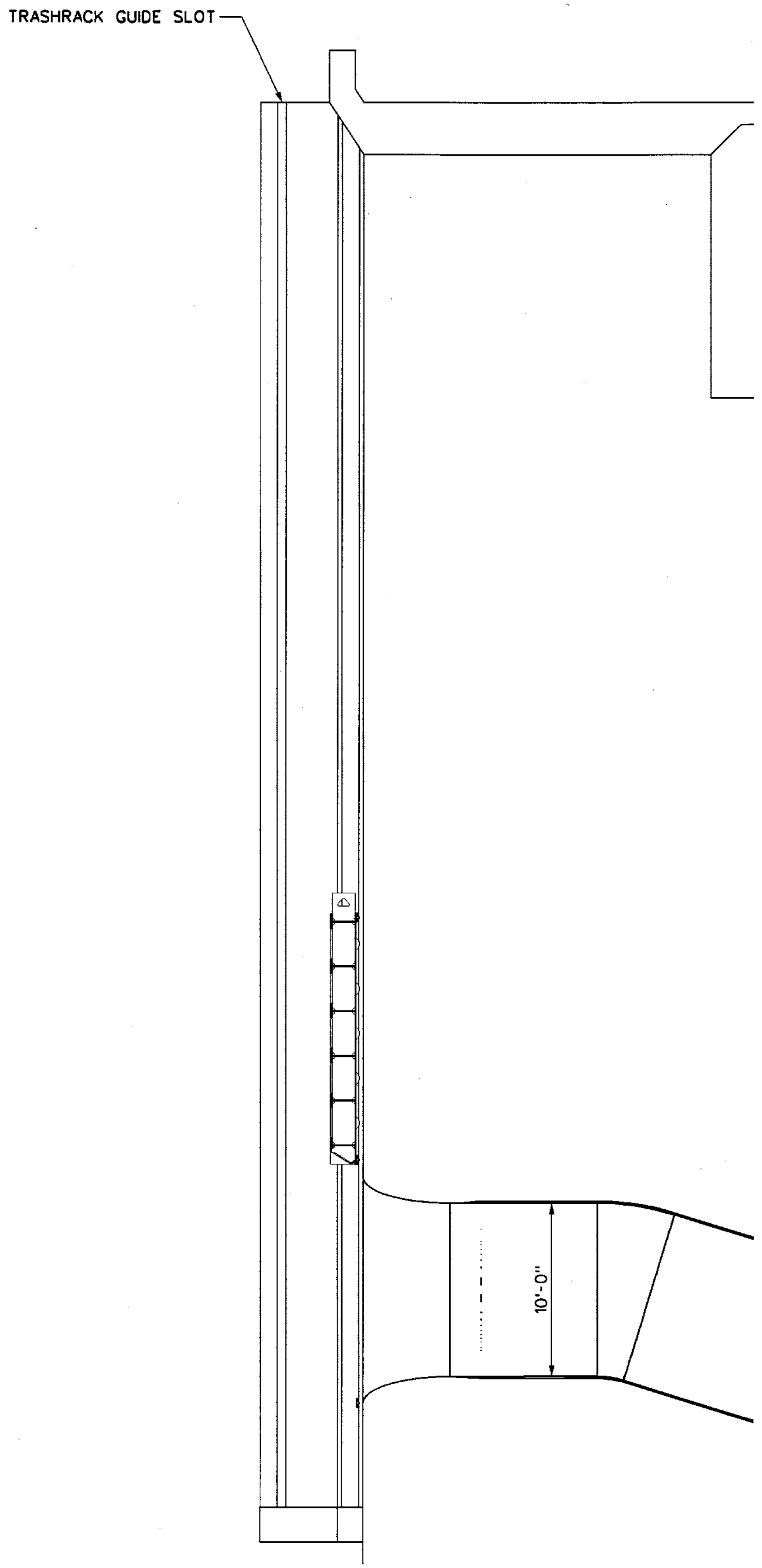


1A PLAN VIEW



1B FRONT VIEW



1C ELEVATION VIEW

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDLLN		DATE: ISSUE DATE
DWN BY: G4EDDJAH	CKD BY: CKD BY	SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTER'S NAME		CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE	PLOT DATE: 6/3/2013	DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE	FILE NAME: FILE NAME	

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
INTAKE

SHEET
IDENTIFICATION
G-102
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\TDEA01G-102---.dgn

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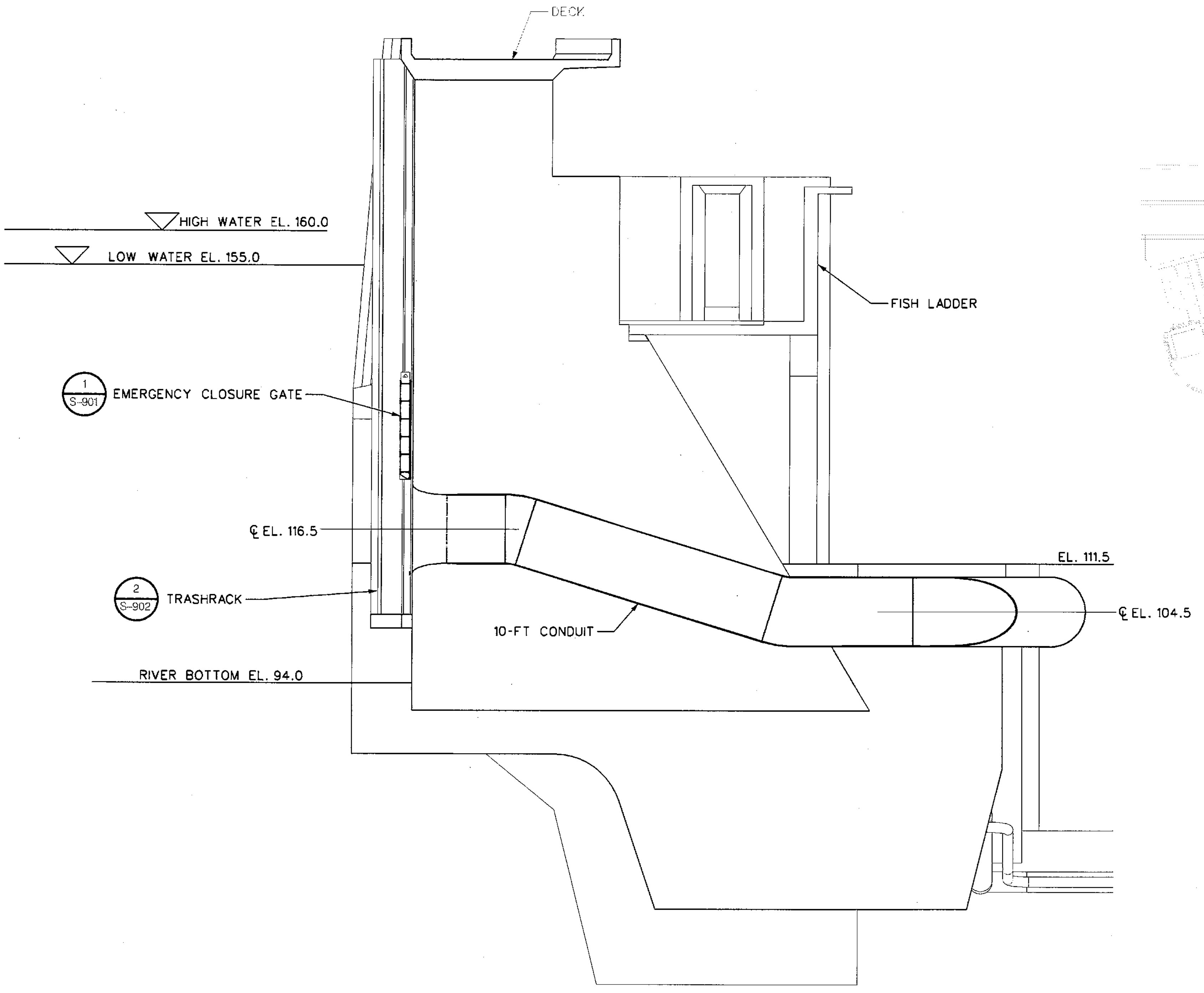
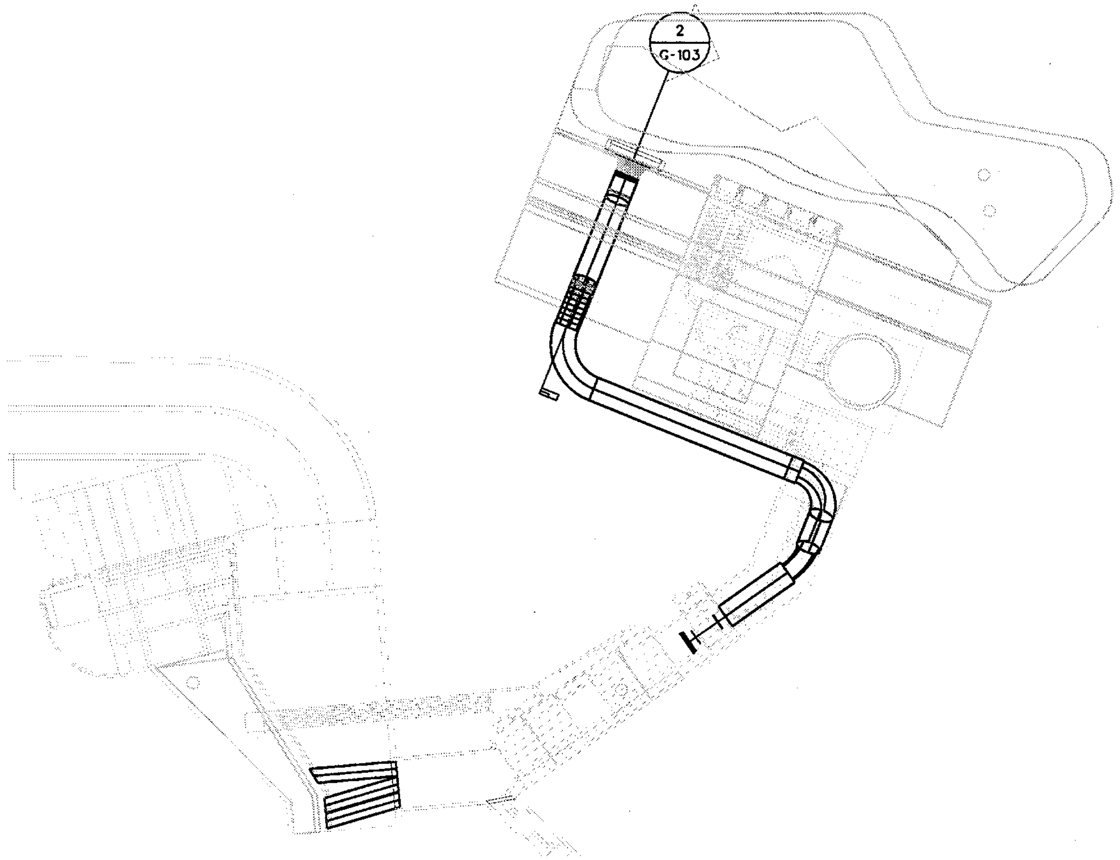


② SECTION: START OF CONDUIT

0' 10' 20'



PLAN VIEW

US Army Corps of Engineers®
DISTRICT NAME

MARK | DESCRIPTION | DATE | APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDLLN
DWN BY: G4EDDJAH
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
SECTION - START OF CONDUIT

SHEET
IDENTIFICATION
G-103
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\TDEA01G-103---.dgn

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DATE AND TIME PLOTTED: 6/3/2013 2:04:18 PM

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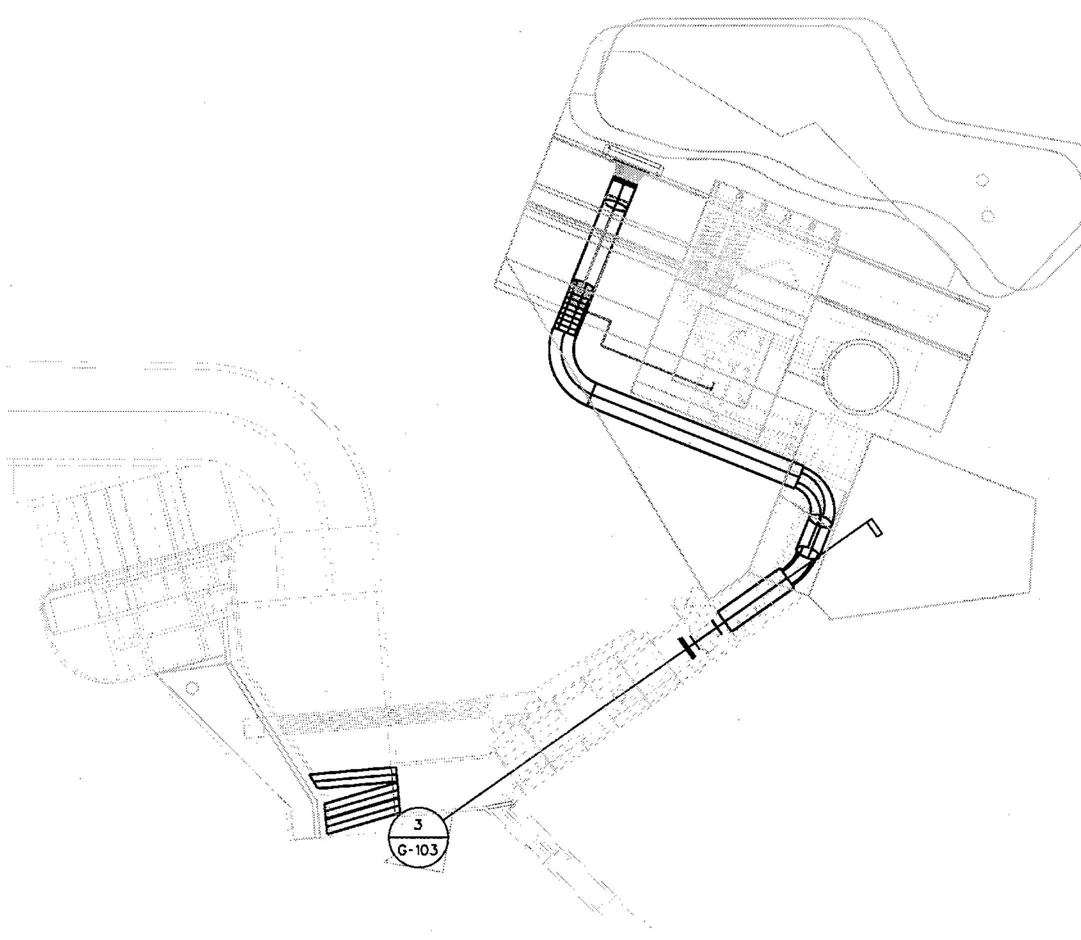
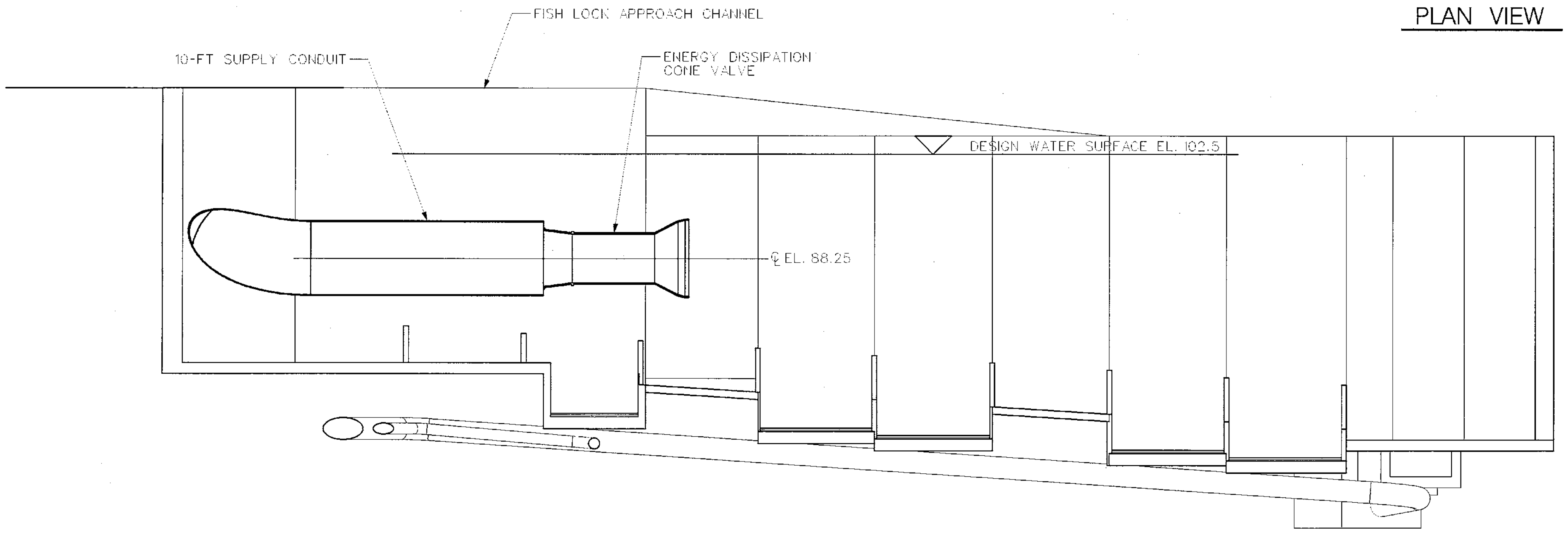


PLAN VIEW



③ SECTION: FISH LOCK APPROACH CHANNEL

0' 10' 20'

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

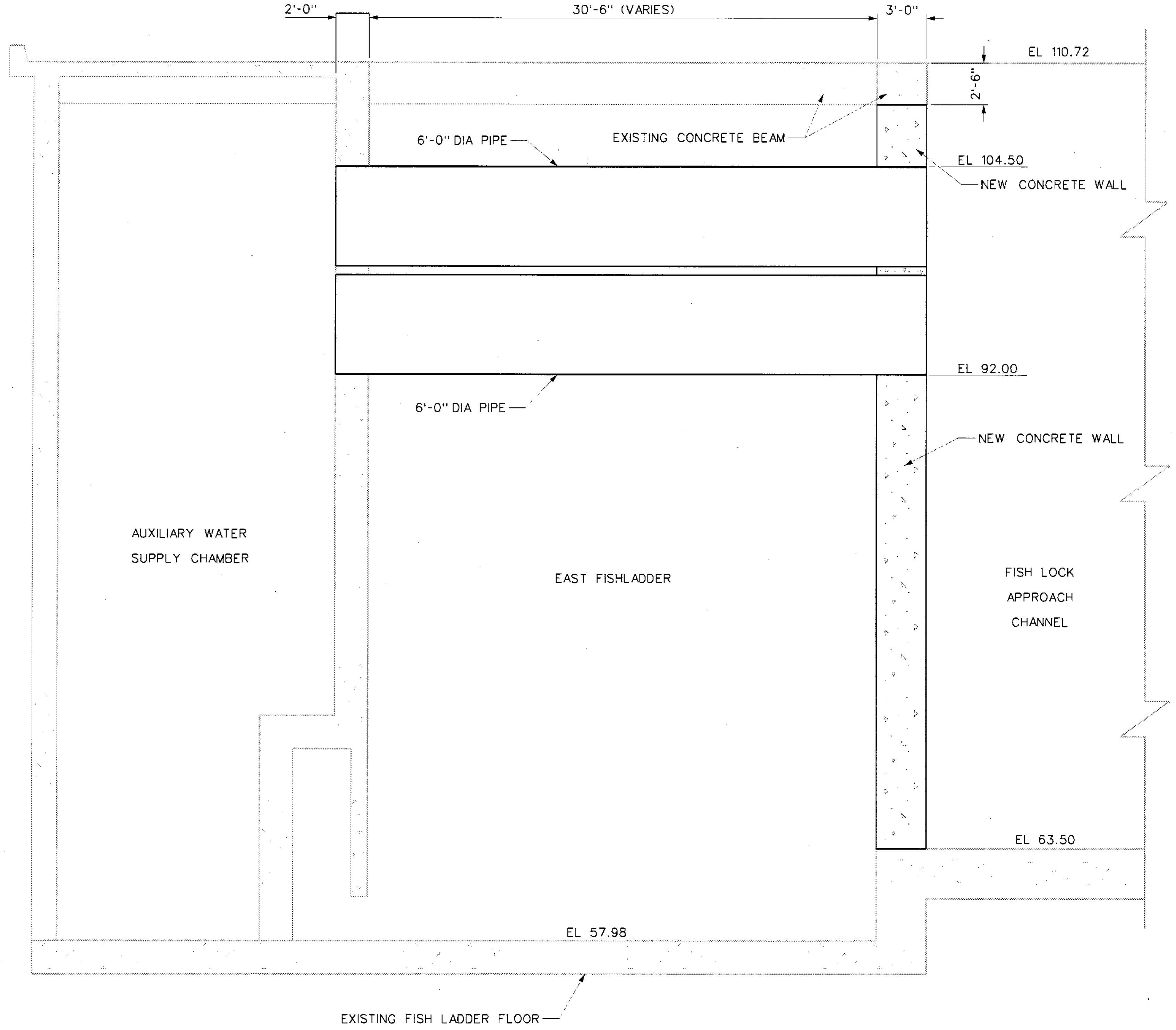
DESIGNED BY: G4EDDLLN		DATE: ISSUE DATE
DWN BY: G4EDDJAH	CKD BY: CKD BY	SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTER'S NAME		CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE	PLOT DATE: 6/3/2013	DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE	FILE NAME: FILE NAME	

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

GENERAL
MAIN AUXILIARY WATER SUPPLY PIPE
SECTION - FISH LOCK APPROACH CHANNEL

SHEET
IDENTIFICATION
G-104
SHEET OF

DESIGN FILE: L:\w\o\cad\TDEA01\TDEA01G-104---.dgn



REF G-101 (5) SECTION

0' 4' 8'

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.
07	ISSUE 07 DESCRIPTION	DATE 07	A-7
06	ISSUE 06 DESCRIPTION	DATE 06	A-6
05	ISSUE 05 DESCRIPTION	DATE 05	A-5
04	ISSUE 04 DESCRIPTION	DATE 04	A-4
03	ISSUE 03 DESCRIPTION	DATE 03	A-3
02	ISSUE 02 DESCRIPTION	DATE 02	A-2
01	ISSUE 01 DESCRIPTION	DATE 01	A-1

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: DESIGNER'S NAME
DWN BY: DWN BY
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

STRUCTURAL
FAC TO AWSC CONDUITS

SHEET IDENTIFICATION
S-301
SHEET OF

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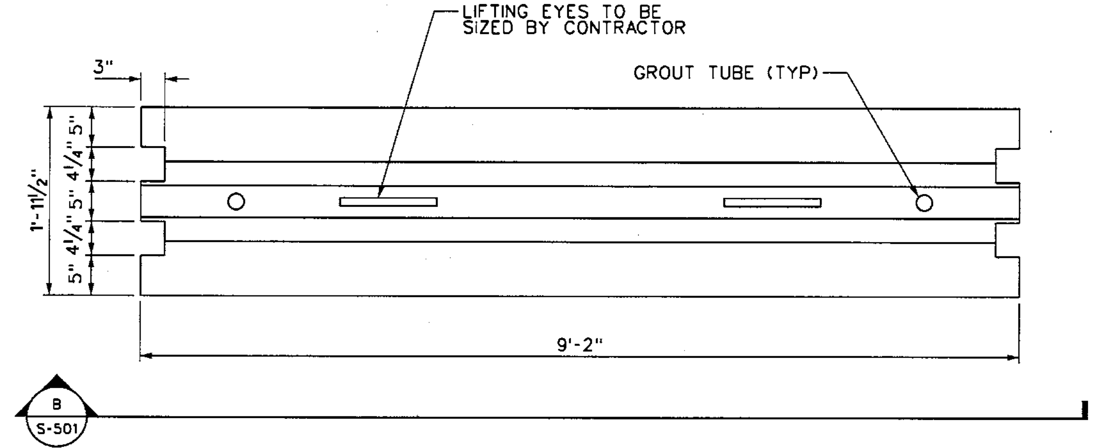
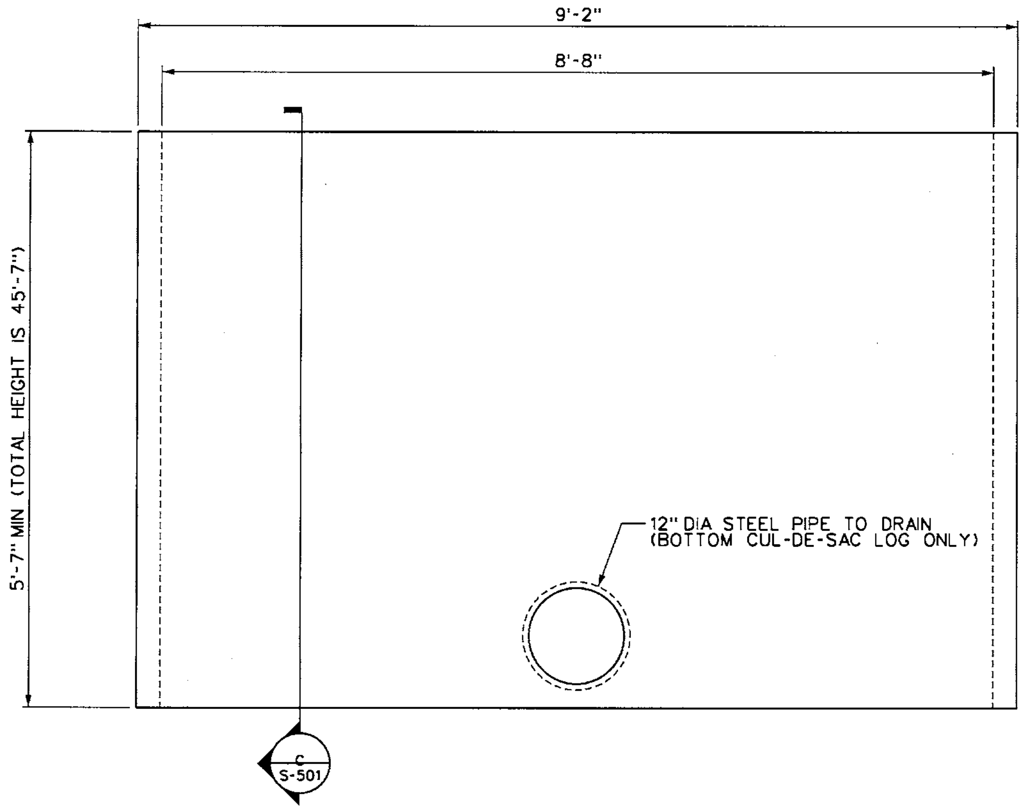


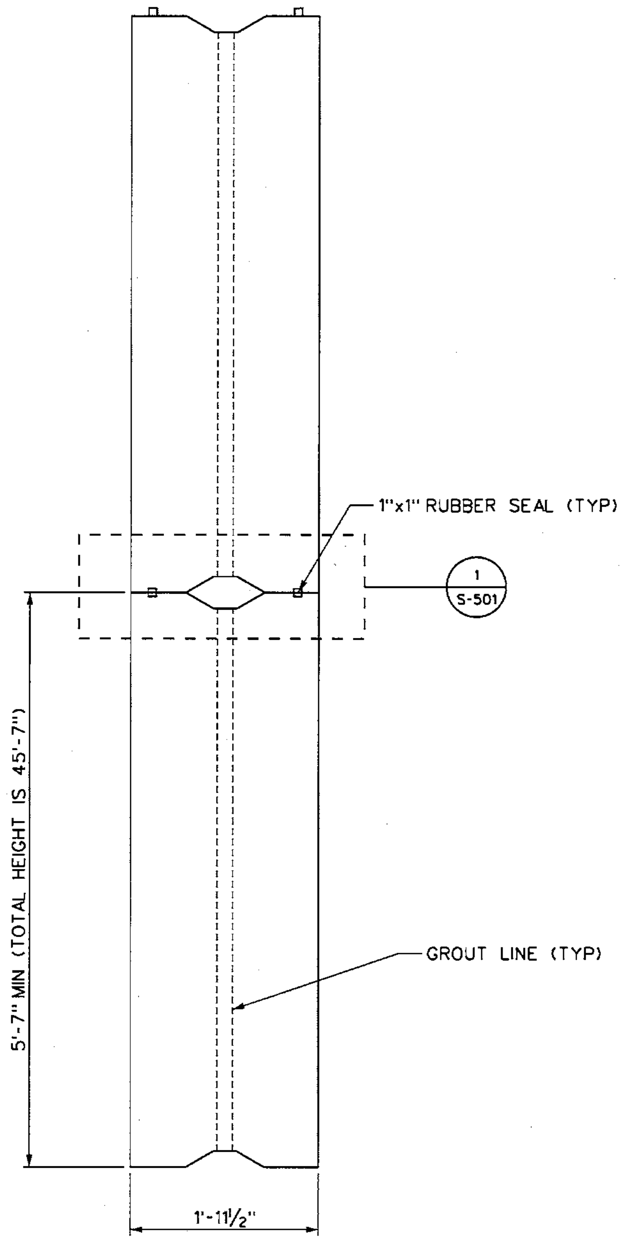
A TOP VIEW

0' 1' 2'



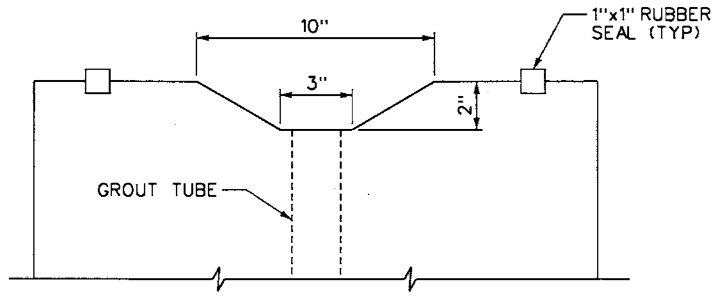
B SECTION

0' 1' 2'



C SECTION

0' 1' 2'



1 DETAIL

0" 4" 8"

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.
07	ISSUE 07 DESCRIPTION	DATE 07	A-7
06	ISSUE 06 DESCRIPTION	DATE 06	A-6
05	ISSUE 05 DESCRIPTION	DATE 05	A-5
04	ISSUE 04 DESCRIPTION	DATE 04	A-4
03	ISSUE 03 DESCRIPTION	DATE 03	A-3
02	ISSUE 02 DESCRIPTION	DATE 02	A-2
01	ISSUE 01 DESCRIPTION	DATE 01	A-1

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: DESIGNER'S NAME
DWN BY: DWN BY
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

STRUCTURAL
CUL-DE-SAC LOGS
DETAILS

SHEET
IDENTIFICATION
S-501
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\TDEA01S-501---.dgn

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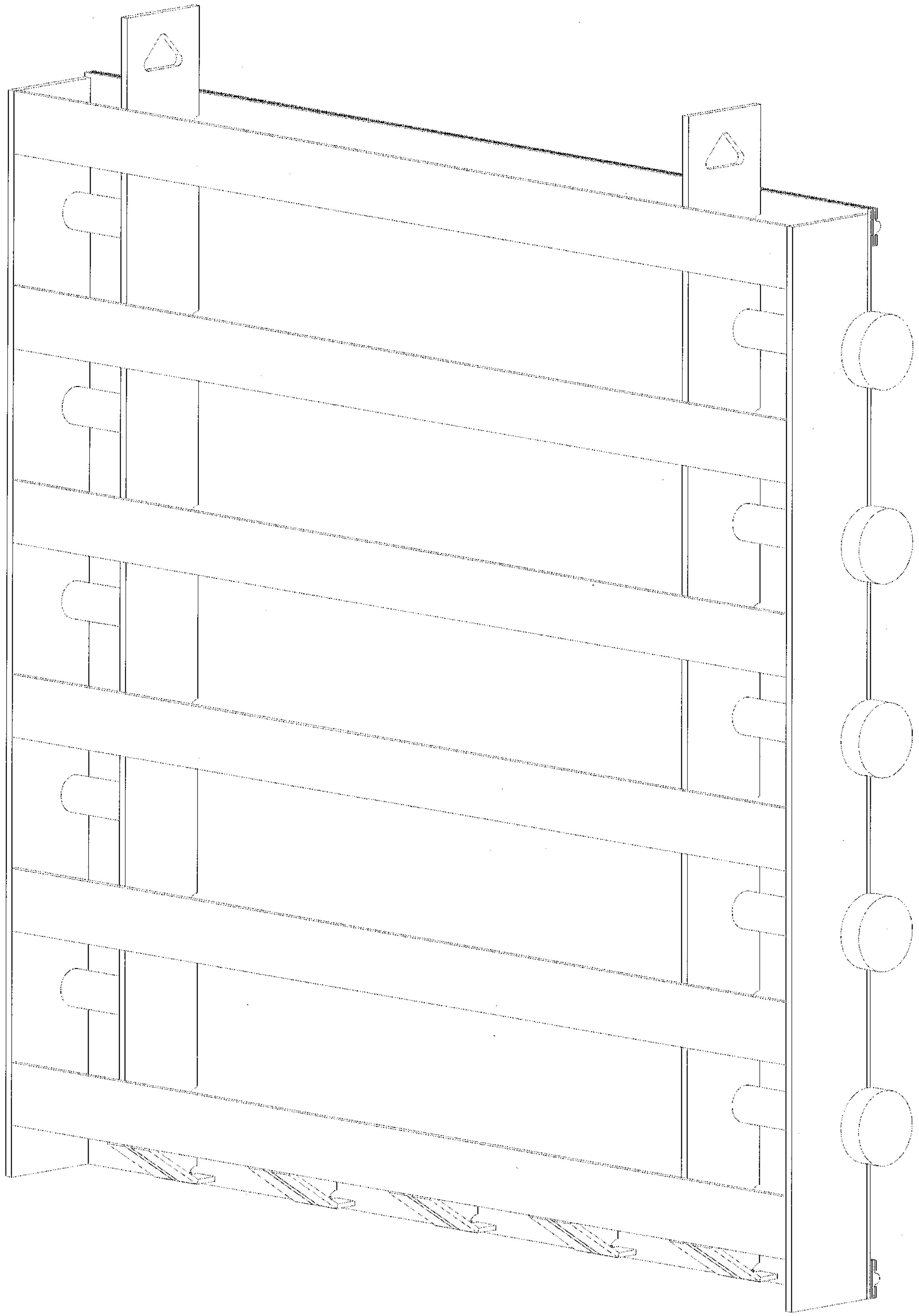

NOTES:

1. OVERALL STRUCTURAL GATE SIZE IS 14.5' x 14.5'.

2. APPROXIMATE TOTAL WEIGHT OF GATE IS 20,500 lbs.

US Army Corps
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DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.
07	ISSUE 07 DESCRIPTION	DATE 07	A-7
06	ISSUE 06 DESCRIPTION	DATE 06	A-6
05	ISSUE 05 DESCRIPTION	DATE 05	A-5
04	ISSUE 04 DESCRIPTION	DATE 04	A-4
03	ISSUE 03 DESCRIPTION	DATE 03	A-3
02	ISSUE 02 DESCRIPTION	DATE 02	A-2
01	ISSUE 01 DESCRIPTION	DATE 01	A-1

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: DESIGNER'S NAME
DWN BY: DWN BY
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

STRUCTURAL
CLOSURE GATE
ISOMETRIC

SHEET
IDENTIFICATION
S-901
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\TDEA01S-901---.DGN

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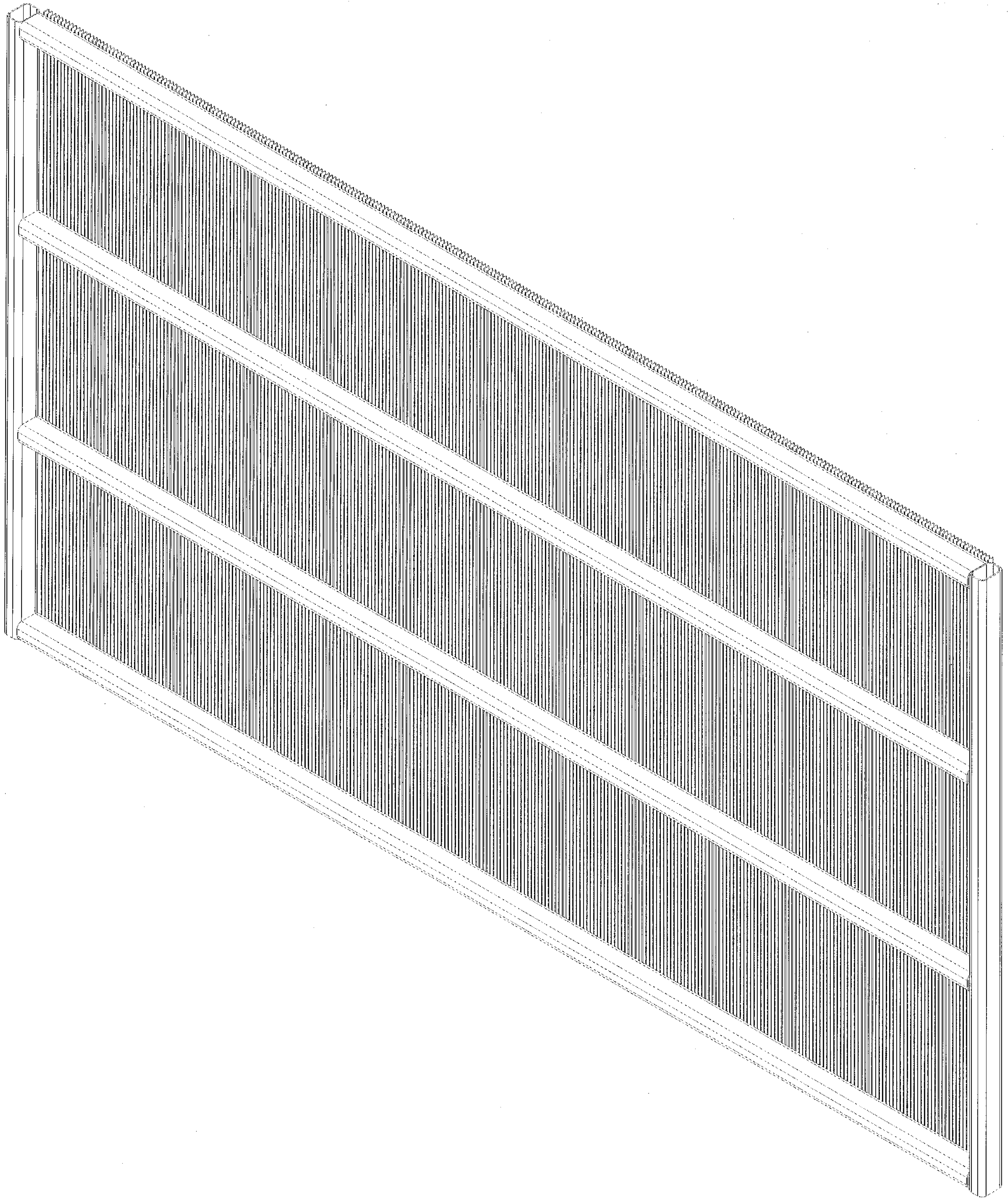

NOTES:

1. TRASHRACK DIMENSIONS ARE 12' x 22'.

US Army Corps of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.
07	ISSUE 07 DESCRIPTION	DATE 07	A-7
06	ISSUE 06 DESCRIPTION	DATE 06	A-6
05	ISSUE 05 DESCRIPTION	DATE 05	A-5
04	ISSUE 04 DESCRIPTION	DATE 04	A-4
03	ISSUE 03 DESCRIPTION	DATE 03	A-3
02	ISSUE 02 DESCRIPTION	DATE 02	A-2
01	ISSUE 01 DESCRIPTION	DATE 01	A-1

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: DESIGNER'S NAME
DWN BY: DWN BY
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

STRUCTURAL
TRASHRACK
ISOMETRIC

SHEET
IDENTIFICATION
S-902
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\TDEA01S-902---.DGN

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DATE AND TIME PLOTTED: 6/3/2013 1:19:01 PM
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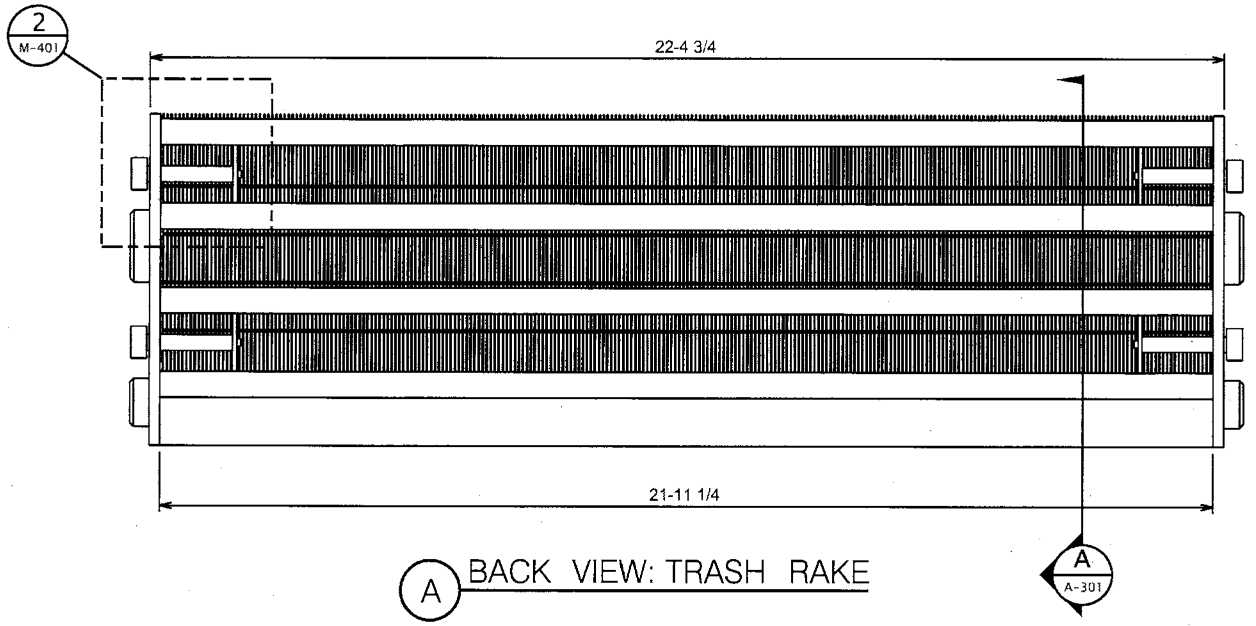
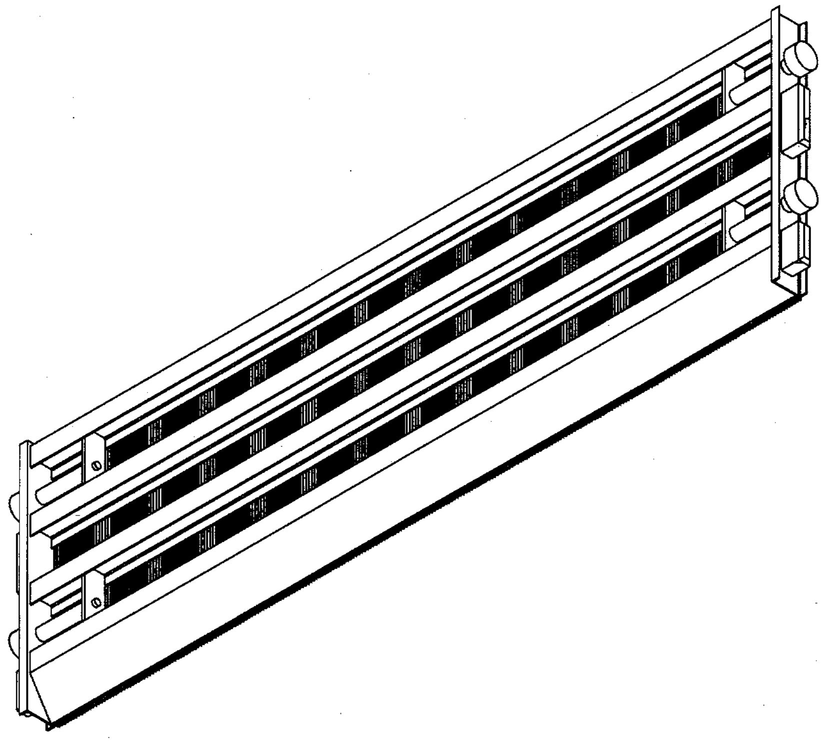
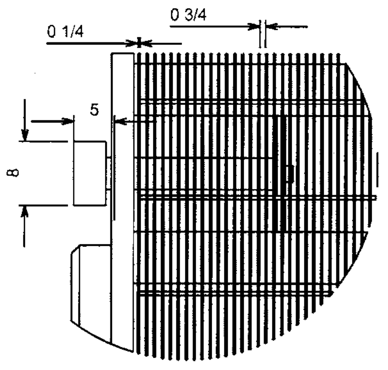


Ⓐ BACK VIEW: TRASH RAKE

Ⓑ PLAN VIEW: TRASH RAKE



① ISOMETRIC: TRASH RAKE



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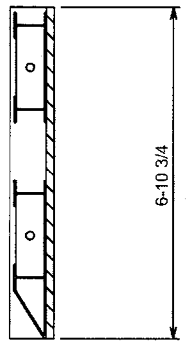
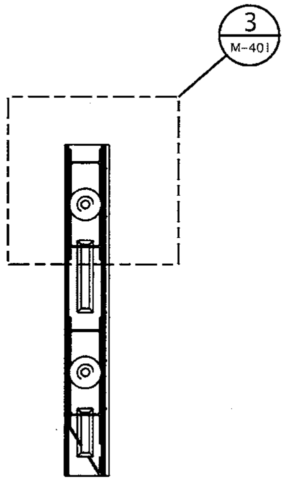
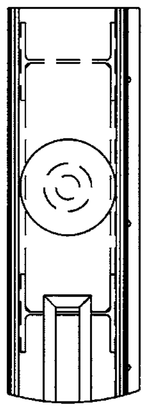


Ⓓ SECTION:



Ⓒ SIDE VIEW: TRASH RAKE



③ DETAIL

US Army Corps
of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

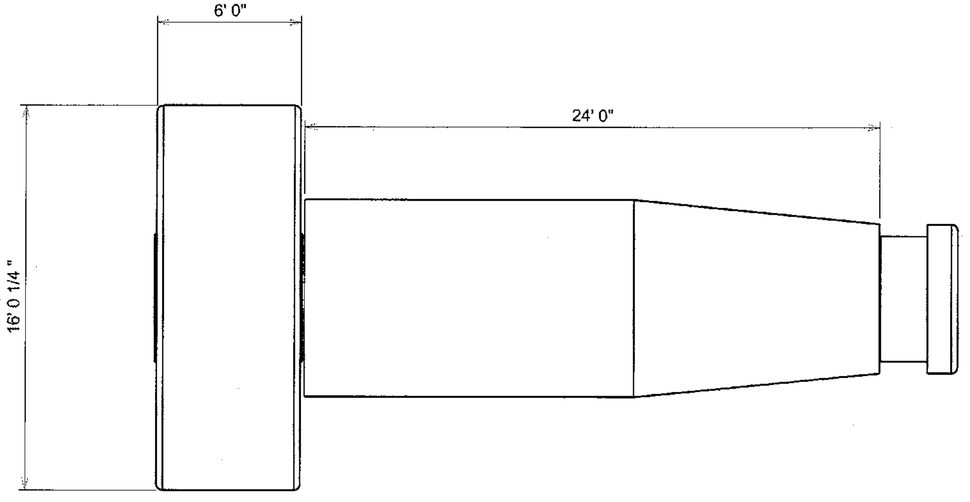
DESIGNED BY: G4EDDPSA
DWN BY: G4EDDJAH
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

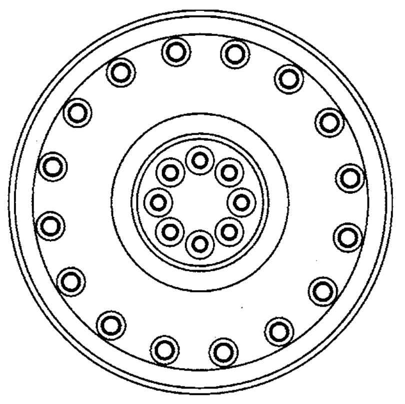
MECHANICAL
INTAKE
TRASH RAKE

SHEET
IDENTIFICATION
M-401
SHEET OF

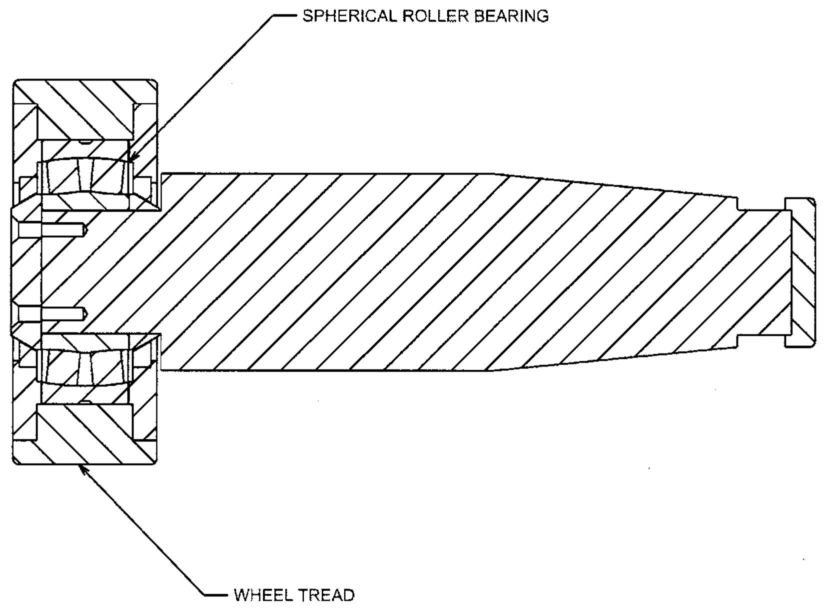
DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_M-401XXX.dgn



2 DETAIL: INTAKE GATE ROLLER WHEEL



A END VIEW:



A SECTION

US Army Corps
of Engineers®
DISTRICT NAME

MARK
DESCRIPTION
DATE
APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDPSA
DWN BY: G4EDDJAH
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

MECHANICAL
INTAKE
GATE WHEELS

SHEET
IDENTIFICATION
M-402
SHEET OF

DESIGN FILE: L:\wfo\cad\TDEA01\DFF1.XXX_M-402XXX.dgn

DRAWING PLOT SIZE: $BORDER$
DATE AND TIME PLOTTED: 6/3/2013 11:57:50 AM
BY USERNAME: $USER$
SHEET NAME: $SHEETN$

① DEMOLITION SITE PLAN: MECHANICAL

0 10' 20' 40'

US Army Corps
of Engineers®
DISTRICT NAME

MARK	DESCRIPTION	DATE	APPR.

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

DESIGNED BY: G4EDDPSA		DATE: ISSUE DATE
DWN BY: G4EDDJAH	CKD BY: CKD BY	SOLICITATION NO.: SOLICITATION NUMBER
SUBMITTED BY: SUBMITTER'S NAME		CONTRACT NO.: CONTRACT NUMBER
PLOT SCALE: SCALE	PLOT DATE: 6/3/2013	DRAWING NUMBER: DRAWING NUMBER
SIZE: SHT SIZE	FILE NAME: FILE NAME	

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

MECHANICAL
DEMOLITION
SITE PLAN

SHEET
IDENTIFICATION
MD101
SHEET OF

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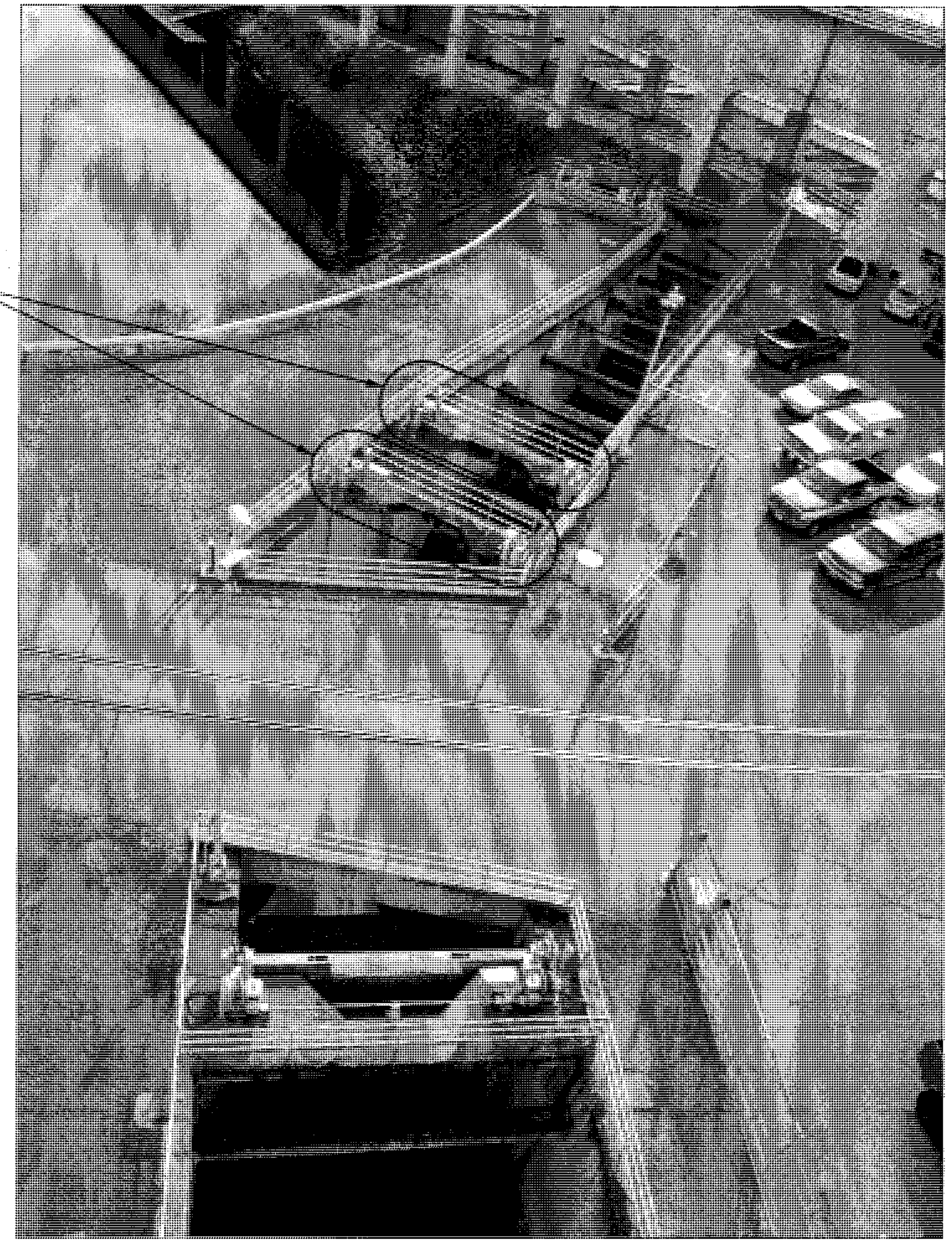
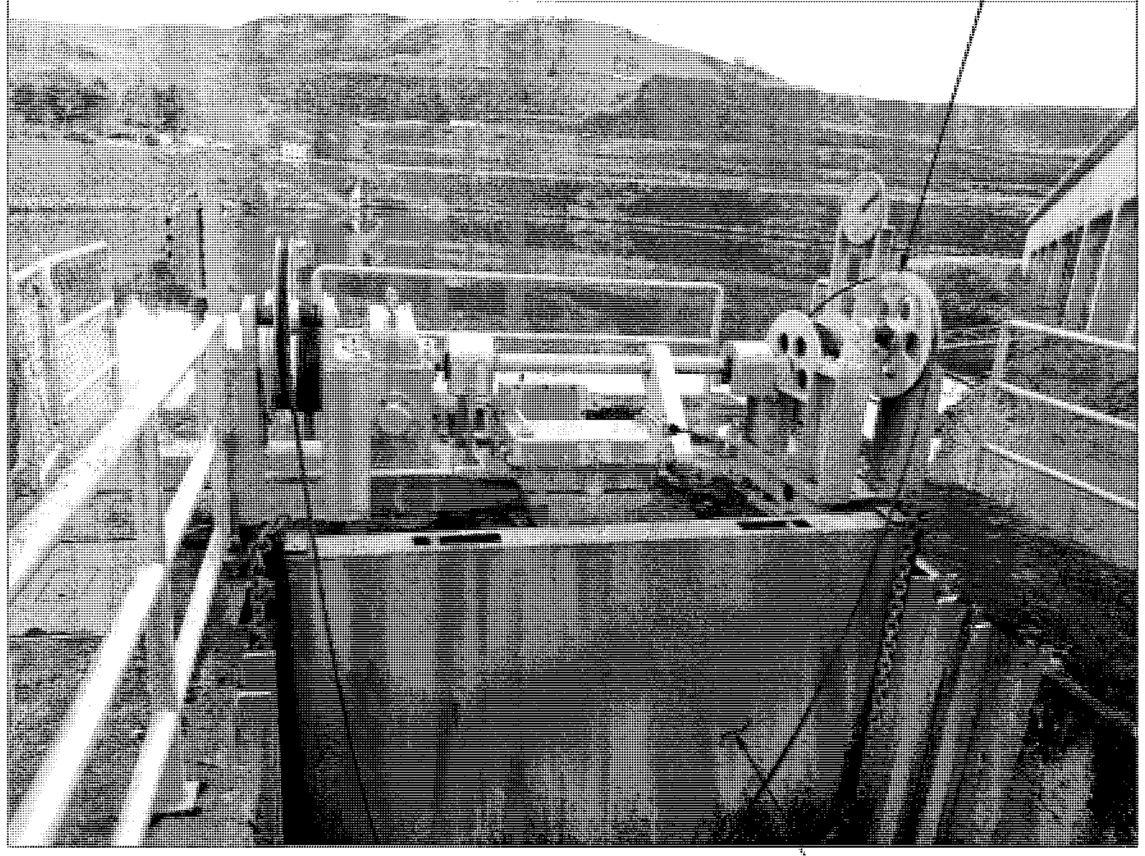


REMOVE HOISTS AMD APPRTENANT EQUIPMENT

① PHOTO
NOT TO SCALE

REMOVE HOIST AND APPURTENANT EQUIPMENT

② PHOTO
NOT TO SCALE



REMOVE GATE HOIST AND APPURTENANT EQUIPMENT

REMOVE ISOLATION BULKHEAD

③ PHOTO
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US Army Corps of Engineers®
DISTRICT NAME

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07	ISSUE 07 DESCRIPTION	DATE 07	A-7
06	ISSUE 06 DESCRIPTION	DATE 06	A-6
05	ISSUE 05 DESCRIPTION	DATE 05	A-5
04	ISSUE 04 DESCRIPTION	DATE 04	A-4
03	ISSUE 03 DESCRIPTION	DATE 03	A-3
02	ISSUE 02 DESCRIPTION	DATE 02	A-2
01	ISSUE 01 DESCRIPTION	DATE 01	A-1

U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
WALLA WALLA, WASHINGTON

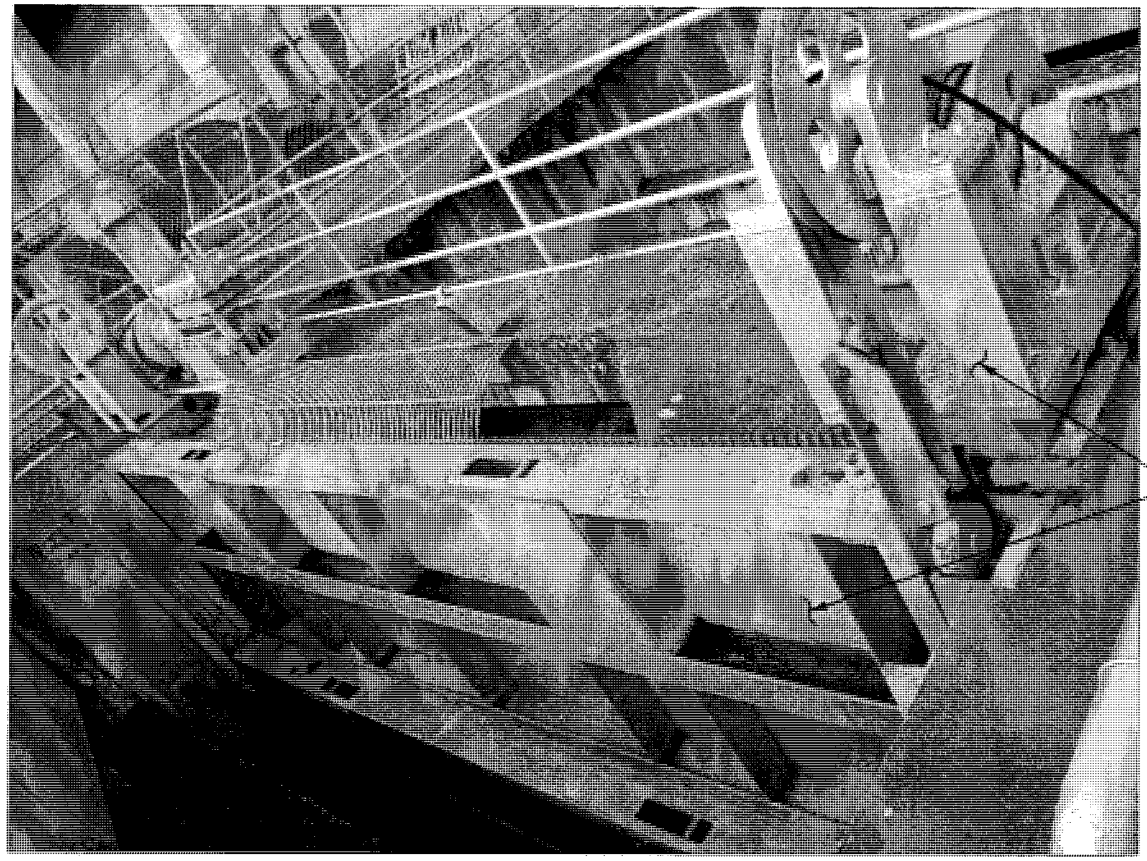
DESIGNED BY: G4EDDPSA
DWN BY: G4EDDJAH
CKD BY: CKD BY
SUBMITTED BY: SUBMITTER'S NAME
PLOT SCALE: SCALE
PLOT DATE: 6/3/2013
SIZE: SHT SIZE
FILE NAME: FILE NAME
DATE: ISSUE DATE
SOLICITATION NO.: SOLICITATION NUMBER
CONTRACT NO.: CONTRACT NUMBER
DRAWING NUMBER: DRAWING NUMBER

THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

MECHANICAL
DEMOLITION
PHOTOS 1

SHEET
IDENTIFICATION
MD901
SHEET OF

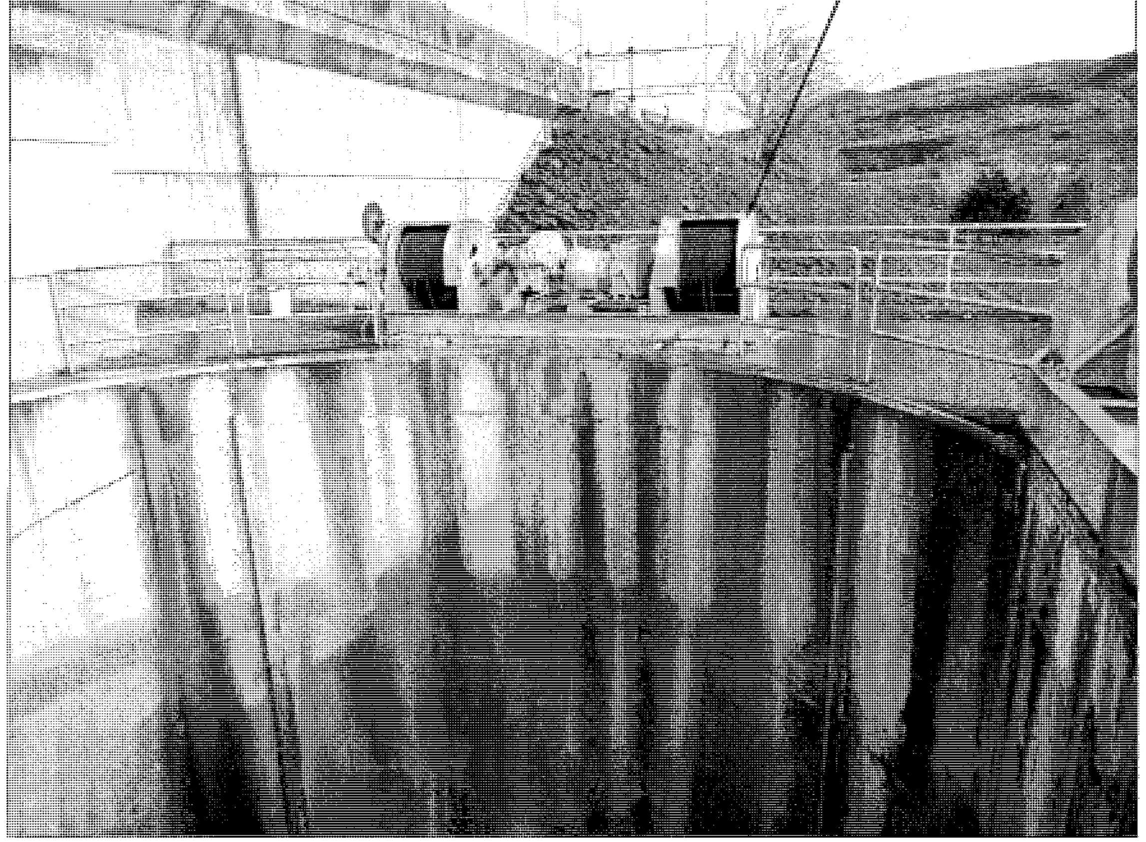
DESIGN FILE: L:\wfoicad\TDEA01\DFF1.XXX_MD901XXX.dgn



REMOVE FINGER WEIR AND HOIST AND APPURTENANT EQUIPMENT

④ PHOTO
NOT TO SCALE

REMOVE HOIST AND APPURTENANT EQUIPMENT



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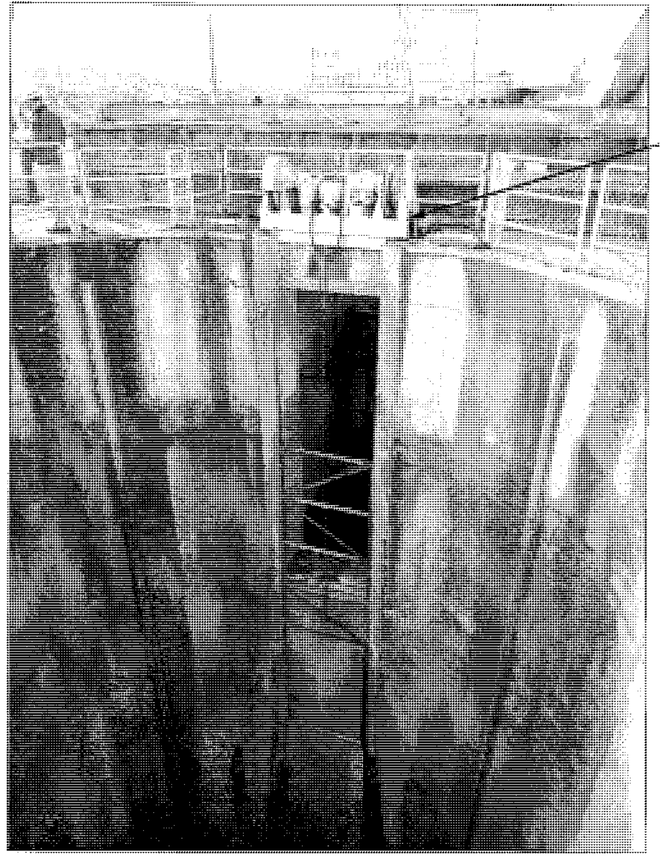
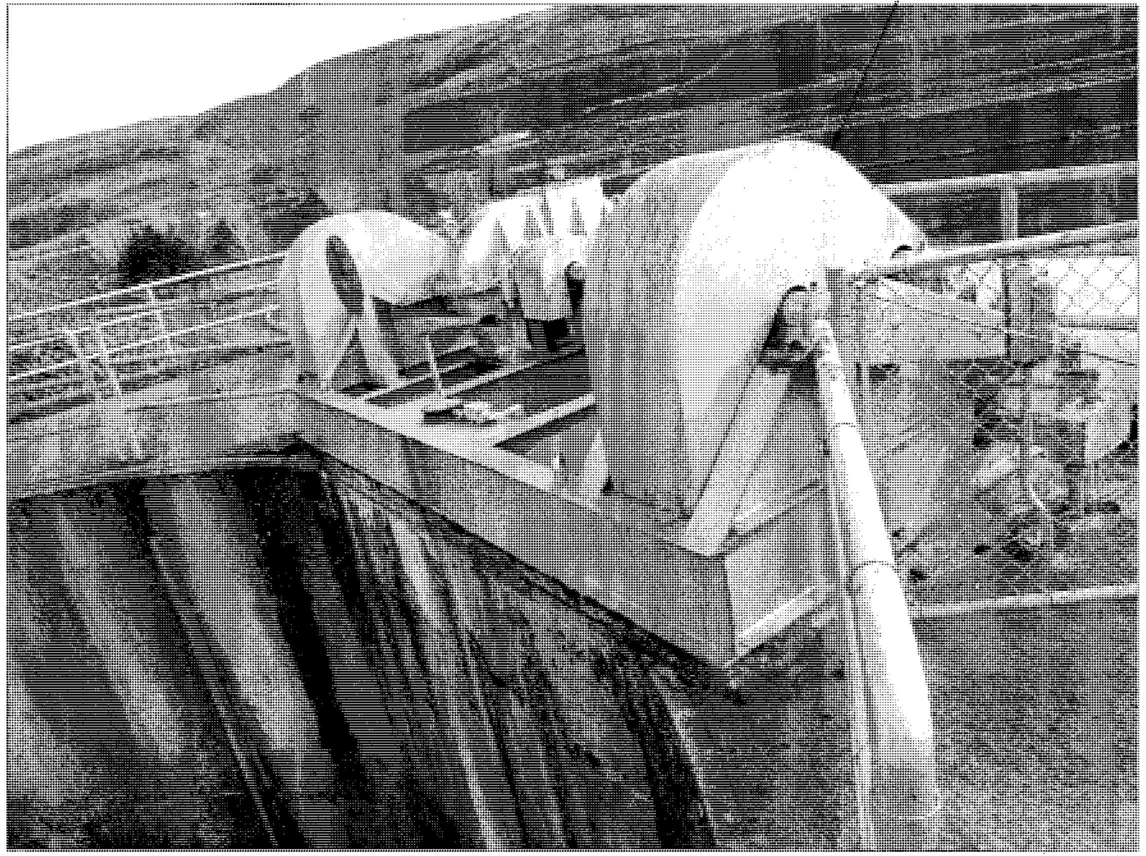


REMOVE HOIST AND APPURTENANT EQUIPMENT

⑥ PHOTO
NOT TO SCALE

REMOVE FISH LOCK GATE HOIST AND APPURTENANT EQUIPMENT



⑦ PHOTO
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U.S. ARMY CORPS OF ENGINEERS
PORTLAND DISTRICT
PORTLAND, OREGON

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
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THE DALLES LOCK AND DAM
NORTH-EAST FISHLADDER
BACKUP AUXILLARY WATER SUPPLY

MECHANICAL
DEMOLITION
PHOTOS 2

SHEET
IDENTIFICATION
MD902
SHEET OF

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