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Design Documentation Report

THE DALLES DAM
COLUMBIA RIVER

NORTH FISH LADDER ROCK WALL STABILIZATION

August 25, 2015

90% DQC Draft

The Dalles North Fish Ladder Rock Wall Stabilization Design Documentation Report

Executive Summary

The purpose of this Design Documentation Report (DDR) is to provide a record of design decisions, assumptions, and methods related to the stabilization of rock cuts along The Dalles Dam North Fish Ladder that forms the side walls of a portion of the fish ladder, between weirs No. 77 and 132. Mechanical weathering over the last 50+ years has caused areas of the steep rock cuts to become unstable creating project life safety and operability concerns. In addition, the open rock joints along the rock faces have allowed brush and trees to establish causing accelerating the destabilization of these rock cuts. The objective of the project is to successfully stabilize the rock cuts along the North Fish Ladder, between weirs No. 77 to 132. Successful stabilization of these faces will include a combination of scaling, rock anchors/bolts, and small shotcrete walls with anchors between weirs 120 and 123.

This DDR include discussion of considered alternatives. The preferred alternative evaluated in this DDR would not significantly alter the existing fish ladder channel, adversely impact the ladder weirs, or encroach into the min. 24 foot width of the design channel. The proposed work is generally considered to be maintenance activity, and is not intended to modify the existing fish ladder structure, or changing ladder performance or operation. The work proposed in this DDR is not intended to permanently stabilize the rock lines fish channel. With time, the exposed rock slopes will continue to weather and future stabilization measures will likely be required. The proposed stabilization work is intended to substantially reduce the rock fall hazards from its current level for at least 20 years.

Proposed 90% DDR design includes rock scaling; localized rock anchors/bolts; and construction of three shotcrete walls with mesh, rebar and rock anchor support, as shown on Plate 1. It is anticipated that scaling will be required for about 22,000 sf of rock cut, with a total scaled rock volume of about 220 cy. A total of 100 rock anchors is anticipated, with average depths of 12 feet; plus an additional 24 anchors to support the shotcrete walls. The construction costs with contingency for this design is estimated to be approximately $XX. The total fully funded project cost is currently estimated to be $XX.

The Dalles North Fish Ladder Rock Wall Stabilization Design Documentation Report

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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/Rise (typical)		1v:16h
North ladder length	Feet	1,761
East Ladder length	Feet	1,801
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

*Note: National Geodetic Vertical Datum of 1929 (NGVD29) = North American Vertical Datum of 1988 (NAVD88) - 3.3 feet.

Acronyms and Abbreviations

°C/°F	degrees Centigrade/degrees Fahrenheit
AASHTO	American Association of State Highway and Transportation Officials
AWS	Auxiliary water supply
cfs	cubic feet per second
cm/s	centimeters per second
DAHP	[Washington] Department of Archaeology and Historic Preservation
DDR	Design Documentation Report
DM	Design Memorandum
EA	Environmental Assessment
EM	Engineer Manual
ER	Engineer Regulation
ESA	Endangered Species Act
ft^2	square foot/feet
ft^3	cubic foot/feet
ft-lb/s	foot-pounds per second
ft/s	foot (feet) per second
FPOM	Fish Passage O&M Coordination Team
FPP	Fish Passage Plan
FY	fiscal year (October 1 through September 30)
GQAR	Government Quality Assurance Representative
HECP	Hazardous Energy Control Program
HTRW	Hazardous, Toxic and Radiological Waste
IBC	International Building Code
in.	inch(es)
k_h	horizontal seismic coefficient
kip	1000 pounds
ksf	kips per square foot
lbs/ft^3	pound(s) per cubic foot
lbs/in^3	pound(s) per cubic inch
LFRD	Load and Resistance Factor Design
MCE	maximum credible earthquake
MDE	maximum design earthquake
mph	miles per hour
mps	meters per second
NAD	North American Datum
NAVD	North American Vertical Datum
NAVFAC	Naval Facilities Engineering Command
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
OBE	operating basis earthquake

O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
PDT	Product Delivery Team
PGA	peak ground acceleration
PPE	Personnel Protection Equipment
psf	pounds per square foot
psi	pounds per square inch
QAP	Quality Assurance Plan
RM	river mile
RO	regulating outlet
SA	spectral acceleration
SLOPES	standard local operating procedures for endangered species
THPO	Tribal Historic Preservation Office
TM	Technical Manual
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

1. INTRODUCTION AND PURPOSE

1.1. Scope and Purpose

The Dalles Dam is the second dam upstream from the mouth of the Columbia River. The vast majority of Columbia Basin salmon and steelhead, including seven Endangered Species Act (ESA) listed fish populations, must pass this dam in order to arrive at their spawning grounds. Since 2009, over 1 million adult salmon (estimates range from 1.1 to 1.3 million) have passed through the fish ladders at The Dalles each year. The adult fish passage facilities at The Dalles Dam consist of the north fish ladder and the east fish ladder (Figures 1 and 2). The majority (about 80%) of all adult salmon and steelhead that pass the dam do so via the east fish ladder (3 entrances), with the remaining passing through the north fish ladder (1 entrance). Fish prefer the east ladder because of the presence of a deep, submerged canyon, which is the original river's thalweg, that leads directly to the east fish ladder entrance. However, the north fish ladder is crucial to provide a secondary passage for fish, and allows continuous passage when the eastern ladder is off-line.

The Dalles Dam North Fish Ladder, between weirs No. 77 and 132, is comprised of vertical to near vertical rock cuts to form the fish ladder side walls (Figures 3 through 5). Mechanical weathering over the last 50+ years has caused areas of the steep rock cuts to become unstable creating project life safety and operability concerns. In addition, the open rock joints along the rock faces have allowed brush and trees to establish causing accelerating the destabilization of these rock cuts.

Rock fall issues pose life safety hazards to personnel who enter the ladder during required annual maintenance. A primary reason workers enter the ladder is to inspect the ladder, and to remove vegetation and debris from along the ladder. The only method of vegetation removal allowed requires workers to be in the ladder pulling, cutting, and removing; herbicides are not allowed in the fish ladder. This method of vegetation removal often loosens and dislodges rock that could fall onto workers. In addition, large rock fall could also damage the concrete weirs in the fish ladder, thus affecting the operability of the ladder.

The objective of the project is to successfully stabilize the rock cuts along the North Fish Ladder, specifically between weirs No. 77 to 132. Successful stabilization of these faces will include a combination of scaling, rock anchors/bolts, and small concrete retaining walls between weirs 120 and 123. This project has also considered options for permanent vegetation control along the slope, including utilizing secured tarps or plastic to inhibit plant growth, or covering the entire rock face with shotcrete.

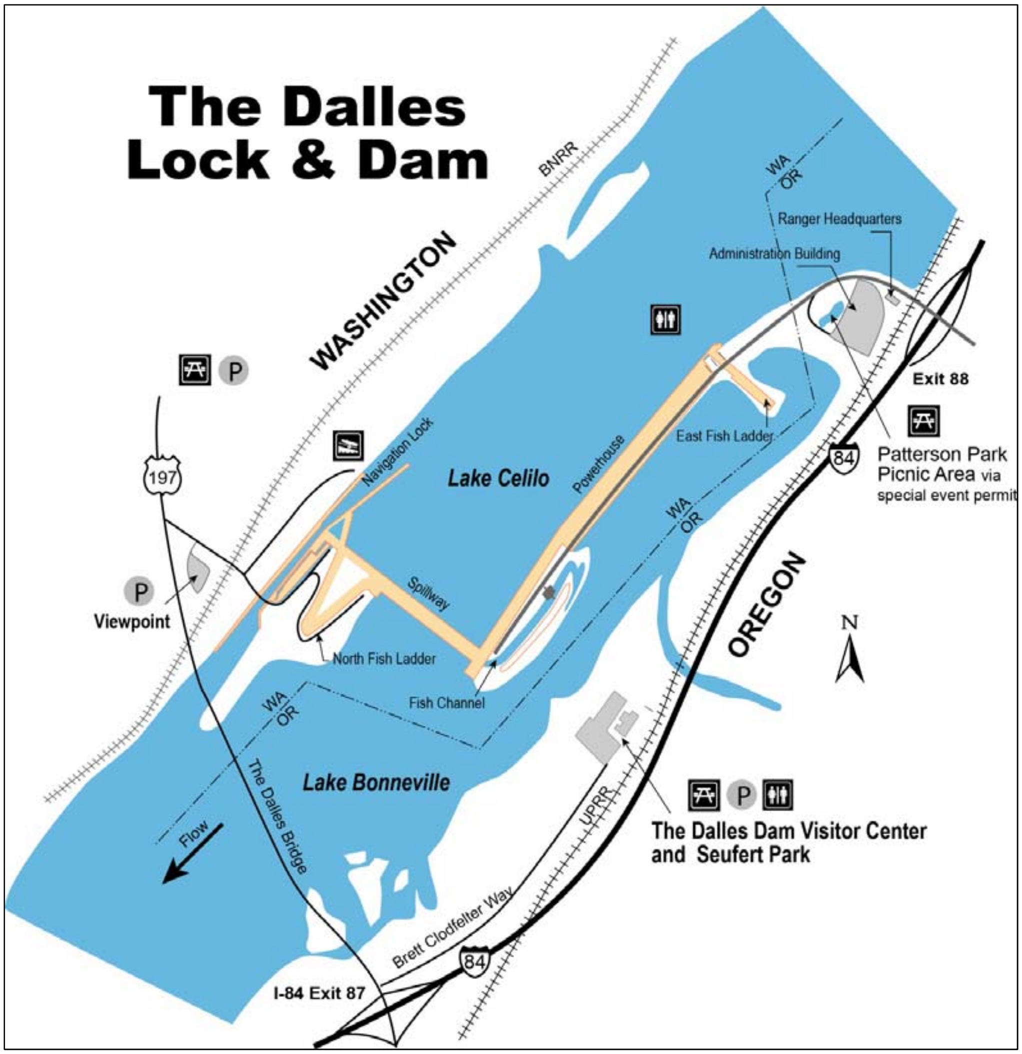


Figure 1 – Site map of The Dalles Lock & Dam

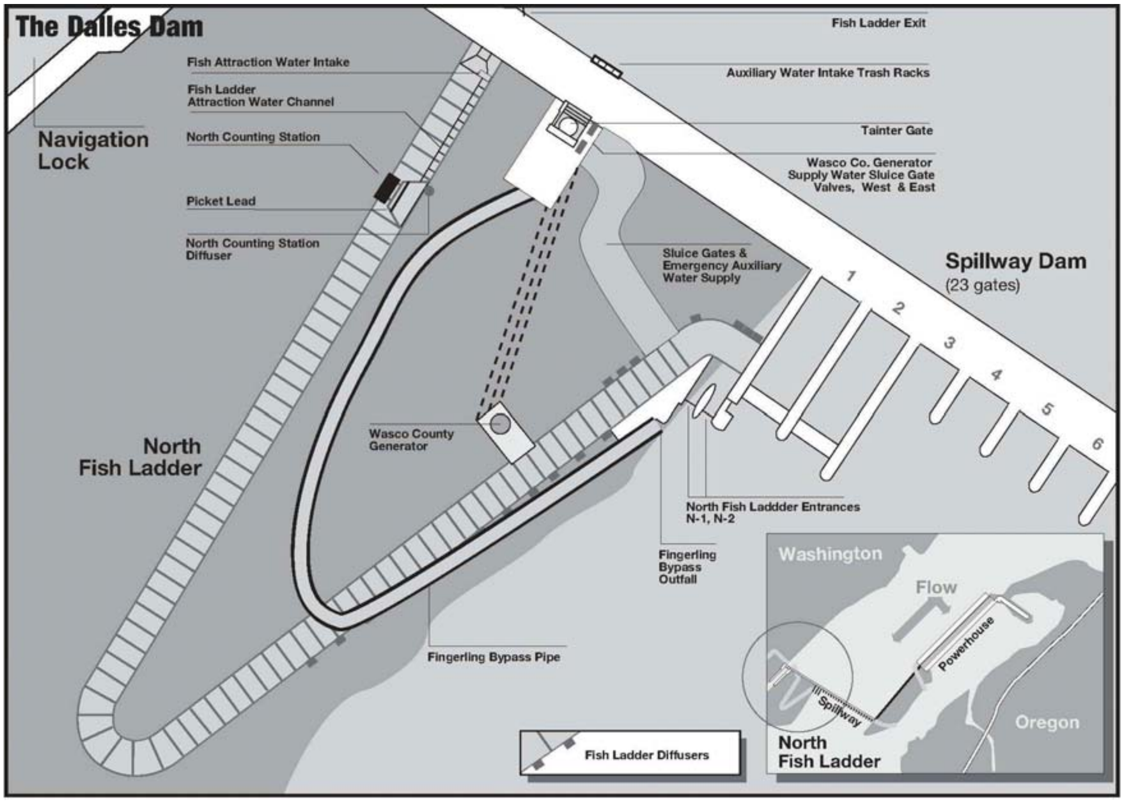


Figure 2 – Site map of the North Fish Ladder

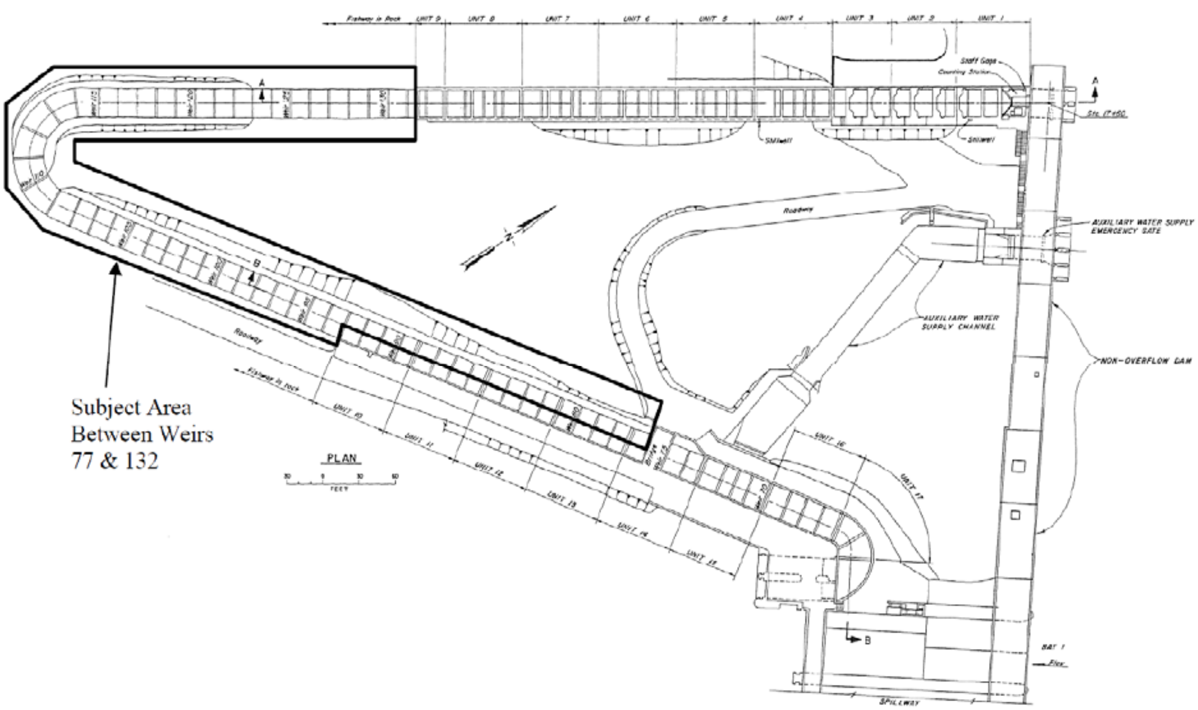


Figure 3 – Plan view of the north fish ladder showing the project area, between weirs No. 77 & 132

1.2. References

USACE, Mar. 1954, Navigation Lock, North Fishway and Non-Overflow Dam Between Lock and Spillway; USACE Portland District, Supplement No. 1 to Design Memorandum (DM) No. 6.

USACE, Jan. 1981, North Fishway Powerhouse and Intake; USACE Portland District, Design Memorandum (DM) No. 25.

USACE, Jan. 1985, The Dalles Lock and Dam, Navigation Lock, North Fishway and Non-Overflow Dam Between Lock and Spillway; USACE Portland District, Supplement No. 2 to Design Memorandum (DM), No. 6. “North Fish Ladder Counting Station and Weir Modification”.

1.3. General Description

The north fish ladder (fishway) system, located between the navigation lock and the spillway, provides a migration route for those adult fish that present themselves at the fishway entrance at the north side of the spillway. The system is composed of an entrance, an auxiliary water supply system, a fish ladder, a counting station and exit water control section at the upper end of the ladder (Figure 2).

1.3.1. Location

The Dalles Dam is located on the Columbia River at the head of Bonneville Lake, 192.5 miles upstream from the mouth of the river and 3 miles east of The Dalles, Oregon. Portland, the largest population and industrial center on the Columbia River, is located 97 river miles below The Dalles Dam. The Oregon-Washington state boundary lies along the main Columbia River channel, dividing the project between the two states (Figure 1). The North Fish Ladder rock stabilization project is in the state of Washington. The North Fish Ladder is located between the navigation lock and spillway dam section (Figure 2).

The North Fish Ladder is 1,761 feet long, 24 feet wide (somewhat wider between weirs No. 77 and 132 due to the variability of the rock cut walls), and has a slope of 1V on 16H. Normal flow in the ladder is 150 cfs which is regulated by a telescoping weir located in the upstream end of the ladder.

1.3.2. History

Construction of the dam was started in February 1952 and the rockfill closure dam was completed in April 1957. The last of the main powerhouse units 1 through 14 began operation in October 1960. Powerhouse units 15 through 22 began operation between December 1972 and October 1973. In the mid. 1980’s, the fish ladder weirs (No. 70 through 151) were modified to reduce flows, and to improve fish passage, and the fishway auxiliary water supply (AWS) system was modified.

On 24 February 2014, an initial site visit was completed by NWP Design and Operations staff to observe and evaluate the rock cut stability issue along the north fish ladder. The results of this site visit, and preliminary recommendations, are presented in a 26 February 2014 Trip Report (Appendix A). This trip report provides a good summary of the rockfall issue, cause, and recommended mitigation options. A Second site visit was also completed in February 2015.

1.3.3. Project Authorization

Construction of The Dalles Lock and Dam was authorized by the Flood Control Act of 1950, in accordance with the Report of the Chief of Engineers in House Document 531, 81st Congress, 2nd Session. The Dalles Lock and Dam were constructed in the 1950's and early 1960's. The first hydroelectric power went on line in September 1957 and this project was dedicated in October of 1959.

1.3.4. Existing North Fish Ladder

Adult fish passage facilities at The Dalles Dam are composed of a north shore fish ladder that passes fish collected at the north end of the spillway, and an east fish ladder that passes fish collected at the south end of the spillway and across the downstream face of the powerhouse.

North Wasco PUD operates a small hydropower facility constructed in 1991 that utilizes the north fishway ladder auxiliary water supply. Adult fishway criteria associated with this facility are monitored and maintained during daily fishway inspections. A backup auxiliary water supply system, unscreened for juveniles, has been upgraded to facilitate its use if required.

The north fish ladder is a minimum of 24 feet wide (slightly wider where rock cuts form side walls) and extends from weir No. 70 to weir No. 153 on a 1 vertical on 16 horizontal slope. The original weirs were 6-foot-high and 16-foot centers, and had a full 24-foot wide crest, with two orifices each (25 inches wide by 26 inches high) flush with ladder floor and centerline and located 3 feet from the outside walls.

In the mid. 1980’s, the fish ladder weirs No. 70 through 151 were modified to reduce flows, and to improve fish passage. Criteria included: a minimum of 80 cfs discharge, normal operating head on weirs at 1 ft.; and minimum orifice size of 18 inches and beveled edges. The weir crest was raised 2 ft. in the center at a length of 18 ft. leaving two 6 ft. long overflow weirs adjacent to the sides of the fish ladder walls. Bevels were included on non-overflow and overflow weirs. Baffles (18 in.) were added upstream to improve flow condition in pools and provide resting areas with lower velocities. The orifice dimensions and locations remained the same.

Two different operations are followed dependent on the species of fish that are travelling upstream (Spring Chinook salmon, Summer Chinook salmon, Fall Chinook salmon, Sockeye, Steelhead, Coho and Lamprey). The two operations that are normally used during the fish passage season include: 113 cfs with 1 ft. of head over the weirs providing plunging flow preferred by salmonids; and 130 cfs with 1.3 ft. (15 inches) of head over the weirs providing streaming flow preferred by shad.

Adult fish count periods and peak passage timing at the Dalles Dam are from April 1st to October 31st. Consequently, annual maintenance of adult facilities is scheduled between December 1st through the end of February (winter maintenance period) to minimize impacts on upstream migrants. Only one ladder at The Dalles Dam (North or East) is dewatered at a time unless otherwise coordinated through Fish Passage O&M Coordination Team (FPOM).

This project is limited to the portion of the fish ladder where the ladder side walls are formed by vertical to near vertical rock cuts, rather than concrete walls, which includes the area between weirs 77 and 132 (Figure 3). From weirs 77 to 92, only the northern wall is rock cut; the southern wall is concrete. In this area of the ladder, reinforced concrete struts support the upper part of the southern concrete wall, and are abutted into the north rock cut (Figure 4). From weirs 92 to 132, both walls are formed in rock cut

(Figure 5). The rock cuts vary in height from approximately 12 feet at the southwestern part of the ladder, to approximately 30 feet at the northernmost part of the ladder.

Figure 4 – Photograph looking north-northeast towards section of fish ladder between weirs No. 77 and 92. Note concrete struts supporting wall to the right of the photo.

Figure 5 – Photograph looking northwest towards the northern section of fish ladder.

1.3.5. Proposed North Fish Ladder Maintenance Work

Because of the age of the excavated channel cuts, all rock faces along the fish ladder are in some need of scaling efforts, but is especially needs at the northern segment of the fish ladder. During rock scaling efforts, existing vegetation along the cuts will also be removed.

In some areas of the fish ladder, again primarily at the northern segment of the ladder, scaling efforts alone may not fully eliminate the risk of future rock fall. Therefore, localized rock anchors (or bolts) will be required to support larger, potentially, unstable rock masses in place. Rock anchors will generally be field located, following initial scaling efforts, to secure rock masses that may be unstable, as determined based on their jointing patterns and occurrence of past rock failures.

Lastly, there are three segments, between weirs No. 120 to No. 123, that have experienced erosion as the result of water flow in the weir. Continued erosion can result in the undermining of the upper rock face, and larger rock failures could occur that could damage the weir structures. In these areas, shotcrete walls are proposed, which will be secured by wire mesh and rock bolts.

The proposed work is generally considered to be maintenance activity. Although, installation of new rock anchors and construction of shotcrete walls are proposed, this work is intended to maintain the stability of the originally designed fish ladder walls, rather than modifying the existing fish ladder structure, or changing ladder performance or operation. The work proposed in this DDR is not intended to permanently stabilize the rock lines fish channel. With time, the exposed rock slopes will continue to weather and future stabilization measures will likely be required. The proposed stabilization work is intended to substantially reduce the rock fall hazards from its current level for at least 20 years.

1.4. AGENCY COORDINATION

Agency coordination is conducted through either Fish Passage Operations and Maintenance (FPOM) or the Fish Facility Design Review Work Group (FFDRWG) regional forum. Members include representatives from the Action Agencies, Federal and State fisheries managers, and Columbia River Inter-Tribal Fish Commission (CRITFC). Agency review will occur during the 90 percent DDR review phase.

1.5. CONSIDERED ALTERNATIVES

In general, the rock cut design along the north fish ladder has performed reasonably well during the past approximately 60 years. Although, there has been periodic rock fall during the ladder's history, only recently has the rock fall been a significant concern. Based on site observations, the more recent increased rock fall risk is primarily the result of weathering of the exposed rock face over time, in conjunction with the presence of vegetation which has loosened rock blocks and fragments, resulting in increase rockfall. This process is the natural consequence the age of the rock cuts, and periodic slope maintenance should be anticipated.

As part of the initial scoping effort for this DDR, several alternatives were considered to help reduce the general risk of rockfall into the ladder. These included: no action, scaling, installation of rock anchors/bolts, installation of rockfall screening, covering unstable rock with shotcrete, and regrading cuts to a flatter and more stable condition.

<u>No Action:</u> Because the rock cuts along the fish ladder has preformed reasonably well during its history, one option would be to do nothing. However, because the rock fall hazard has the potential of impacting life safety, the 'no action' alternative was not selected as a preferred alternative.

<u>Scaling</u>: Scaling the exposed rock cuts is considered the easiest and most cost effective option to reduce the rockfall hazard in the area of the north fish ladder. It is anticipated that once the cuts are scaled, and loose rock removed, the rock cuts will remain generally stable for many years without additional slope stabilization efforts. In addition, vegetation removal can be performed at the same time as scaling efforts. Scaling the slopes is also required prior to performing the other considered alternatives, with the possible exception of regrading the cuts to a flatter condition. Scaling was selected as a preferred alternative because of its relatively low cost and effectiveness.

<u>Rock Anchors/Bolts</u>: Utilizing rock anchors or bolts is commonly used when unstable rock blocks or masses exist that cannot be easily removed. Based on site observations, there are a number of rock

blocks or masses larger than 3 feet diameter that appear to be unstable. If these blocks/masses were to fail, they could damage the weir structures and threaten workers safety. Because of the large size of these blocks, removal (i.e. scaling) would be difficult without damaging the weirs. Therefore, stabilizing these blocks/masses with rock anchors or bolts was selected as a preferred alternative, in conjunction with scaling, to help stabilize the rock cuts.

<u>Installation of Rockfall Screening</u>: Rockfall screening uses a wire mesh with supporting anchors and cables to cover an unstable rock slope, to help protect workers and structures from falling rock. Screening can be designed to help support rock block in-place, but is mostly used to slow the downward momentum of failed rock and retain failed material. Although rockfall screening would reduce the rockfall risk, screening is expensive, and requires periodic maintenance to remove accumulated rock and repair damaged screened sections. The presence of the screening may also reduce the ability of workers to effectively clear vegetation, and could increase vegetation growth, since accumulated material behind the meshing tends to promote plant growth. Because of the high installation cost and maintenance requirements, rockfall screening was not selected as a preferred alternative.

<u>Covering Slopes with Shotcrete (not to be confused with the proposed shotcrete walls between weirs 120 and 123)</u>: Coving the unstable slopes with shotcrete would both mitigate for future rockfall hazards and help control vegetation along the cuts. However, simply applying shotcrete to the slope would not be a long term solution since the shotcrete adhesions to the rock surface would reduce with time, resulting in spalling and failure of the shotcrete itself. Therefore, an effectively shotcrete design would include using a wire mesh reinforcement and rock anchors to secure and support the shotcrete facing to the slope. In addition, drainage behind the shotcrete would likely be required to prevent pore pressure buildup. The cost associated with facing the rock cuts with shotcrete is high, would significantly alter the design of the fish ladder channel, and is beyond the scope and authorization of this project. Therefore, covering the slopes with shotcrete was not considered a preferred alternative.

<u>Regrading the Rock Slopes</u>: Regrading the rock slopes to a flatter, more stable, condition would help eliminate the rock fall hazard. However, regrading the slopes would significantly impact other structures and roads adjacent to the fish ladder, would significantly alter the original design of the fish ladder channel, and is outside the authorization of this project. Therefore, regrading the rock slopes to a flatter condition was not considered a preferred alternative.

Three alternatives were considered for the rock cut sections between weirs 120 and 123, which are experiencing erosion and undercutting as the result of water flow in the fish ladder. These alternatives included: No action, construction of a shotcrete wall with anchors, and construction of a cast-in-place concrete wall with anchors.

<u>No Action:</u> Water flow in the fish ladder has cause significant erosion and undercutting along a bedding plane between weirs 120 and 123. This erosion has caused undercutting of several feet in one location, which threatens to cause failure of the overlying rock face, which can damage the weir. Because of the fractured nature of the rock above the eroded section, it was determined that installing rock anchors alone would not protect the weirs from future rock failure. Because of the rock fall threat to the weirs, the ‘no action’ alternative was not selected as a preferred alternative.

Shotcrete Wall with Anchors: Shotcrete is mortar or concrete conveyed through a hose and pneumatically projected at high velocity onto a surface. The force of the jet impinging on the surface compacts the material. Properly applied shotcrete is a structurally sound and durable construction material which exhibits excellent bonding characteristics to existing concrete, rock, steel, and many other materials. It can have high strength, low absorption, good resistance to weathering, and resistance to some forms of chemical attack. Many of the physical properties of sound shotcrete are comparable or superior to those of conventional concrete or mortar having the same composition. Shotcrete walls are typically reinforced with wire mess and/or rebar, and secured to the rock face by anchors or bolts. Shotcrete walls are generally cost effective and more easily constructed in confined spaces, or where irregular rock surfaces are present. Because of the easy of construction, and lower construction costs, the use of shotcrete walls was selected as a preferred alternative.

Cast-in-place Concrete Wall with Anchors: A conventional cast-in-place concrete wall could be selected as a permanent wall in front of the rock face. However, the use of shotcrete is advantageous in situations when formwork is cost prohibitive or impractical and where forms can be reduced or eliminated, access to the work area is difficult, thin layers or variable thicknesses are required, or normal casting techniques cannot be employed. Additional savings are possible because shotcrete requires only a small, portable plant for manufacture and placement. Shotcreting operations can often be accomplished in areas of limited access to make repairs to structures. Therefore, the use of a conventional cast-in-place concrete wall was not selected as a preferred alternative.

2. BIOLOGICAL CONSIDERATIONS AND CRITERIA

2.1. General

2.1.1. Pertinent Data

Adult fish passage facilities at the Dalles Dam consist of a north and east fish ladder. The adult passage facilities are operated year-round with the majority of the fish passage occurring from April 1st through October 31st. Annual maintenance on the adult passage facilities is scheduled from December 1st through February 28th (winter maintenance period). During the winter maintenance period, only one of the adult passage facilities (north or east ladder) is taken out-of-service at a time, allowing continued adult passage during the maintenance period (USACE, 2015).

2.1.2. Purpose

This section lists the biological criteria for the north ladder rock stabilization project at The Dalles Dam. Guidelines for the design of fishways is provided by the National Marine Fisheries Service (NMFS). As stated by NMFS (2011):

> *The purpose of a fish ladder is to convert the total project head at the passage impediment into passable increments, and to provide suitable conditions for fish to hold, rest, and ultimately pass upstream. The criteria provided in this section have been developed to provide conditions to pass all anadromous salmonid species upstream with minimal delay and injury.*

2.1.3. Fish Species of Concern

The adult passage facilities at The Dalles Dam has the following species passing throughout the year: spring, summer, fall Chinook salmon (Oncorhynchus tshawytscha), sockeye (Oncorhynchus nerka), steelhead (Oncorhynchus mykiss), coho (Oncorhynchus kisutch), and Pacific lamprey (Entosphenus tridentatus).

The morphology and swimming abilities of salmonids and lamprey are very different and need to be considered when making modifications to the ladder. Salmonids are known to be strong swimmers, for example adult Chinook salmon passing a Columbia River dam had swimming speeds ranging from 80 to 106 cm/s (Brown et al., 2006). Conversely, Pacific lamprey are relative weak swimmers (sustained swimming of 10-30 cm/s), but are able to employ a “burst and attach” behavior to navigate high-velocity and high-turbulence environments (Keefer et al., 2013; Robinson and Bayer 2005). Examples of higher velocity features found in fishways include entrance weirs, overflow weir crests, and submerged orifices. At these locations, lamprey attach to the substrate and either inch forward using their sucker-like mouths or periodically burst forward, resting in between forward bouts. Based on telemetry study results, the north fish ladder passes about 38% of the total lamprey passing The Dalles Dam, however, lamprey passage efficiency through the overflow weir section of the north ladder is very high (>90%) compared to other fishway segments at The Dalles Dam (Keefer et al. 2013). This is thought to be partially because of the rock wall creating a more natural migration route for lamprey due to the structural heterogeneity of the unique basalt rock walls and the hydraulic conditions they create on a micro scale (Sean Tackley, personal communication). As such, creating a more uniform surface along the fishway walls could potentially negatively affect lamprey passage conditions in the ladder.

2.1.4. Water Temperature Considerations

As temperatures in adult passage facilities reach 70°F, then all fish handling activities must be coordinated with regional fisheries managers.

2.2. Biological Criteria and Passage Criteria

Modifications (e.g., shotcrete, fencing, or tarps) made below the water line in the fishway must not negatively impact fish passage and consideration must be made not only to salmonids but also to lamprey and shad. Potential negative effects could include noise and vibration from tarps flapping in the wind, texture of shotcrete and the filling of fractures in the rock wall, and microscale changes in the hydrology.

Shotcrete placed below the waterline will be finished to ensure smooth surfaces with protrusions not exceeding more that ⅛". The color of the shotcrete will match the existing concrete in the fish ladder as closely as possible.

2.3. References

Brown, R.S., D.R. Geist, M.G. Mesa. Use of electromyogram telemetry to assess swimming activity of adult spring Chinook salmon migrating past a Columbia River Dam. Transactions of the American Fisheries Society, 135:2, 281-287.

Keefer, M.L., T. C. Clabough, M. A. Jepson, E. L. Johnson, C. T. Boggs, and C. C. Caudill. 2013. Adult Pacific Lamprey passage: Data synthesis and fishway improvement prioritization tools. Report to U.S. Army Corps of Engineers, Portland District, Portland, Oregon.

NMFS (National Marine Fisheries Service). 2008. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.

Robinson, T. C., and J. M. Bayer. 2005. Upstream migration of Pacific lampreys in the John Day River, Oregon: behavior, timing, and habitat use. Northwest Science 79:106-119.

USACE (U. S. Army Corps of Engineers). 2015. 2015 Fish Passage Plan. USACE, Portland District, Portland, Oregon.

3. GEOTECHNICAL DESIGN

3.1. GENERAL

This chapter describes expected provides preliminary geologic and geotechnical design parameters for The Dalles North Fish Ladder rock stabilization project. The information and recommendations presented in this chapter are based on existing references and a brief field visits. Additional information gained through more detailed site observations and measurements, including measurements of joint orientations, is needed and recommended to confirm assumptions and provide a basis for geotechnical design prior to development of plans and specifications.

3.2. REFERENCES

a. Tolan, T. L., and Reidel, S. P., 1989, Structural map of a portion of the Columbia River flood-basalt province; The Geological Society of America, Special Paper 239.

b. USACE, Apr. 1956, Foundation Report, The Dalles Dam – Part I: Introduction and Spillway; USACE Portland District.

c. EM 1110-1-2907 Rock Reinforcement

d. EM 1110-1-2908 Rock Foundations

3.3. GEOLOGY

The Dalles Dam is located on the western margin of the Columbia Basin where it abuts the Cascade Range. The Columbia basin is filled with up to about a maximum of 5,000 feet of Miocene age Columbia River Basalt Group (CRBG). The Columbia River Basalt Group consists of flood-basalts which were erupted from fissures in eastern Oregon and Washington and western Idaho from approximately 16.5 to 6 million years ago. The bedrock exposed along the bottom and side walls of the fish ladder is likely the Wanapum Basalt Member of the CRBG, approximately 15 to 14.5 million years old.

In the vicinity of the dam, the formation is about 3,000 feet thick, and consists of multiple flow-on-flow layers with little or no intervening soil horizons between flows (Figure 6). Individual flows range between 60 to 100 feet thick. In the area of the north fish ladder, 5 distinct flows have been mapped (Figures 6 and 7). These flows have been designated as flows N, O, P-1, P, and Q (from bottom to top). The flows generally dip to the southwest at about 2 degrees. Steeper dips, and a few reverse dips, occur adjacent to fault; these steeper dips are not found in the area of the north fish ladder.

Many of the jointing patterns and textures of the flows were developed during the cooling process. The top surface of some flows may have a smooth or ropy characteristic if the molten material stopped flowing before the top surface cools and solidifies. If the top surface solidifies while the interior was still molten and moving, the top surface may have been disrupted or fragmented forming a flow breccia crust. Flow breccia is generally lower strength rock quality. At The Dalles, flow breccias are a small

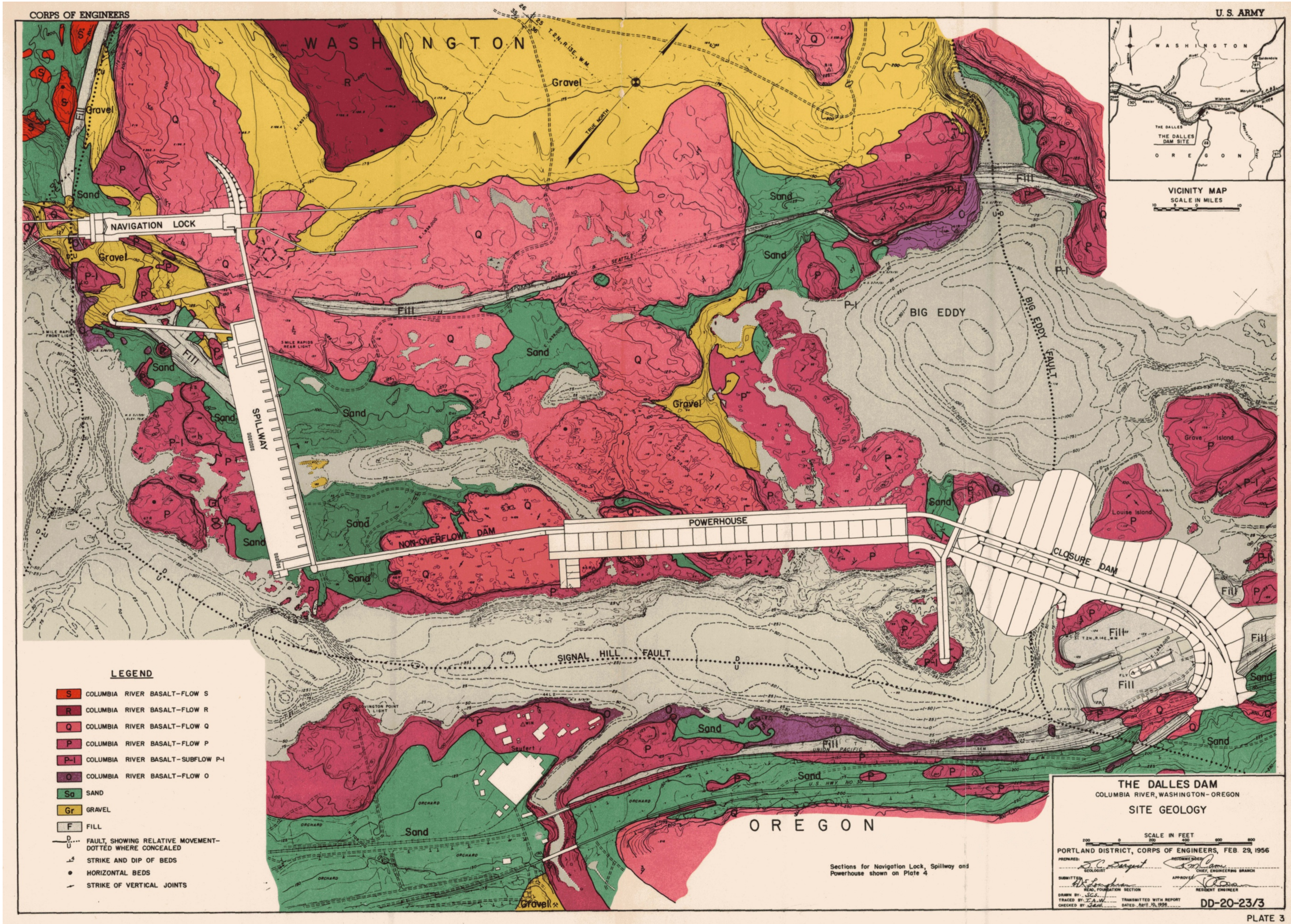


Figure 6 – Site geology map from Sheet DD-20-23/3.

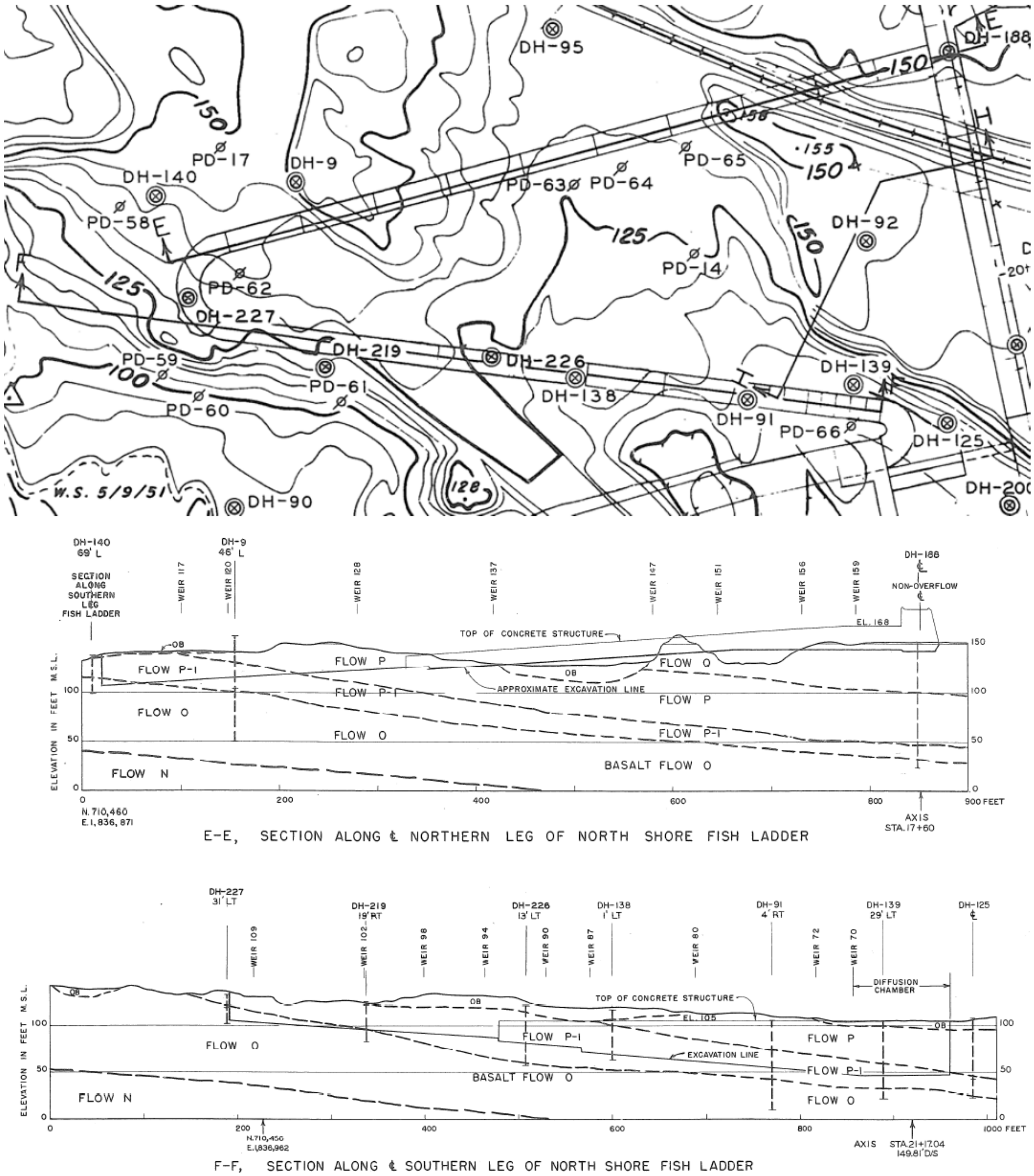


Figure 7 – Boring location map (above) and geologic sections (below). Drawings from parts of Sheet DDG-1-9-6/1 and Sheet DDG-1-9-6/7. Topographic contours show topography prior to dam construction. Approximate excavation line of fish ladder shown in the section.

percentage of the total rock mass and they generally were removed when exposed in the foundation. The interior of the flows typically form a more dense rock. However, tree casts voids or open lava tube can be found in isolated areas.

3.3.1. Joints and Fractures

The Columbia River Basalt developed a common set of characteristic patterns of fractures and distribution of vesicles (bubbles) in flows as it cools. A single flow may be comprised of one or more subflows, where more fluid molten lava overran a partially cooled and solidified lobe. As the molten lava cooled, gas bubbles tend to form and the bubbles rose and concentrate towards the top, forming a 5 to 15 foot vesicular zone that is typically more porous and weaker than the underlying rock. In addition, the cooling and solidifying rock mass thermally contracts and tension fractures. These cooling fractures tend to form coherent patterns in the large mass or flow.

A molten lava flow cools from both the top and bottom towards the center, which is the last to solidify. Typically, the top of a flow has two types of fractures. First, there are vertical fractures spaced 1 to 6 feet apart. These fractures are randomly oriented and form crude polygonal columns, and are typically wavy.

In addition to the vertical fractures, there may be horizontal fractures that form 6-inch to 2-foot thick slabs parallel to the top of the flow. There may be 0 to 3 inch voids beneath the slabs. With increasing depth below the top of a flow, intensity of fracturing decreases. The horizontal fracture spacing increases to 4 to 8 foot spacing and the fracture surfaces become more wavy and tighter. Also, there are generally no large voids present below the horizontal fractures. At greater depths within the flow, fractures may begin to form more organized columnar fracture patterns or curvilinear patterns. Vertical fractures continue from the top and bottom cooling zones. The center of a flow is the densest with the widest fracture spacing. The center may be columnar or equi-dimensional blocks measuring 3 to 8 feet across. Near the base of each flow, cooling fractures become more closely spaced sub-horizontal/horizontal due to rapid cooling at the bottom contact. Occasionally, there may be a little flowage at a late stage which will crack and form fissures up to about one foot wide and feet long. These may be filled with later secondary minerals or may remain open.

3.3.2. Faults and Structures

Locally, the CRBG is deformed into a smaller structural sub-basin about 10 miles wide. The northern edge is bounded by the Columbia Hills anticline/fault which has folded and faulted the basalt (Figure 8). The main fault passes about four miles north of the dam and has on the order of 1,500 feet of displacement. The age of faulting is mostly Miocene through Pliocene, but more resent faulting may have occurred. The Columbia Hills anticline/fault is segmented by a series of northwest trending strike-slip faults.

Three primary faults have been mapped in the immediate vicinity of the site; the Big Eddy fault, the Threemiles fault, and the Signal Hills fault (Figure 9). These faults have offsets of fifty to three hundred feet. Minor faults were also found in the foundation excavations of every structure. These minor faults generally had offsets of only a few inches, and were related to low angle thrusts.

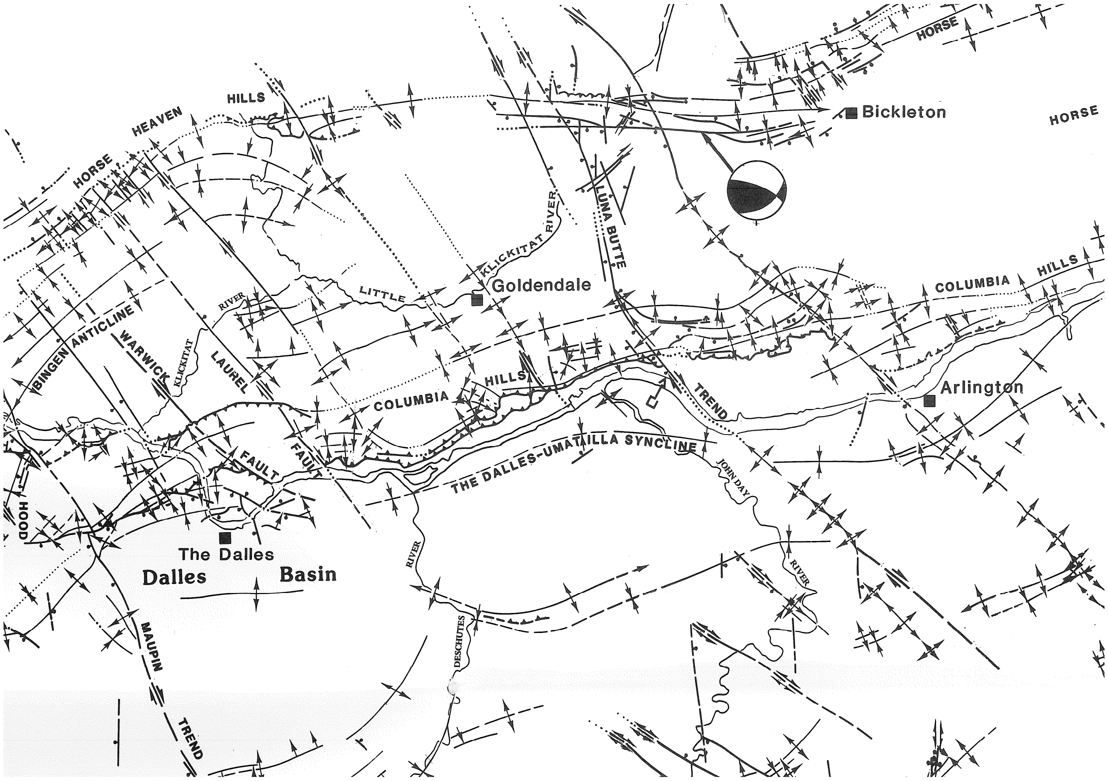


Figure 8 – Regional structural map. From Tolan and Reidel (1989).

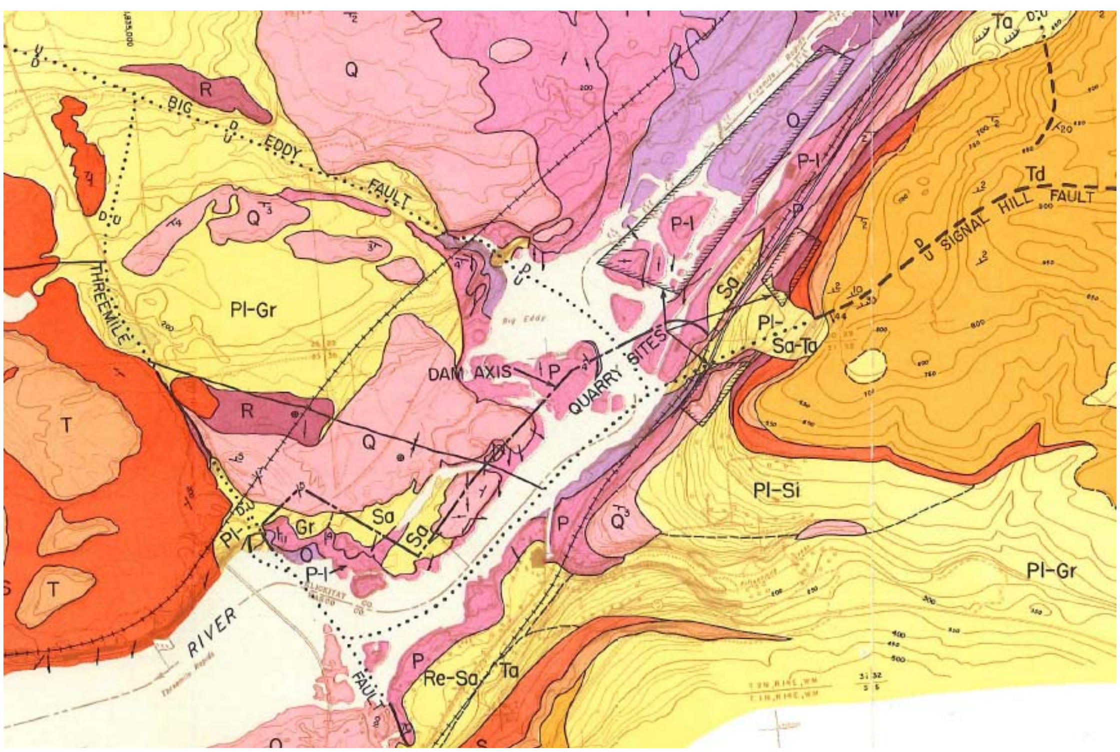


Figure 9 – Geologic Map showing faults in the vicinity of the dam site. Map from part of Sheet DD-20-23/1.

3.4. GROUNDWATER CONDITIONS

Ground water in the basalt is likely obtained primarily from interflow zones, with internal fractures and joints being a secondary source. Interflow zones are generally much more fractured/jointed than the central parts of the flows, and may have minor sedimentary beds which can be sources for groundwater. Interflow paleosols can act as confining layers causing localized water bearing units. The relatively high permeability of the interflow zones can provide high flow rates. However, because the interior of the flows tend to be denser than the interflow zones, vertical permeability of the rock tends to be much lower, which can reduce the recharge rate to the rock unit and the vertical movement of groundwater between individual flows. This variation in permeability can cause some zones within the aquifer to behave in a confined to semi-confined manner.

In the subject area, the top of the main groundwater aquifer is believed to be at or within several feet above the tailwater elevation. During stormy weather conditions, the groundwater table can locally rise, possibly by several feet or more. In additional, perched groundwater is more likely during rainy weather.

When water is actively flowing through the fish ladder, the groundwater likely rises in the basalt immediately near the fish ladder, as the result of water recharge from the ladder. When water flow in the ladder is stopped, the groundwater table in the basalt lowers, but likely takes several hours to several days before achieving equilibrium. At the time of the February 2014 and 2015 site visits, water seepage was observed emanating from rock joints along the ladder side wall cuts; about 8 to 12 feet above the bottom of the latter.

3.5. PROJECT ENGINEERING GEOLOGY

3.5.1. Discontinuities

The term discontinuity refers to any mechanical "break" in a rock mass having zero or reduced tensile strength relative to the surrounding intact rock. It is a collective term that includes joints, bedding planes, folds, shear zones and faults. In general, most of the rock fragments and blocks that are causing the stability concern along the ladder, have been formed by the presence of the rock discontinuities.

As part of the early 1980's modification of the north shore fishway auxiliary water supply (AWS) system, mapping of fractures and joints were completed in the area of the AWS channel to determine the predominant joint orientations. The water supply channel is located in the area of the North Fish Ladder (Figure 10). Because the modified channel was cut in the same lava flows as the north fish ladder (Flows P and Q), the measured joint orientations are believed to be similar to that found in the ladder.

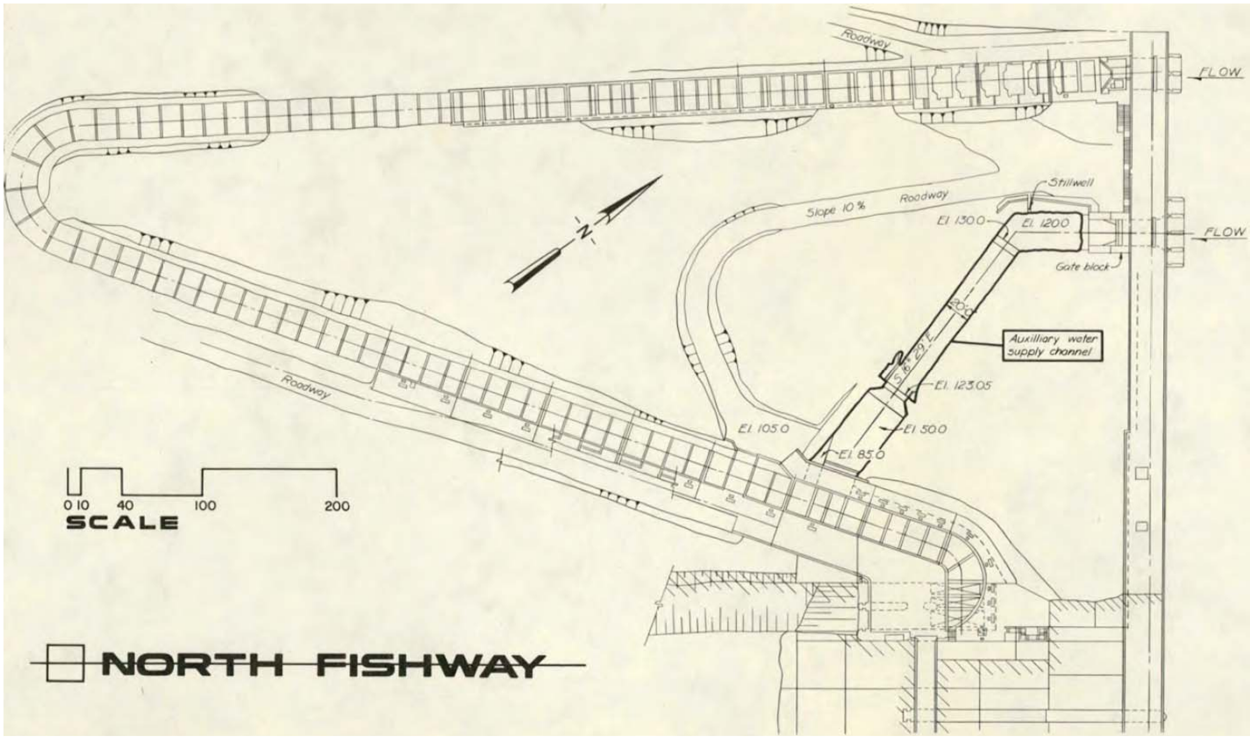


Figure 10 – Site plan shows the locations of the Auxiliary Water Supply channel relative to the north fish ladder. From DM-25 (part of Sheet DD-20-41/1).

Fracturing in the basalt rock exposed in the north fish ladder and AWS channel generally consist of widely spaced primary fractures (cooling joints) and close to moderately spaced secondary fracture which bisect the blocks formed by the primary fractures. The fractures are tight to slightly open and often curve away from the vertical toward the bottom of a flows. Based on mapping completed in the AWS channel, fracture surfaces are generally smooth, and are typically stained with iron oxide or coated with an altered secondary mineral. Average fracture spacing ranged from 0.7 feet to 1.6 feet with an overall average spacing of about 1 foot. However, intact blocks or boulders which have weathered from the exposed rock cut faces in the fish ladder are commonly greater than 2 feet diameter, and can be up to 6 feet in diameter (Figure 11).

In addition, an average fracture frequency of 1.7 fractures per foot was obtained from three core borings completed in the AWS area. Rock quality designation (RQD) was determined for the full depth of rock penetrated by these borings, which indicated that the rock quality was fair to good, with a range of 75 to 90% recovery.

Figure 11 – Photograph looking south towards the southern fish ladder rock cut near weir 130. Rock blocks up to 6 feet in diameter have weathered out of the cut face in this area.

During the AWS channel work, field measurements were made on a total of 152 fractures at four outcrop locations. The data was plotted on a Schmidt equal area stereo net and contoured (Figure 12). The plot of polar density contours indicate a roughly vertical (80 to 90 degrees) joint dominance. The strike of the joints is generally variable, but indicates a strike preference of about N84°W and N53°E. An approximately horizontal joint set is also present, which most often occurs in the upper portion of the flows. The primary joint sets are provided in Table 1.

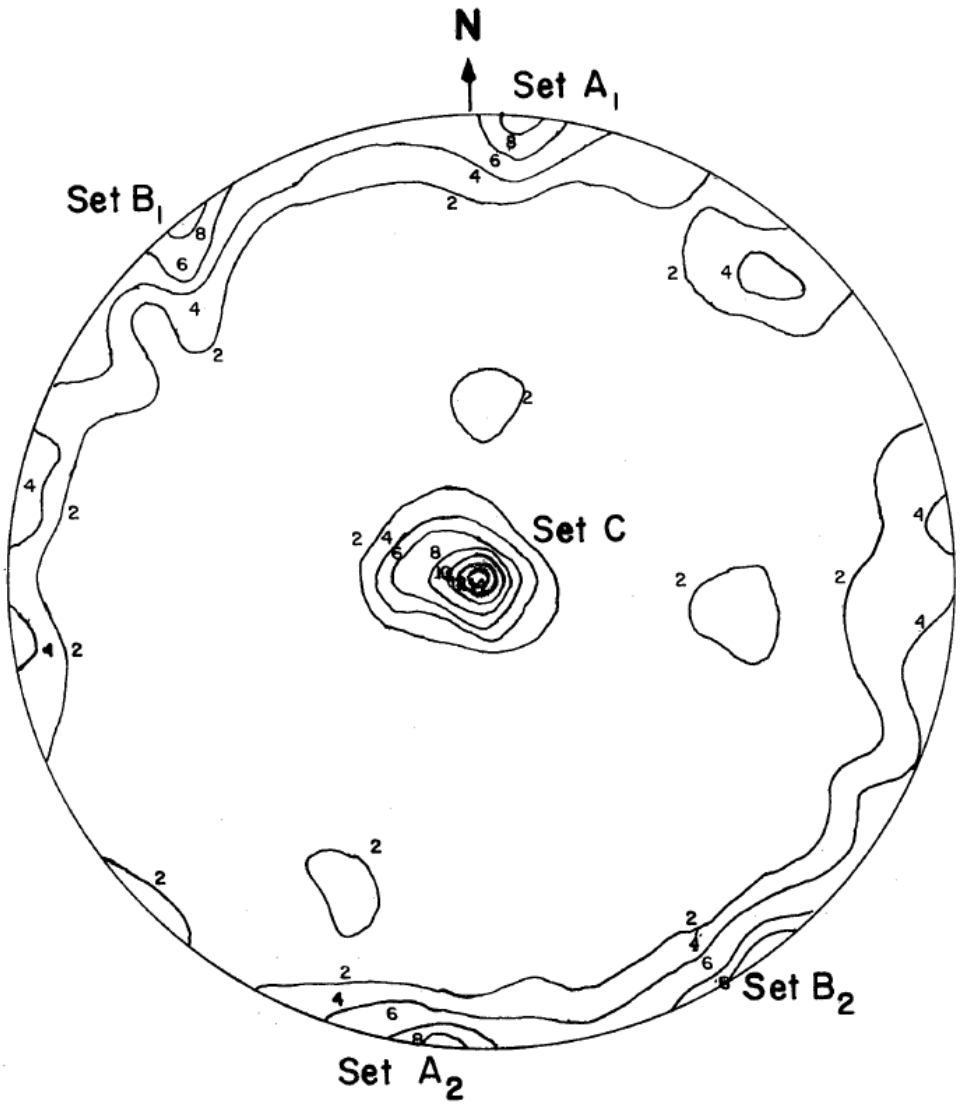


Figure 12 – Polar plot of 152 fracture orientations completed in the auxiliary water supply channel adjacent to the North Fish Ladder. Plot from DM No. 25.

Table 1 – Joint Set Orientations

Joint Set	Strike	Dip
A_1	N84°W	80°SW
A_2	N84°W	84°NE
B_1	N53°E	80°SE
B_2	N53°E	84°NW
C	N10°E	15°SE

3.5.2. Failure Type and Kinematic Analyses

Based on site observations of the north fish ladder slopes, the primary block failure types are wedge to planar-wedge (Figure 13). Both types of failures are primarily controlled by the orientation and the spacing of the discontinuities with respect to the slope face. There are also indications of the occurrence of toppling type failures in some locations, where columns of rock, formed by steeply dipping discontinuities in the rock, rotates about a fixed point causing rock fall. In general, the fragments and blocks that fail are a few inches to a few feet diameter. However, large failures are possible, which can mobilize blocks up to 6 feet diameter (Figure 11)

Figure 13 – Photograph looking west towards the northern part of the fish ladder, showing recent rock fall.

Kinematic analysis is a method used to analyze the potential for the various modes of rock slope failures (plane, wedge, toppling failures), that occur due to the presence of unfavorably oriented discontinuities. Kinematic analysis can be used to assess the likelihood of rock failures, and to assist in design to mitigate for future failures. The stability of the existing rock cuts was analyzed using the fracture/joint orientation data obtained from the 1981 North Fishway Powerhouse and Intake Design Memorandum No. 25. Although a total of 152 fracture orientations were measured for the 1981 study, only the 5 primary average joint set originations were provided in the DM (Table 1); the actual measured orientations were not provided, but a contour polar plot is available (Figure 12).

The fish ladder cuts generally strike in two directions, (1) N33°E along the northern ladder section, and (2) N56°E along the southern ladder section. The cuts along the west bend of the fish ladder are variable. Although the side wall cuts vary, they generally slope into the channel at about 80 degrees, but can be near vertical.

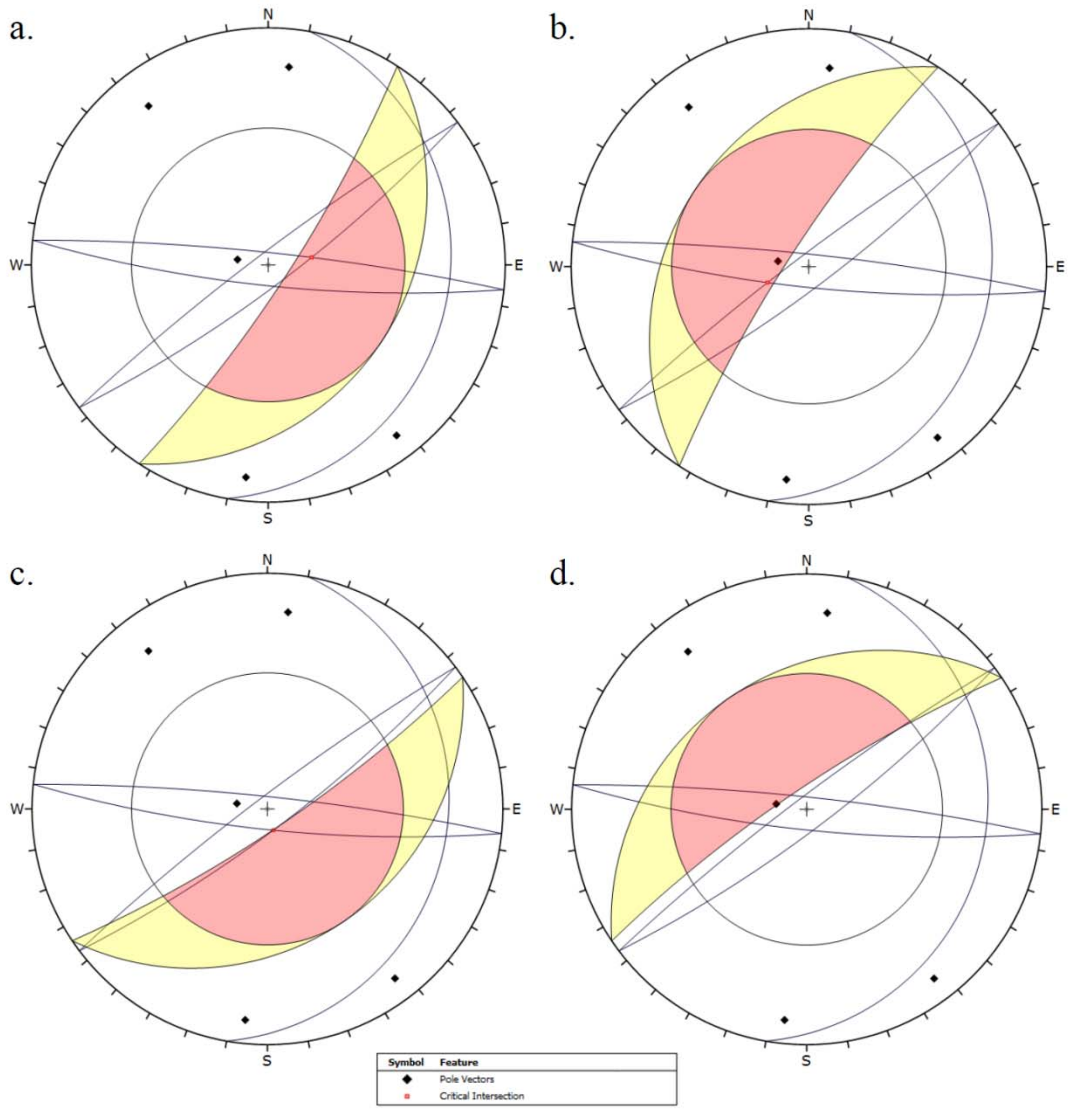


Figure 14 – Stereographic plots showing requirements for wedge failures for the north (a, b) and south (c, d) fish ladder sections. Joint intersections within the red shaded areas indicate that wedge failures are possible. Central circle represents an assumed joint fiction angle of 30 degrees.

3.6. ROCK DESIGN PARAMETERS

During the early 1980's geologic and geotechnical investigation for the auxiliary water supply (AWS) channel, five representative core samples of basalt collected from Flows P-1 and O were tested for various physical parameters, including unit weight, unconfined compressive strength, Poisson's ratio and modulus of elasticity (Table 2).

Table 2 - Report of Tests on Basalt Cores

Core No.	Description	Depth (ft.)	Unit Weight (pcf)	Modulus of Elasticity (psi) x 10^6	Poisson's Ratio	Compressive Strength (psi)
1	Dense Basalt	68.5-69.4	173.5	8.54	0.218	25,700
2	Vesicular Basalt	74.1-75.5	158.5	7.26	0.223	12,790
3			160.4	8.28	0.259	7,180
4			156.0	6.32	0.198	10,330
5		78.3-79.5	158.5	3.24	0.227	6,260
6			155.4	5.82	0.191	8,960
7	Slightly Vesicular Basalt	82.7-84.1	167.2	6.23	0.205	9,200
7A			168.5	6.52	0.238	19,700
8			168.5	7.54	0.207	19,500
9		88.5-89.8	168.5	7.33	0.174	23,200
10			169.1	7.55	0.196	25,010
Average			164.0	6.78	0.212	15,260

In addition to the laboratory test values, DM No. 25 provided the following bedrock properties:

Point Load Index
 Range: 288-1661 psi (6912-39,864 psi unconfined compressive strength)
 Average: 1042 psi (25,000 psi unconfined compressive strength)
RQD: Fair to Excellent (Average = 71.87 = Fair)
Fracture Frequency: 1.7 fractures/ft. (from boreholes)
Fracture Spacing: 0.l ft. to 4.8 ft. (Average = 1.2 ft.)

3.7. Rock Slope Stabilization Methods

To stabilize the rock slopes along the north fish ladder channel, three preferred rock slope stabilization methods were selected; (1) rock slope scaling, (2) use of rock anchors and dowels to support isolated rock blocks or masses, and (3) construction of shotcrete walls with supporting anchors to protect eroding rock surface from flowing water in the channel. These methods are further discussed below.

3.8. Rock Slope Scaling

Rock scaling is generally defined as the removal of loose rock from slopes. This process is commonly accomplished by removing loose surface rock material using pry-bars, picks, or similar hand held tools. Where large sections of rock, or large boulders, require removal, a variety of techniques can be utilized including winching, air bags/pillows, and power tools. Removal of trees and other vegetation is commonly included in the scaling process. Temporary rockfall protection measures are often used in the rock scaling and rock removal process. In the area of the north fish ladder, the concrete fish ladder weirs can be damaged as the result of rockfall.

For the 90% DDR design, it is anticipated that significant scaling will be required for about 8,500 sf of rock cut (primarily at the northern section of the ladder), moderate scaling will be required for about 10,000 sf of rock cut, and minor scaling will be required for about 3,500 sf of rock cut. The total cubic yardage of material scaled is estimated at about 220 cy.

3.9. ROCK ANCHORS AND DOWELS

A rock anchor, or rock bolt, is a tensioned reinforcement element consisting of a rock, a mechanical or grouted anchorage, and a plate and nut for tensioning or for retaining tension applied by direct pull or by torquing.

A rock dowel is an untensioned reinforcement element consisting of a rock embedded in a mortar or grout filled hole. Once installed, stress is developed passively in the element as rock movements take place. Although the installation of tensioned fully grouted elements is preferred for rock reinforcement, some conditions may make desirable the installation of fully grouted untensioned elements (such as rock dowels). In the north fish ladder, rock dowels are preferred for those areas below the water line, where fish can be present. Because rock dowel do not require a plate and nut to pre-tension, the dowel can be installed completely in the rock, with no elements extending beyond the face of the rock, which can impact water flow and/or be a hazard to fish.

3.9.1. Rock Reinforcement Design

The analytical methods used for assessing the stability of rock cuts and slopes are direct developments from structural analysis and applied mechanics. Their complexity ranges from the simple case of a block sliding on a surface of known frictional resistance to highly complex finite element solutions that include the effects of slippage along discontinuities and fracture of rock blocks. The analysis of the stability of a rock structure requires the behavior of the structure to be stated in terms of its geometry, the load deformation characteristics of its materials, the virgin in situ stresses, the geological characteristics of the rock, and the conditions induced by the excavation. Such statements may range from a simple case, such as a rock block on the surface under gravity load, to the highly indeterminate conditions associated with intersections of underground openings. Because the main hazard along the north fish ladder is related to individual rock fall blocks, the more simple case of rock block stability under gravity loading was considered.

For preliminary design, there are a number of empirical guidelines for rock reinforcement design. EM 1110-1-2907 provides guidance for minimum length and maximum spacing for rock reinforcement, as summarized in Table 3.

Table 3 – Minimum Length and Maximum Spacing of Rock Reinforcement (per EM 1110-1-2907)

Parameter	Empirical Rules
Minimum Length	Greatest of: a. Two times the bolt spacing b. Three times the width of the critical and potentially unstable rock block
Maximum Spacing	Least of: a. ½ the bolt length

	b. 1-½ the width of the critical and potentially unstable rock block c. 6 ft.
*Greater spacing than 6 feet would make attachment of surface treatment, such as chain link fabric, difficult.	

The design and analysis of anchor systems include determination of anchor loads, spacing, depth, and bonding of the anchor. Safety factors are determined by considering failures within the rock mass, between the rock and grout/anchor, and yield of the anchor.

For those anchors supporting unstable rock masses, the load on each anchor will be dependent on the mass of the rock mass being supported, minus the resistance forces applied along the joint surfaces. Factors which contribute to this include, (1) the irregularities of joints are nominal, (2) the resistance force against sliding along joints is low, (3) the angle the joints make with the surface of the excavation is small, and (4) the force of gravity tends to induce motion of the block. Blocks present along the roof of an excavation may be entirely free to fall, but blocks along a wall would likely have to slide or rotate along the joints at its sides and base before fallout could occur.

It is anticipated that only isolated rock anchors/bolts will be needed to secure discrete unstable blocks or rock masses. The use of a gridded rock bolt patter, with pre-defined 'maximum' spacings, is not proposed. For larger rock masses, 2 to more anchors may be required to adequately support the mass.

The depth of a single anchor in competent rock, containing few joints, may be computed by considering the shear strength of the rock mobilizing around the surface area of a circular cone within an apex angle; an apex angle of 90 degrees may be assumed for preliminary design, per EM 1110-1-2908. However, for a single anchor in fractured rock, the strength of the rock mass cannot typically be relied upon to provide the necessary resistance, and the strength of the material is more like a granular soil than competent rock. In general, the rock behind unstable rock blocks or masses to be secured along the fish ladder channel is considered competent rock, and therefore the shear strength of the rock, beyond the unstable block or mass, may be assumed. For preliminary design, in areas of the fish ladder where rock anchors are necessary, the unstable rock masses should be assumed to extend back from the rock face a minimum of 3 feet, to a maximum of 6 feet. The depth of the anchor beyond this point should be determined based on the shear strength of the competent rock. For the shotcrete wall designs, the rock within 3 feet of the shotcrete wall facing should be considered non-competent rock, and should be considered to have zero resisting forces.

For preliminary design, rock anchor lengths should be designed assuming three times the potential unstable rock block/mass size. Because the large rock blocks at the site typically range from 3 to 6 feet in diameter, the rock anchor lengths would vary from 9 to 18 feet long. Because unstable rock blocks smaller than about 3 feet diameter would likely be safely scaled without damaging the weir structures (using shielding), securing rock blocks smaller than 3 feet diameter is not currently proposed.

The anchors should be grouted to their full length. If mechanical anchors are used to initially seat the anchor, the seated anchor should be then grouted in place. The bond length that defines the anchor socket shall be determined by the required resisting forces. It should be assumed that the potential failure surface within the supporting competent rock will initiate at the midpoint of the grouted socket.

For the 90% DDR design, it is anticipated that 100 rock anchors will be required, installed at average depths of 12 feet. An additional 24 anchors will be needed for the shotcrete walls, as detailed in Section 5 (Structural Design).

3.10. Retaining Structures

Although much of the fish ladder rock cuts are undergoing rockfall primarily as the result of weathering and gravitational forces, there is one section of ladder, between weirs 120 and 123 (south wall) where water flow has caused erosion of the lower rock cut, forming undercuts that could destabilize overlying rock masses (Figure 15; also see Figure 1 and Photos 6 & 7 of Appendix A). In this area, the contact between flows P-1 and P dip down below the waterline, and this weaker zone is more easily eroded by water. An existing concrete wall exists on the south side of the channel, between weirs 119 and 120, which appears to have been constructed in conjunction with fish ladder weir modifications completed in the 1980's. This existing wall was likely constructed to help protect the cut from water erosion along the same contact.

Based on site observations, continued water erosion along this contact zone, between weirs 120 and 123, could result in a rock failure that could damage the weirs. Therefore, wall structures (shotcrete walls) are proposed in this area. There would be three separate wall segments, one between weirs 120 and 121, one between weirs 121 and 122, and one between weirs 122 and 123. The top of the walls will be at the top of the non-overflow portion of the weirs; making the walls approximately 8 feet high. Between weirs 120 and 121, part of the weathered flow contact extends above the non-overflow portion of the weirs; in this area the contact has been eroded and forms as 1 to 2 foot overhang. Shotcrete or dental concrete may need to extend above non-overflow elevation in this area to fill this gap.

Prior to wall construction, the exposed rock face will need to be scaled and cleaned of loose rock material. Along the contact, removal of rock could extend back from the adjacent rock face several feet; this volume will need to be filled with shotcrete. Additional excavation may be required to provide the minimum wall thickness, without impacting the weirs or flow criteria.

The walls should be designed assuming hydrostatic pore pressures to the top of the walls, with no water loading inside the channel. Lateral loads from the bedrock may be assumed to be zero.

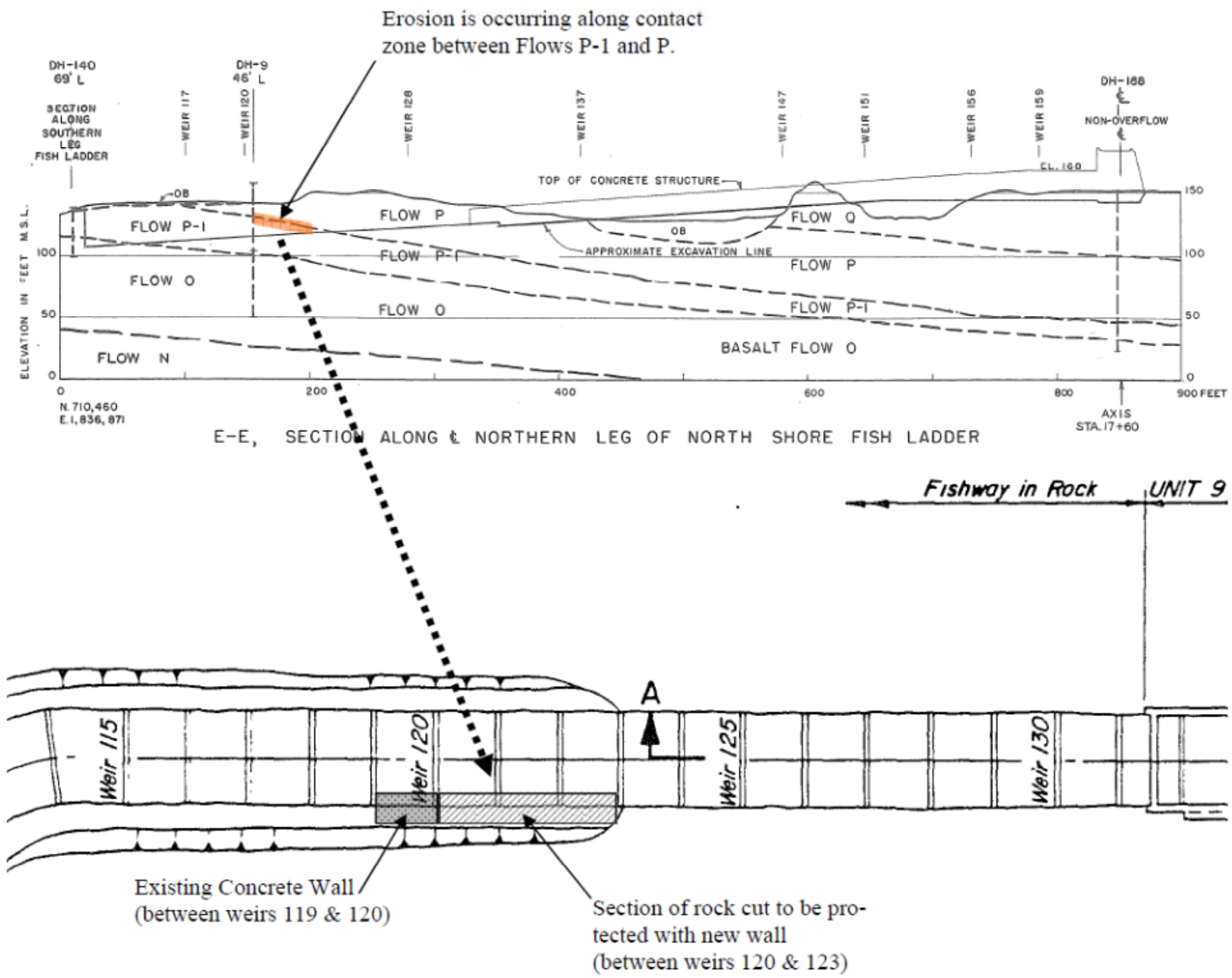


Figure 15 – Plan and section showing proposed shotcrete wall locations.

4. HYDROLOGIC AND HYDRAULIC DESIGN

4.1. General

The principal hydraulic considerations are to maintain passage criteria within the fish ladder. Any increase in weir or orifice width or depth would alter the geometry and require hydraulic analysis. If any modifications radically change average velocities, pool volumes, and energy per pool criteria it will need to be analyzed. Significant changes to these parameters would not be acceptable. Local effects to flow patterns and investigation of possible areas of turbulence could also require further analysis.

Current anticipated design changes are not likely to substantially modify pool volumes but further analysis will be taken as the design is clarified.

4.2. References

- Hydraulic Design References
  - Hydraulic Evaluation of Lower Columbia River Adult Bypass System: The Dalles East Fishway.
  - Anadromous Salmonid Passage Facility Design; National Marine Fisheries Service Northwest Region, July 2011.

- Hydraulic Evaluation of Lower Columbia River Adult Bypass System: The Dalles North Fishway
  - 2015 Fish Passage Plan (FPP): U.S. Army Corps of Engineers, northwestern Division Lower Columbia & Lower Snake River Hydropower Projects; CENWD-PDW-R
  - Fisheries Handbook of Engineering Requirements and Biologic Criteria: Fish Passage Development and Evaluation Program, Corps of Engineers, North Pacific Division , Portland, Oregon, 1990
  - The Dalles Lock and Dam Columbia River, Washington and Oregon Design Memorandum No. 6; Navigation Lock, North Fishway and Non-Overflow Dam Between Lock and Spillway
  - DM #5 Supplement No. 2; North Fish Ladder Counting Station and Weir Modifications January 1985.

4.3. Hydrologic Design/Considerations

4.3.1. Design Project Outflows and Elevations

Normal Forebay Operating Range: 155-160 ft.
Tailrace Rate of Change Limit: 3 ft./hr.
Powerhouse Hydraulic Capacity: 375 kcfs
Spillway Hydraulic Capacity: 2290 kcfs

4.4. Hydraulic Design Criteria

4.4.1. Entrance and Fish Ladder Criteria

Elevation entrance weir crest or sluice opening invert should be 8 feet below tailrace level (or entrance submergence ≥ 8 feet).
Head difference across entrances should be between 1-2 feet with 1.5 feet optimum.
Channel velocities should be between 1.5 and 4 feet per second (ft/s), 2 ft/s optimum. Ladder head should be 1.0 foot (± 0.1 feet). If the shad fish numbers exceed criteria specified in the Fish Passage Plan, then the ladder head should be raised to 1.3 feet (± 0.1 feet).
The hydraulic drop per pool shall be between 0.5 and 1.0 feet in the exit channel section.
The *fishway* pools must have a minimum water volume of:

$$V = \frac{\gamma \cdot Q \cdot H}{\left(4\,ft - \frac{lbs}{sec}\right)/ft^3}$$

where V = pool volume, in cubic feet (ft^3)
γ = unit weight of water, 62.4 pounds (lbs) per ft^3
Q = *fish ladder* flow, in ft^3/s
H = energy head of pool-to-pool flow, in feet

4.4.2. Lamprey Criteria and Passage Considerations

Pacific lamprey is a species of special concern to the USACE and agency partners. Existing fish ladders, which were designed for salmon and steelhead passage, generally perform relatively poorly for adult Pacific lamprey. In accordance with the 2008 Columbia Basin Fish Accords, the USACE is committed to improving adult lamprey passage at all Columbia and Snake River dams and ensuring that any future modifications consider potential impacts on adult lamprey passage. While lamprey passage criteria are less refined than those for salmonids, the following must be considered when evaluating alternatives and making design decisions:

- 4-inch minimum radius on all outside corners (>180 degree in change in bearing in any surface) of fish passage openings, wherever weir opening is not flush with sidewall or orifice opening is not flush with floor.

- Ramping from floor to raised orifices, with a maximum ramp slope of 45 degrees.

- The mean critical swim speed (speed at which physical exhaustion occurs) for Pacific lamprey is 0.85 meters per second (2.8 ft/s; Mesa et al. 2003) and laboratory experiments suggest that most adult lamprey will not pass weir orifices or other constrictions at velocities of 2.5 to 3.0 meters per second (8.2 to 9.8 ft/s; Keefer et al. 2010). Therefore, velocities through weir orifices or count slots should be no greater than 8 ft/s.

- For passage structure features associated with velocities approaching 8 ft/s (see above), such as weir orifices and vertical slots, the distance through which lamprey must pass should be minimized and existing ladder geometry should be maintained. Of particular concern are high-velocity passage distances that approach or exceed the body length of a typical adult Pacific lamprey (15-25 inches).

- All edges should be smooth to the touch to prevent injury.

4.4.3. Lamprey References

a. Clabough, T.S., E.L. Johnson, M.L. Keefer, C.C. Caudill, and M.L. Moser. 2011. General Passage and Fishway Use Summaries for Adult Pacific Lamprey at Bonneville, The Dalles and John Day Dams, 2010. Technical Report 2011-5 of Idaho Cooperative Fish and Wildlife Research Unit to U.S. Army Corps of Engineers, Portland District.

b. Keefer, M.L., W.R. Daigle, C.A. Peery, H.T. Pennington, S.R. Lee, and M.L. Moser. 2010. Testing adult Pacific lamprey performance at structural challenges in fishways. *North American Journal of Fisheries Management* 30:376–385.

c. Mesa, M.G., J.M. Bayer, and J.G. Seelye. 2003. Swimming performance and physiological responses to exhaustive exercise in radio-tagged and untagged Pacific lampreys. *Transactions of the American Fisheries Society* 132: 483–492.

d. NOAA Fisheries. 2008. Anadromous Salmonid Passage Facility Design. Northwest Region, Portland, Oregon.

5. STRUCTURAL DESIGN

5.1. GENERAL

Surface treatment of rock face between weirs 120 and 123, to protect the cut against water erosion and scour, can be accomplished by a variety of methods. Construction of a shotcrete wall with rock anchors are the most common methods used. EM 1110-1-2907 provides guidance for each method of surface treatment. This chapter describes consideration and criteria for the structural design of The Dalles North Fish Ladder Rock Wall Stabilization.

5.2. REFERENCES

a. EM 1110-2-2005 Standard Practice for shotcrete.

b. EM 1110-2-2100 Stability Analysis of Concrete Structures.

c. EM 1110-2-2104 Strength Design for Reinforced-Concrete Hydraulic Structures.

d. EM 1110-1-2907 Rock Reinforcement

e. American Concrete Institute (ACI), ACI 350-06, Code Requirements for Environmental Engineering Concrete Structures.

f. American Concrete Institute (ACI), ACI 318-14, Code Requirements for structural Concrete

g. American Society of Civil Engineers (ASCE), ASCE 07-10, Minimum Design Loads for Buildings and Other Structures.

h. American Society of Concrete Contractors, Guide for Surface Finish of Formed Concrete.

i. American Institute of Steel Construction (AISC), 14th Edition Steel Construction Manual (LFRD and ASD).

j. American Welding Society (AWS), Structural Welding Codes for Steel and Aluminum.

k. U.S. Geological Survey (USGS) 2002 National Seismic Hazard Maps.

5.3. ENGINEERING PROPERTIES OF CONSTRUCTION MATERIALS

- Anchor Rods: ASTM F1554 Grade 55, fy = 55,000 psi.
- Shotcrete compressive strength of 4.5 ksi at 28 day , in accordance with ASTM C42/C42M
- Reinforcement steel: ASTM A615 Grade 60
- Wire Reinforcement in accordance with ASTM A82/A82M or ASTM A1064/A1064M.
- Nuts: ASTM A563.
- Washers: ASTM F436

5.4. DESIGN LOADS

a. Dead Loads. Dead loads consist of the weight of concrete, metal, and fixed equipment. Concrete unit weight is assumed to be 150 lb/ft^3. Steel unit weight of 0.283 pounds per cubic inch is based upon AISC values for structural plates and shapes. Aluminum unit weight of 0.098 pounds per cubic inch is based on Aluminum Association values for structural shapes and plates.

b. Live Loads. The minimum distributed 5-2

c. live loads are based on ASCE 7-10, Table 4.1.

d. Hydrostatic Loads. The hydrostatic loads against the structure include internal and external pressures for all design load conditions. The unit weight of water is assumed to be 62.4 lb/ft^3. The Shotcrete surface will be subject to a maximum of 8 feet of hydrostatic load (the full height of the surface treatment).

5.5. STRUCTURAL DESIGN

This section covers stabilization of the The Dalles North Fish Ladder Rock Wall Stabilization; the rock cut, above the fish ladder. All of the The Dalles North Fish Ladder Rock Wall Stabilization structural elements are designed to meet the strength, stability, and serviceability requirements outlined in applicable design references listed above.

Hydraulic Structures. : Concrete structures /shotcrete surface will be considered hydraulic structures with the appropriate load factors, as defined in EM 1110-2-2104 and ACI 350.

All reinforced shotcrete hydraulic surface must satisfy both strength and serviceability requirements. In the strength design method this is accomplished by multiplying the service loads by appropriate load factors and for hydraulic structures multiplying by an additional hydraulic factor, $H_f = 1.3$. The hydraulic factor is applied to the overall load factor equations. This increased loading is then used for obtaining the required nominal strength for the hydraulic structures. The hydraulic factor is used in lieu of performing an additional serviceability analysis.

The stability analysis of hydraulic Shotcrete surface must be performed using unfactored loads in accordance with EM 1110-2-2100 Stability Analysis of Hydraulic Structures. The unfactored loads and the resulting reactions are then used to determine the unfactored moments, shears and thrusts as critical sections of the structure. The unfactored moments, shears, and thrusts are then multiplied by the appropriate load factors, and hydraulic factors, when appropriate, to determine the required nominal strengths to be used in establishing the section properties.

The basic requirements for the stability of the different features of this Project are as follows:

- The structure should be safe against overturning at the base, and at any horizontal plane within the structure.
- The structure should be safe against sliding on any plane within the structure on any rock seam within the contact.

5.6. FEATURES

Shotcrete walls with rock anchors will be designed between water flows and existing rocks to stabilize and prevent any further deterioration of existing rock surface. The shotcrete walls are required to be constructed between weirs 120 and 123 against the surface of existing rock wall. The walls will contain rock anchors, wire mesh for temporary shotcrete and reinforcement steel for permanent Shotcrete (Plate 1). The rock anchors consists of the passive reinforcement of existing rock by installing closely spaced steel bars, which are subsequently encased in grout. The face of the permanent shotcrete will be trowel smooth surface.

6. ENVIRONMENTAL AND CULTURAL RESOURCES

6.1. GENERAL

This chapter outlines the environmental and cultural resources and permitting requirements as they may apply to The Dalles Dam North Fish Ladder Rock Stabilization Project. During plans and specifications, the design will be further refined.

6.2. ENVIRONMENTAL PLANNING

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 facility 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 NWP 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. 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.

7. CONSTRUCTION

7.1. GENERAL

This section presents the basic construction considerations, restrictions, and coordination of the major feature construction for The Dalles North Fish ladder Rock Fall Stabilization. A product development and construction schedule is located in Appendix C.

7.2. SCHEDULE

7.2.1. General

Funding for this project is unknown at this time. The assumption is that this contract will be fully funded. The acquisition strategy is assumed to be a small business set aside completed construction contract.

7.2.2. In-water Work Period

As outlined in The Fish Passage Plan, the in-water work period for The Dalles Dam and the Columbia River is from December 1 to February 28. However, if a timeframe has to be outside of the in water work window or both fish ladders are dewatered at the same time, per the Fish Passage Plan (FPP) (Section 4.2.2), here is what is required:

> *Non-Routine Maintenance. Maintenance of all fish-related facilities will be carried out as described below. Unscheduled maintenance that will have a significant impact on juvenile fish passage shall be coordinated through FPOM on a case-by-case basis by Project and CENWP-OD biologists. The CENWP-OD biologists will be notified as soon as possible after it becomes apparent that maintenance and/or repairs are required. The Operations Project Manager has the authority to initiate work prior to notifying CENWP-OD when delay of work will result in unsafe situations for people, property, or fish. Information required by CENWP-OD includes: (see also FPP Chapter 1 - Overview for the Memo of Coordination (MOC) template):*
>
> *i. Description of the problem.*
> *ii. Type of outage required.*
> *iii. Impact on facility operation.*
> *iv. Length of time for repairs...*
> *v. Expected impacts on fish passage.*

7.2.3. Fish Ladder Shutdown Period

[Schedule needs to be discussed with project biologist to ensure both fish ladders will not be dewatered at the same time during the in water work period and if it is necessary to have both dewatered, coordination with FPOM will have to occur.]

7.3. EXCAVATION AND DEMOLITION

7.3.1. Excavation

Excavation of the rocks will be a mixture of some sort of crane or long reach excavator and by hand. Cranes will likely be staged between the two fish ladder sections, or along the existing access road south of the fish ladder. Rocks small enough to be lifted by man can be placed in buckets and lifted out of each weir section. Large stone may require hydraulic equipment. Hydraulic equipment staged in the fish ladder will need to be small enough to fit and operate between the weirs. Material will be removed from site. The weir structures will need to be protected from falling rock during scaling operations.

7.3.2. Demolition

No demolition of existing structures is anticipated.

7.4. RESTRICTED ACCESS

7.4.1. Access Road

Access to the jobsite will be from the Washington side of the Columbia River off highway 14, there is adequate road access for the Contractor to get setup and access the fish ladder. Temporary access road may need to be constructed between the fish ladder sections to provide crane access.

7.4.2. Public Access

There will be no public access during construction. All visitors to the site will be required to make prior arrangements through the USACE construction office and will be required to be escorted by personnel with site access and sign in upon arrival, also attend a safety briefing for each visit.

7.5. CONTRACTOR OPERATIONS

7.5.1. Contractor Work, Office, Staging, Parking

The Dalles Dam has plenty of space for staging material and temporary construction offices. The staging area should be place in location that will minimize the impact on the Operating Project staff.

7.5.2. Environmental Controls

All federal, state, and local laws and regulations will be complied with concerning this work. All runoff from construction site activities will be controlled with best management practices provided by the contractor and approved by the Government, along with controls implemented under the NPDES permit and the Erosion and Sediment Control Plan. Capture of job site runoff in retention ponds will allow settlement of sediments and removal of contaminants.

7.6. QUALITY ASSURANCE AND CONTRACTOR QUALITY CONTROL

7.6.1. Quality Assurance

Quality assurance will be accomplished by a well programmed policy as covered in the Resident Office Quality Assurance Plan (QAP). The QAP will be augmented by a site-specific QAP Supplement prepared by the Construction Project Engineer. Staffing of the quality assurance surveillance will be by assigning one Project Engineer and a suitable number of Government Quality Assurance Representatives (GQAR) to perform the day to-day surveillance, which purpose is to assure adherence to specification requirements for quality and safety. The PDT will periodically travel to the site to participate in partnering meetings, periodic scheduling meetings, and to observe the work as part of required engineering during construction protocols.

7.6.2. Contractor Quality Control

Contractor quality control will be monitored by the Quality Assurance Team, Project Engineer and GQAR(s), as part of the QAP and QAP Supplement requirements. The contractor will be required to follow the guidelines of Division 1 specifications, particularly the sections on Quality Control System, Submittal Procedures, and Contractor Quality Control. These sections specify criteria for outlining the work to be performed and for communicating the quality to the workers performing the work. A Quality Manager is required to be on the contractor staff with the responsibility for executing all quality related matters, which include preparing submittals and conducting the three phases of control for each definable feature of work.

8. OPERATIONS AND MAINTENANCE

8.1. GENERAL

The north fish ladder is operated in accordance with the annual Fish Passage Plan (FPP). Any deviation from the requirements of the FPP must be coordinated through the Fish Passage Operation and Maintenance regional forum.

8.2. FEATURES

Flow into the fish ladder is controlled by vertical slot weirs and one valve in the upper section of the ladder. A count station for visual counting is between this flow control section and the remaining downstream overflow weirs. Approximately 25% of the overflow weirs are within a concrete lined portion of the ladder. The remainder is excavated into basalt. Wasco Co PUD turbine provides attraction water to the lower portion of the ladder. A backup overflow system (original construction) provides redundancy for the PUD turbine. Attraction flow is provided via diffuser valves and through grating on the floor of the lower portion of the ladder. There are two entrance openings available, but only one is operated due to amount of available attraction flow. The operating entrance has a telescoping weir to maintain criteria depth and differential at the entrance.

8.3. MAINTENANCE

Routine maintenance is primarily done during 1 month within the winter maintenance season (December 1 – February 28). The fish ladder and channel below tailwater elevation is normally dewatered for inspection. Preventative maintenance is completed on count station moving parts, diffuser valves and the entrance weir. Inspections are completed on all portion of the ladder. Maintenance is also completed during passage season if needed and accessible.

8.4. SAFETY

All work is completed under the Hazardous Energy Control Program (HECP) clearance program to assure worker and equipment safety. Prework safety meetings are also mandatory. Safety Personnel Protection Equipment (PPE) is required during all work. Project safety office reviews work plans.

8.5. ENVIRONMENTAL

All environmental protection requirements are applied during all work. Project environmental section reviews all work plans.

8.6. DOCUMENTATION

All operation of fishway components are recorded with 3 daily fishway inspection to assure FPP compliance. All maintenance of fishways are documented through FEM for work history and funding sources.

8.7. TRAINING

All personnel working on fishway must complete HECP training and confined space training.

8.8. COMMISSIONING

Following construction, it is anticipated that water flow in the fish ladder, in the area of the new shotcrete walls, will need to be observed and monitored to ensure flows are as anticipated.

9. COST ESTIMATING

9.1. GENERAL

This section presents the cost estimate for the The Dalles North Fish ladder Rock Fall Stabilization, as presented in this DDR. The total project cost (design and construction) estimated at the 90% DDR phase is $XX million including a XX% contingency. The risk analysis and total project cost summary sheet can be found in Appendix C.

The scope of work includes removal of rock in the north fish ladder as well as stabilize the rock walls so further erosion will not occur. Rocks will be removed by hand and hydraulic equipment. Shotcrete wall will be construction, and will include installation of rock anchors, wire mesh and rebar.

9.2. CRITERIA

Engineer Regulation 1110-2-1302, Engineering and Design Civil Works Cost Engineering, provides policy, guidance, and procedures for cost engineering for all Civil Works projects in the USACE. For a project at this phase, the cost estimates are to include construction features, lands and damages, relocations, environmental compliance, mitigation, engineering and design, construction management, and contingencies. The cost estimating methods used are to establish reasonable costs to support a planning evaluation process. The design is at the 90% DDR level and the cost estimate is at a similar level.

9.3. BASIS OF THE COST ESTIMATE

The cost estimate is based on engineering calculations from the design team and data presented in the DDR. The estimate is calculated with the Micro Computer Cost Estimating System (MCACES) MII, using historical data, labor and equipment crews, quantities, production rates, and material prices. Prices are updated for July 2014 in MII, and escalated to the midpoint of construction on the total project cost summary sheet.

9.4. COST ITEMS

The cost estimates includes costs for engineering for plans and specifications, construction costs, engineering during construction, construction management for supervision and administration, escalation costs, and contingency to account for unforeseen details at this level. Other possible costs are not shown separately, such as lands and damages, relocations, cultural resources, environmental mitigation, environmental compliance and hazardous, toxic and radiological waste (HTRW) costs. These costs are either not applicable or integrally part of the construction costs and are included in the construction features. Escalation costs to account for inflation are applied according to Engineer Manual (EM) 1110-2-1304, Civil Work Construction Cost Index system.

9.5. CONSTRUCTION SCHEDULE

Detailed information about the construction schedule can be found in Section 10 of this DDR. Overtime is anticipated due to the short in-water work window. Assume 50 hour work weeks will be used to complete the work.

9.6. ACQUISITION STRATEGY

The cost estimate assumes competitive pricing will be obtained by a single phase request for proposals with a best value source selection. Competition will be restricted to small business.

9.7. SUBCONTRACTING PLAN

The cost estimate assumed that the prime contractor will be experienced in heavy civil construction and that no subcontracting will be needed.

9.8. PROJECT CONSTRUCTION

Access to the project will be form highway 14 in Washington. This allows road access directly to the site by trucks, equipment and personnel.

Steel and concrete materials required for the project are readily available by commercial sources. The nearest established suppliers are in the Portland area about 60 miles from the site. The cost estimate assumes concrete will be trucked to the site from concrete plants in the Portland area. The estimate assumes inclusion of the Buy American Act.

9.9. FUNCTIONAL COSTS

Planning Engineering and Design (30 Account). Engineering and design costs are determined from the budgets for the expected design and engineering effort. These costs include engineering costs for design and development of a contract package (plans and specifications), Portland District review, contract advertisement, award activities, and engineering during construction. This effort is estimated to cost $XX million for the plans and specifications phase. The cost of all design phases is estimated to cost $XX million.

Construction Management (31 Account). Construction management costs are determined from the budget of the expected effort for supervision, administration and quality assurance for the construction contract. This effort is estimated to cost $XX million.

Annual Operations and Maintenance. Annual operations and maintenance costs are estimated at $XX.

10. PERMANENT VEGETATION CONTROL OPTIONS

10.1. GENERAL

As previously discussed, rock fall hazards in the fish ladder are of primary concern when workers enter the fish ladder to remove vegetation along the cut walls. Because the use of herbicides is not allowed in the fish ladder, workers need to access the walls from inside the ladder and physically cut and remove the vegetation by hand; commonly while standing on ladders. This process can loosen unstable rocks, resulting in rockfall that can endanger workers. In addition, fractures and joints in the rock allow the plant roots to penetrate as they grow. The growing roots exert a huge force on the rock, widening the joints, and breaking the solid rock into fragments and blocks. This weakens the rock over time and makes the exposed cuts even more prone to root penetration and freeze-thaw mechanical weathering. The plants along the cut walls accelerates the weathering process of the cut face, and therefore slope stabilization efforts are required more frequently where plants are present.

Providing permanent vegetation control along the fish ladder would likely significantly alter the channel design and appearance, and is generally out of the scope of this project. However, two vegetation control options are presented here for future consideration; (1) using plastic or burlap tarps secured by rock bolts to cover the cuts to discourage plant growth, or (2) using shotcrete to cover the cuts to form a barrier that would prevent plant establishment.

10.2. TARPS

Construction method: Following initial scaling and vegetation removal, rock bolts would need to be installed at a defined spacing, with fasteners, to secure tarps in-place. Tarps will also likely need to be supported by ropes or cables between bolts.

Pros: Less expensive than shotcrete. Tarps can be removed, and easily replaced.

Cons: Requires rock bolt anchors. Wind can easily damage tarps. Damaged tarps fragments can fall into fish ladder. Wind-blown tarps would also impact and vibrate against rock face which could loosen rocks resulting in rock fall, and could impact fish. There could also be visual concerns. Tarps may require wire cables/ropes between rock anchors. Sunlight will also likely degrade/damage tarps.

10.3. SHOTCRETE

Construction method: As discussed in Section 1.5, following scaling, vegetation removal, and rock anchor installation, shotcrete would be sprayed onto the rock face. May require installations of a wire messes secured with rock bolts. Shotcrete could be colored using color additives to match color of rock face.

Pros: Would be less susceptible to damage caused by wind and rain activity. Would provide long term vegetation control. Would also help prevent future rock fall and would slow weathering of the rock face.

Cons: Likely more costly than tarps. Cannot be easily removed. If reinforcing mesh is not used, there is a rick that section of the shotcrete could loosen and fail into the fish ladder.

APPENDIX A

2014-02-24 Trip Report

U.S. Army Corps of Engineers
Portland District

MEMORANDUM FOR RECORD (TRIP REPORT)

MEMORANDUM FOR: Bryan Mason, P.E. (CENWP-OD-D)
DATE: 26 February 2014
SUBJECT: 24 February 2014 North Fish Ladder Rockfall Observations
Prepared by: Christopher Humphrey, C.E.G. (CENWP-EC-DG)

On 24 February 2014, Chris Humphrey (engineering geologist) and Bryan Mason observed rock cuts, exposing basaltic rock, along the north fish ladder of The Dalles Dam. Reportedly, rockfall along the steep cuts of the fish ladder is an on-going problem, and is considered a safety concern when workers are in the ladder doing maintenance.

The cuts were excavated at the time of the construction of the fish ladder. Since construction, the cuts have experienced extensive chemical and mechanical weathering. In particular, fracture and joint fillings have weathered creating openings (or apertures) along the rock face, reducing the connectivity and bond between individual rock fragments or blocks. Roots and freeze/thaw activity has also opened up discontinuities in the rock; along with animal activity (burrows, etc.). This has resulted in unstable rock fragments and blocks, causing the observed rockfall.

The most significant rock fall hazard lies north-northwest of the main ladder switchback (Figure 1). In this area, mitigation measures are recommended to reduce the risk of rockfall. These measures include vegetation removal, scaling, localized installation of rock anchors, and construction of concrete walls. The cuts along the switchback, and east-southeast of the switchback, appear in more stable condition, but are still in need of some localized scaling efforts.

There is an area of the ladder, near the footbridge, that has unstable rock, including large unstable rock blocks (Figure 1 and photo 8). Unfortunately, it is likely that any scaling or rock anchor activity completed in this area could cause rock fall that could damage the fish ladder. Therefore, this area of the fish ladder could simply monitored, with special precautions given to personnel who work in this area of the ladder.

<u>Vegetation Removal</u>

At the time of our observations, there were significant blackberry growth along cut slopes, and numerous small trees. It is recommended that all the vegetation along the rock cuts be removed. If allowed, herbicides should be used to permanently kill and control the unwanted vegetation. If herbicides are not allowed, the vegetation removal should be periodically completed to reduce the risk of mechanical weathering due to roots and tree fall. It is recommended that vegetation be removed prior to or in conjunction with scaling efforts.

Scaling

Because of the age of the excavation, all rock faces along the fish ladder are in some need of scaling efforts, but is especially needs at the northern segment of the fish ladder, as shown on Figure 1. The scaling should effectively remove debris and loose rock fragments that are at risk of falling. The scaling should be completed by trained personnel who are experienced with scaling rock slopes.

Rock Anchors

Figure 1 and photo 2 shows an area of the fish ladder that has experienced rock block fall as the result of jointing in the rock that slope steeply down towards the fish ladder. In this area of the site scaling alone may not fully eliminate the risk of future rock fall. Therefore, localized rock anchors will likely be required to hold larger, unstable rock blocks in place.

Concrete Wall

There is one section of the ladder where water flow has caused erosion of the lower rock cut, essentially undercutting the slope (See Figure 1 and photos 6 & 7). Continued erosion can result in larger rock fall that could damage the ladder. In this area of the ladder some kind of concrete wall will likely be required to protect the cut from on-going erosive forces. The wall could be supported by rock anchors.

Prior to implementing any rock stabilization work, a qualified engineering geologist or geological engineer should be hired to evaluate the cuts in detail, and develop a stabilization design/plan.

Figure 1 - Aerial photo showing north fish ladder and areas of interest.

Photo 1 - looking north up fish ladder.

Photo 2 - Showing areas of recent rock block fall. Localized rock anchors are required.

Photo 3 – Showing large rock blocks that may be at risk of toppling. Localized rock anchors may be required.

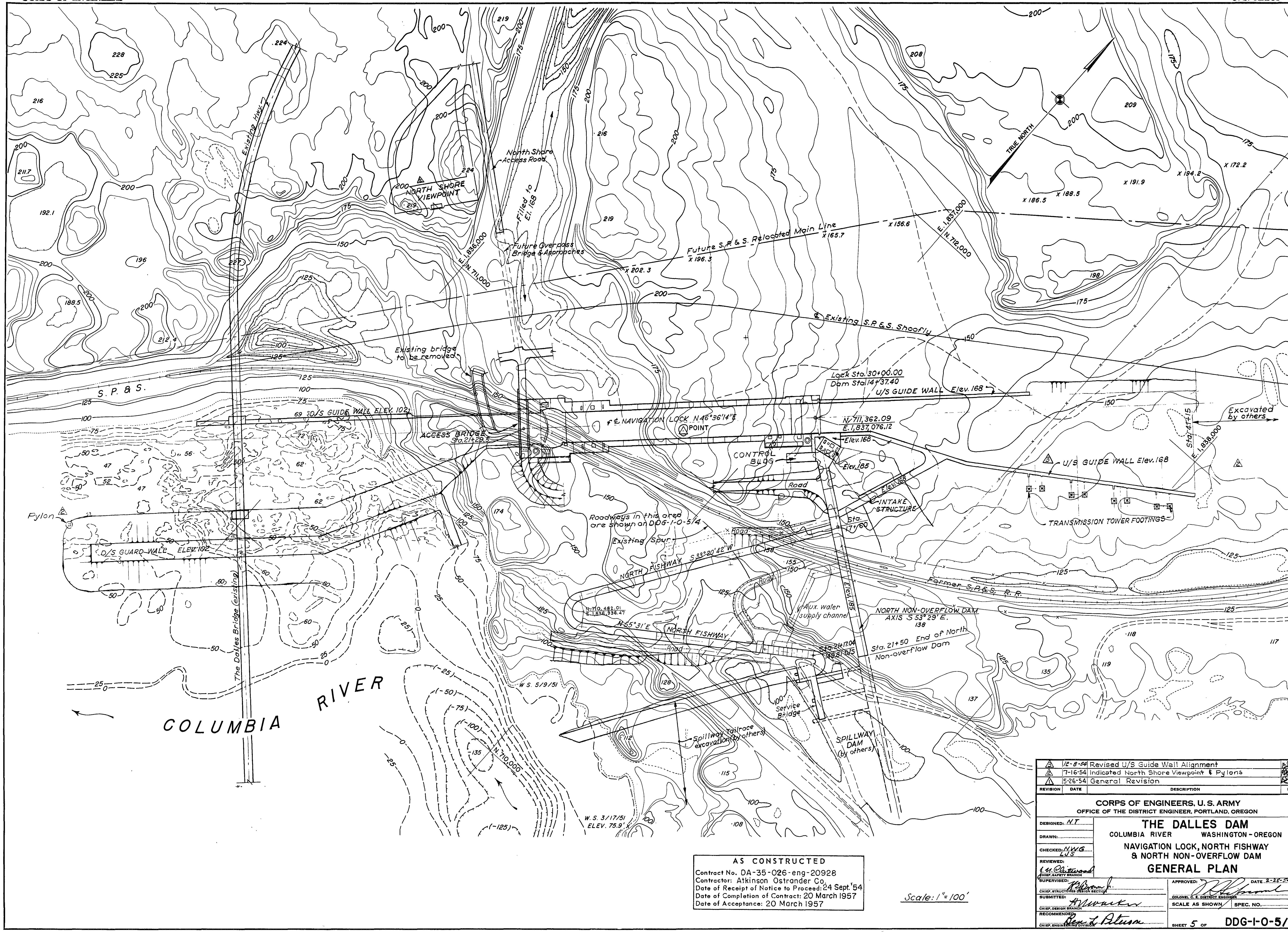
Photos 4 & 5 – Sections of rock cut needing vegetation removal and scaling.

Photos 6 & 7 – Area of lower rock cut being eroded and undermined by water flow. This area of cut may require construction of a concrete wall structure to protect lower rock cut for further erosion.

Photo 8 – Area of unstable rock blocks, near footbridge. Although these blocks appear unstable, it would be difficult to anchor or scale this area without threatening damage to the fish ladder. This area should be monitored, and any work in the area should be done to limit impacts to the slope. Workers access to this area should be limited.

Photo 9 – Looking towards the southern section of the fish ladder.

APPENDIX B
Reference Plan Sheets



REVISION	DATE	DESCRIPTION	BY
3	12-8-54	Revised U/S Guide Wall Alignment	
2	7-16-54	Indicated North Shore Viewpoint & Pylons	
1	5-26-54	General Revision	

AS CONSTRUCTED
Contract No. DA-35-026-eng-20928
Contractor: Atkinson Ostrander Co.
Date of Receipt of Notice to Proceed: 24 Sept. '54
Date of Completion of Contract: 20 March 1957
Date of Acceptance: 20 March 1957

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM

COLUMBIA RIVER WASHINGTON - OREGON

NAVIGATION LOCK, NORTH FISHWAY
& NORTH NON-OVERFLOW DAM

GENERAL PLAN

DESIGNED: N.T.
DRAWN:
CHECKED: NWG LJS
REVIEWED: J. U. Clutwood, CHIEF, SAFETY BRANCH
SUPERVISED: CHIEF, STRUCTURES DESIGN SECTION
SUBMITTED: CHIEF, DESIGN BRANCH
RECOMMENDED: Ben L. Peterson, CHIEF, ENGINEERING DIVISION
APPROVED: COLONEL C. E. DISTRICT ENGINEER — DATE 2-25-54
SCALE AS SHOWN — SPEC. NO.
SHEET 5 OF — DDG-1-0-5/5

NO.	DATE	REVISION	AUTH.
3	29 Jan 54	Added Construction Drill Holes thru DH-235C	A.L.P.
2	19 Oct. 53	Added Drill Holes thru DH-227	J.M.W.
1	9 Mar. 53	Added Structure lines	B.I.B.

THE DALLES DAM

COLUMBIA RIVER, WASHINGTON-OREGON

GEOLOGIC INVESTIGATIONS

TOP OF ROCK CONTOURS

NAVIGATION LOCK AND FISH LADDER

SCALE IN FEET

50 0 50 100 150 200 250

PORTLAND DISTRICT, CORPS OF ENGINEERS

SUPERVISED: Lloyd L. Ruff.
CHIEF, GEOLOGY SECTION

RECOMMENDED:
CHIEF, ENGINEERING DIVISION

SUBMITTED:
CHIEF, FOUNDATION & MATERIALS BRANCH

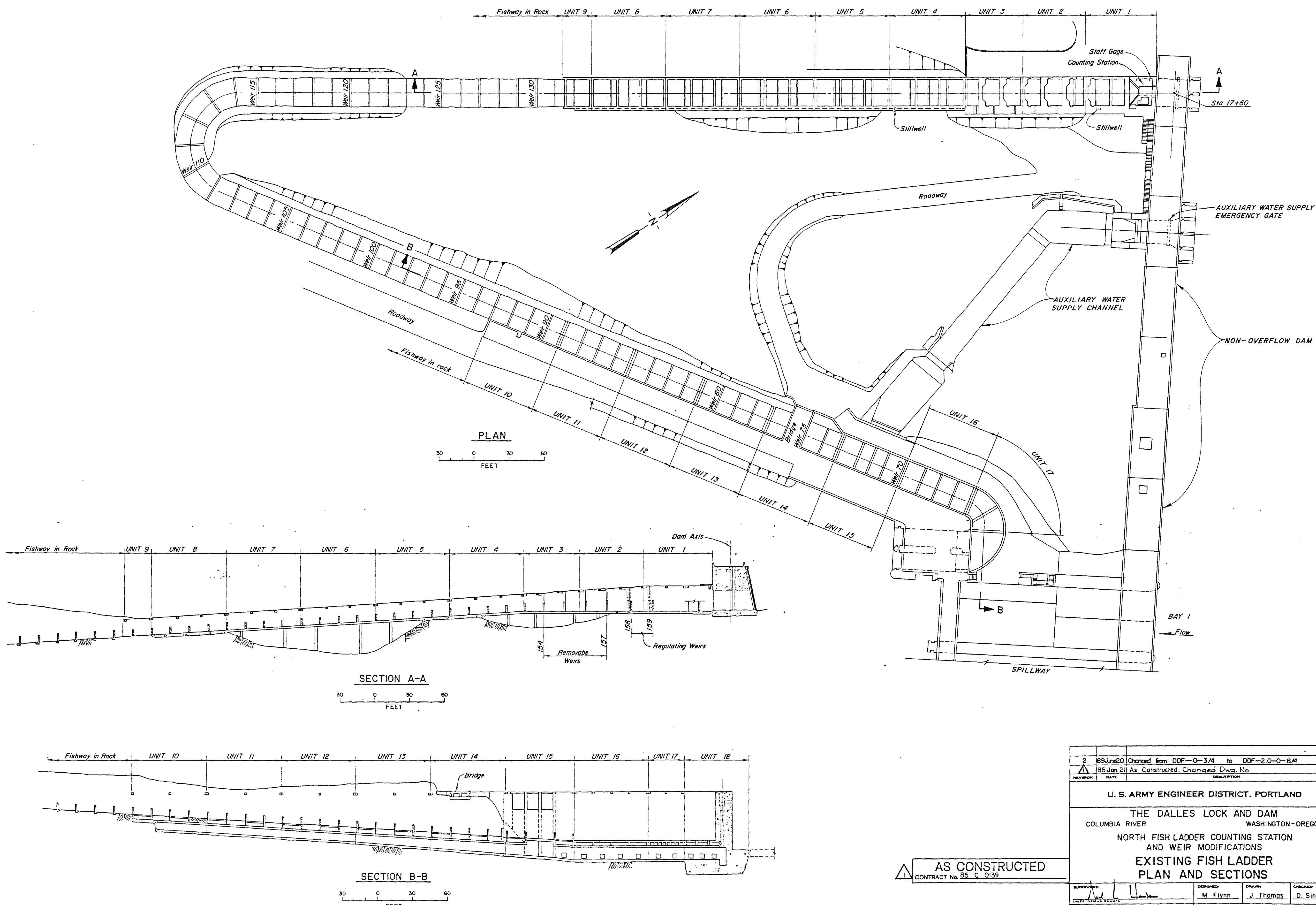
APPROVED:
COLONEL, CORPS OF ENGINEERS
DISTRICT ENGINEER

DRAWN BY:
TRACED BY: G.F.H.
CHECKED BY:

DD-5-31

To accompany 19 March 1954 SUPPLEMENT to Design Memorandum No. 6, Navigation Lock, North Fishway, and Non-Overflow Dam between Lock & Spillway

PLATE 16



AS CONSTRUCTED
CONTRACT No. 85 C 0139

REVISION	DATE	DESCRIPTION	BY
2	89 June 20	Changed from DDF-0-3/4 to DDF-2.0-0-8/4	RAM
1	88 Jan 21	As Constructed, Changed Dwg. No	RJS

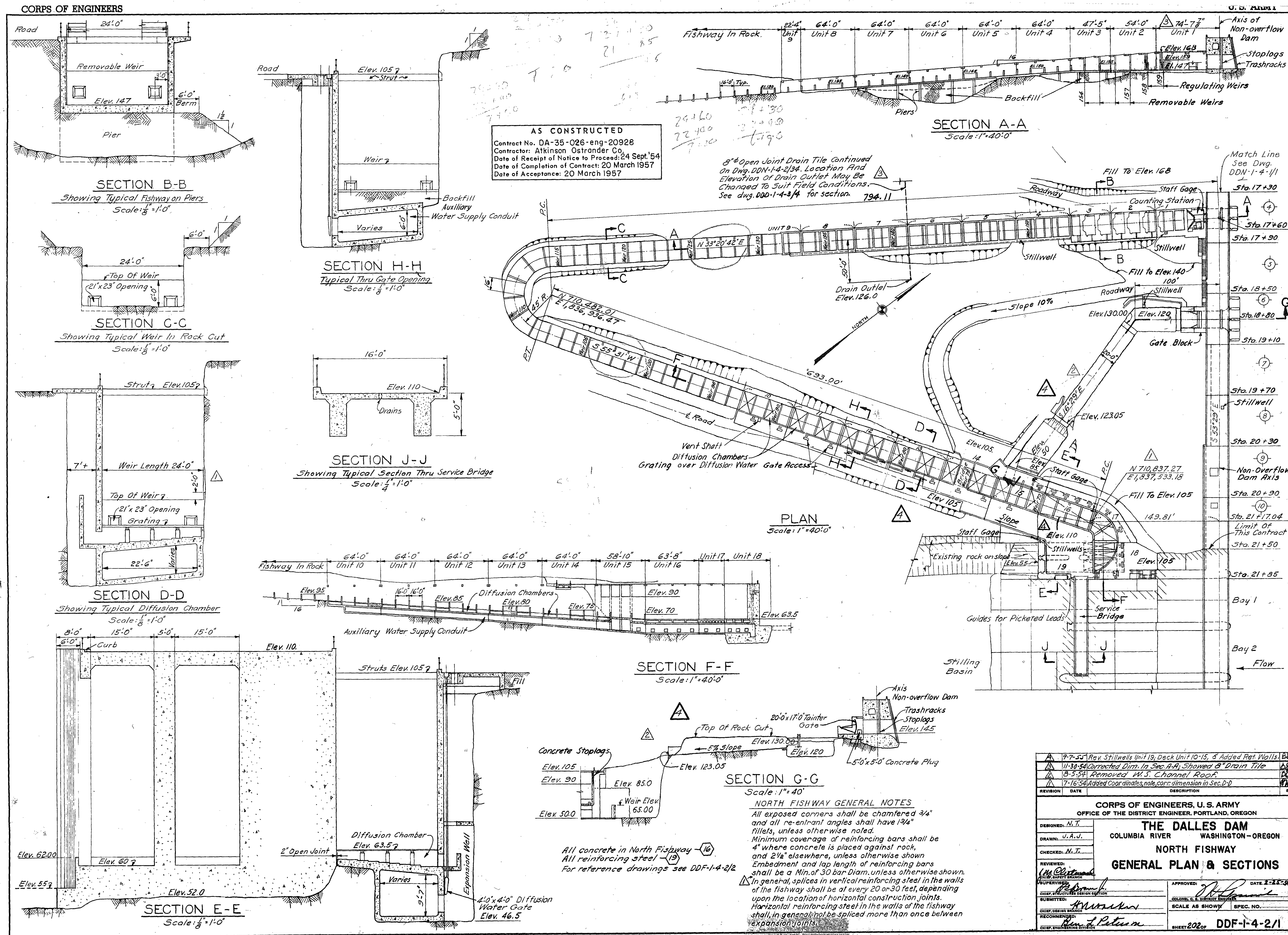
U. S. ARMY ENGINEER DISTRICT, PORTLAND

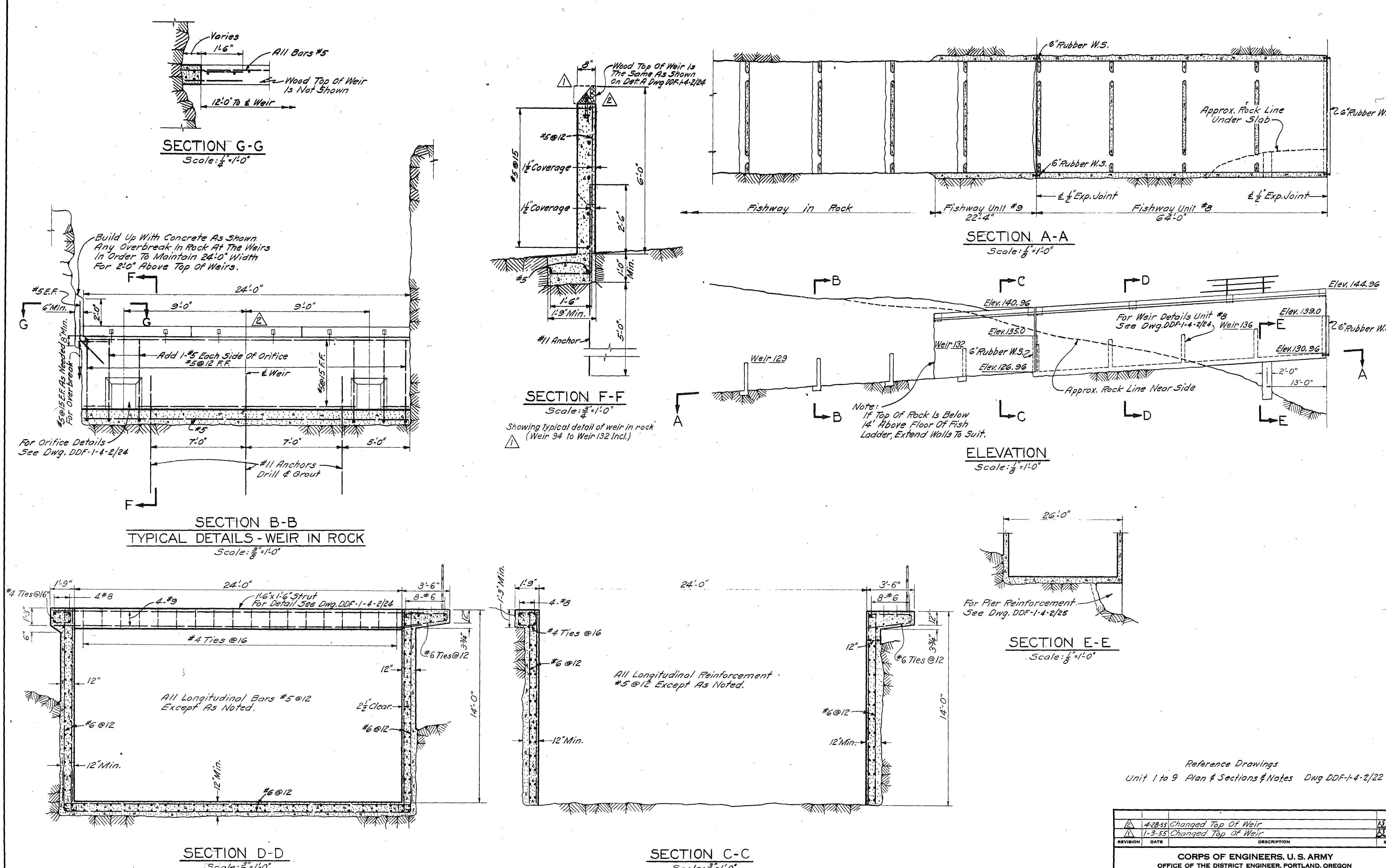
THE DALLES LOCK AND DAM
COLUMBIA RIVER WASHINGTON-OREGON

NORTH FISH LADDER COUNTING STATION AND WEIR MODIFICATIONS

EXISTING FISH LADDER PLAN AND SECTIONS

SUPERVISED: CHIEF DESIGN BRANCH
DESIGNED: M. Flynn
DRAWN: J. Thomas
CHECKED: D. Sinclair
DATE: 85 Jul 11
SHEET: 4
DDF-2.0-0-8/4
PLATE


AS CONSTRUCTED
Contract No. DA-35-026-eng-20928
Contractor: Atkinson Ostrander Co.
Date of Receipt of Notice to Proceed: 24 Sept. '54
Date of Completion of Contract: 20 March 1957
Date of Acceptance: 20 March 1957
SECTION B-B
Showing Typical Fishway on Piers
Scale: 1/8" = 1'-0"
SECTION C-C
Showing Typical Weir In Rock Cut
Scale: 1/8" = 1'-0"
SECTION H-H
Typical Thru Gate Opening
Scale: 1/8" = 1'-0"
SECTION J-J
Showing Typical Section Thru Service Bridge
Scale: 1/4" = 1'-0"
SECTION D-D
Showing Typical Diffusion Chamber
Scale: 1/8" = 1'-0"
SECTION A-A
Scale: 1" = 40'-0"
PLAN
Scale: 1" = 40'-0"
SECTION F-F
Scale: 1" = 40'-0"
SECTION G-G
Scale: 1" = 40'
SECTION E-E
Scale: 1/8" = 1'-0"
8" Ø Open Joint Drain Tile Continued On Dwg. DDN-1-4-2/34. Location And Elevation Of Drain Outlet May Be Changed To Suit Field Conditions. See dwg. DDD-1-4-3/4 for section.
Match Line See Dwg. DDN-1-4-1/1
Axis of Non-overflow Dam
Limit Of This Contract
All concrete in North Fishway (16)
All reinforcing steel (19)
For reference drawings see DDF-1-4-2/2
NORTH FISHWAY GENERAL NOTES
All exposed corners shall be chamfered 3/4" and all re-entrant angles shall have 1 3/4" fillets, unless otherwise noted.
Minimum coverage of reinforcing bars shall be 4" where concrete is placed against rock, and 2 1/2" elsewhere, unless otherwise shown.
Embedment and lap length of reinforcing bars shall be a Min. of 30 bar Diam. unless otherwise shown.
In general, splices in vertical reinforcing steel in the walls of the fishway shall be at every 20 or 30 feet, depending upon the location of horizontal construction joints. Horizontal reinforcing steel in the walls of the fishway shall, in general, not be spliced more than once between expansion joints.
4 | 9-7-55 | Rev. Stillwells Unit 19; Deck Unit 10-15, & Added Ret. Walls.
3 | 11-30-54 | Corrected Dim. In Sec. A-A; Showed 8" Drain Tile
2 | 8-5-54 | Removed W.S. Channel Roof.
1 | 7-16-54 | Added Coordinates, note, corr. dimension in Sec. D-D
REVISION | DATE | DESCRIPTION | BY
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON
DESIGNED: N.T.
DRAWN: J.A.J.
CHECKED: N.T.
THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
NORTH FISHWAY
GENERAL PLAN & SECTIONS
SCALE AS SHOWN
SHEET 202 OF
DDF-1-4-2/1



Revision	Date	Description	By
2	4-28-55	Changed Top Of Weir	
1	1-3-55	Changed Top Of Weir	

AS CONSTRUCTED
Contract No. DA-35-026-eng-20928
Contractor: Atkinson Ostrander Co.
Date of Receipt of Notice to Proceed: 24 Sept. '54
Date of Completion of Contract: 20 March 1957
Date of Acceptance: 20 March 1957

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER WASHINGTON - OREGON
NORTH FISHWAY
UNITS 8 & 9

Designed: F.W.B.
Drawn: J.A.J.
Checked: N.T.
Approved: Date 2-25-55
Scale as shown
Sheet 226 of
DDF-1-4-2/23

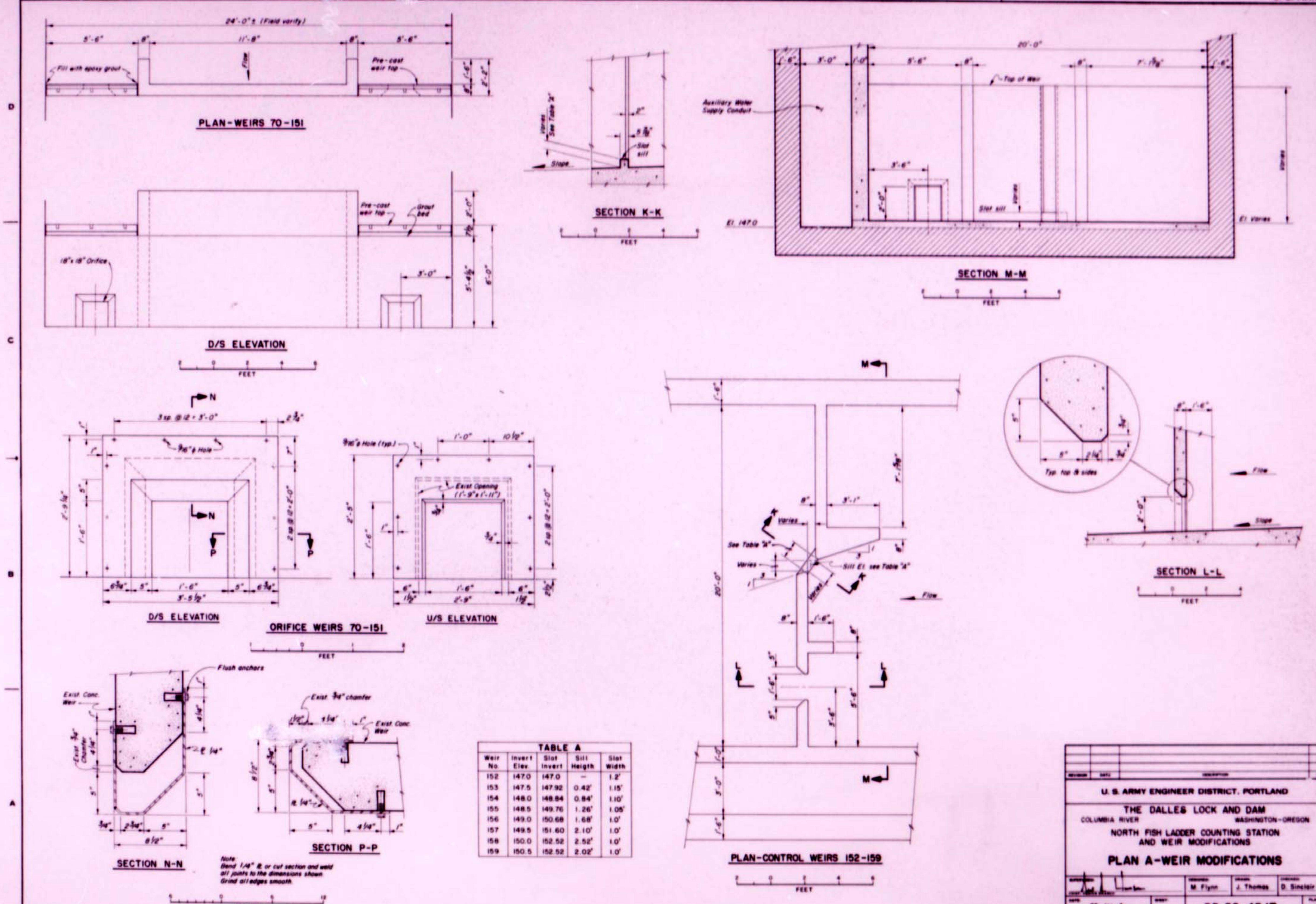


TABLE A				
Weir No	Invert Elev.	Slot Invert	Sill Heigth	Slot Width
152	147.0	147.0	—	1.2'
153	147.5	147.92	0.42'	1.15'
154	148.0	148.84	0.84'	1.10'
155	148.5	149.76	1.26'	1.05'
156	149.0	150.68	1.68'	1.0'
157	149.5	151.60	2.10'	1.0'
158	150.0	152.52	2.52'	1.0'
159	150.5	152.52	2.02'	1.0'

U. S. ARMY ENGINEER DISTRICT, PORTLAND

THE DALLES LOCK AND DAM

COLUMBIA RIVER — WASHINGTON-OREGON

NORTH FISH LADDER COUNTING STATION AND WEIR MODIFICATIONS

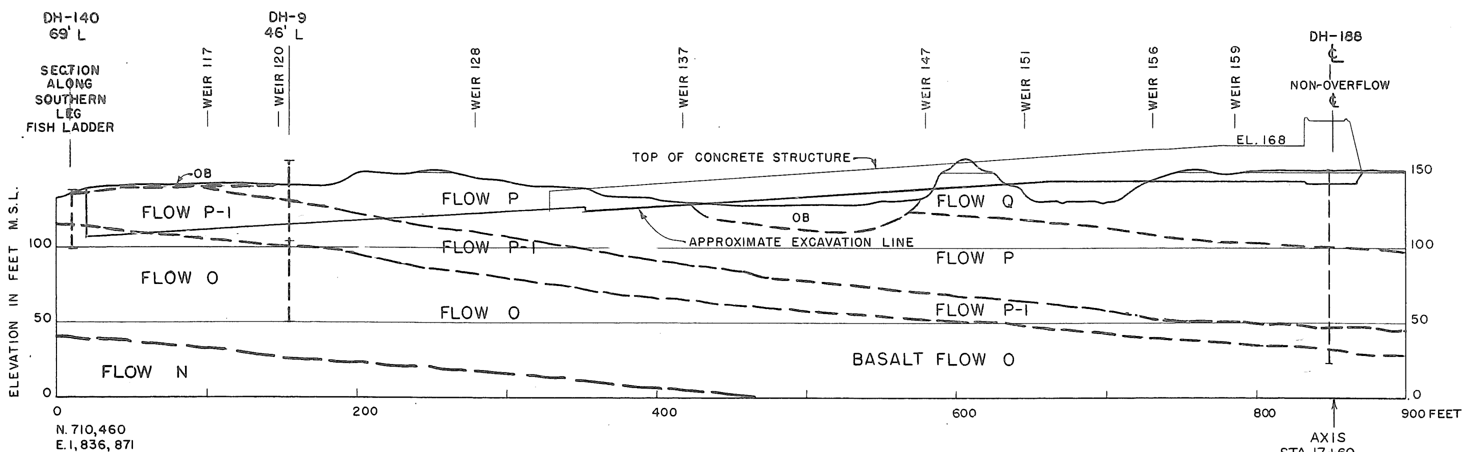
PLAN A-WEIR MODIFICATIONS

Designed: M. Flynn — Drawn: J. Thomas — Checked: D. Sinclair

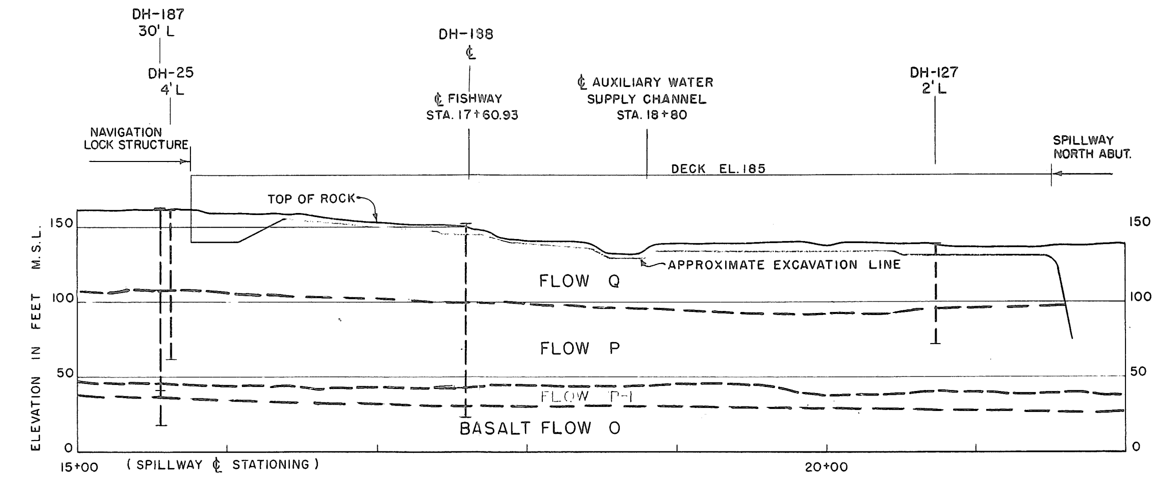
Date: 85 Jan 4

DD 20-45/7

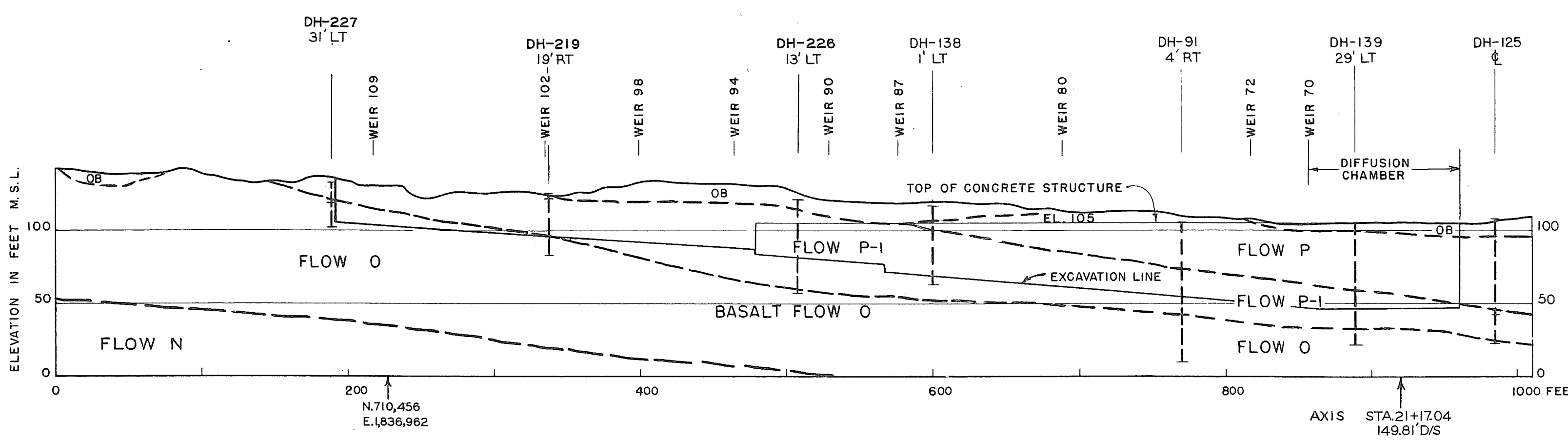
Plate 7



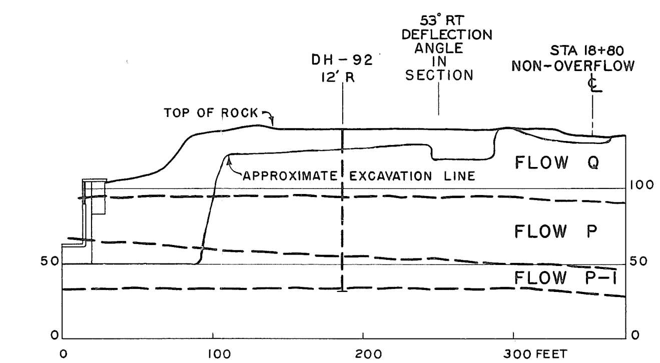
E-E, SECTION ALONG ℄ NORTHERN LEG OF NORTH SHORE FISH LADDER



G-G, NON-OVERFLOW DAM — SPILLWAY TO NAVIGATION LOCK

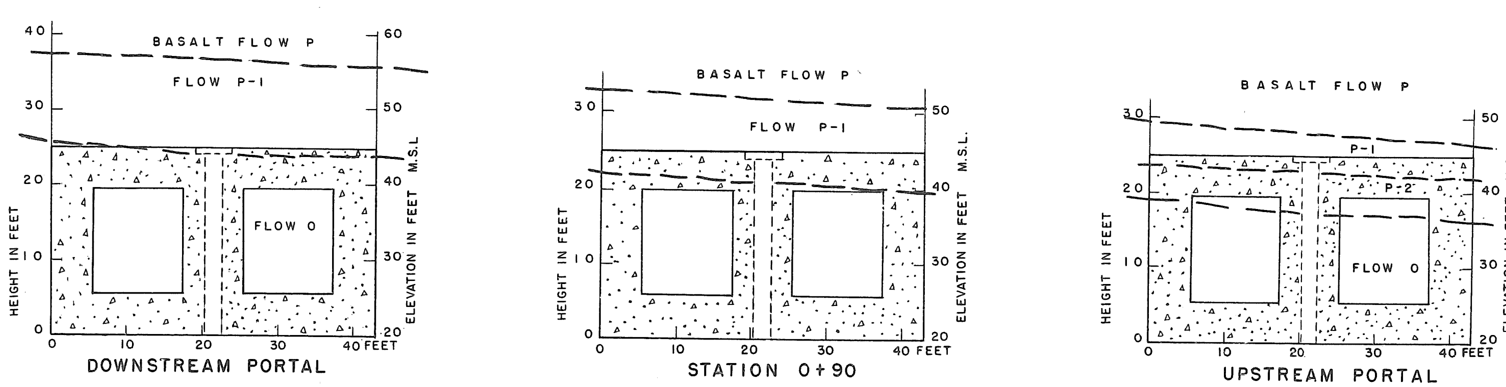


F-F, SECTION ALONG ℄ SOUTHERN LEG OF NORTH SHORE FISH LADDER



H-H, SECTION ALONG ℄ AUXILIARY WATER SUPPLY CHANNEL

NOTE:
IT IS UNDERSTOOD THAT THE INTERPRETATION OF SUBSURFACE CONDITIONS AS CONTAINED IN THIS DRAWING IS ONLY A DIAGRAM OF ASSUMED GEOLOGIC CONDITIONS AND SHOULD NOT BE USED BY THE CONTRACTOR AS RELIABLE FOR THE BASIS OF ESTIMATES



NAVIGATION LOCK - INTAKE TUNNEL
GEOLOGIC SECTIONS

LEGEND

OB — OVERBURDEN, SILT, SAND OR GRAVEL

DH-25 4'L — CORE DRILL HOLE WITH OFFSET SHOWN

— — — APPROXIMATE CONTACT OF BASALT FLOWS.

REVISION	DATE	DESCRIPTION	BY

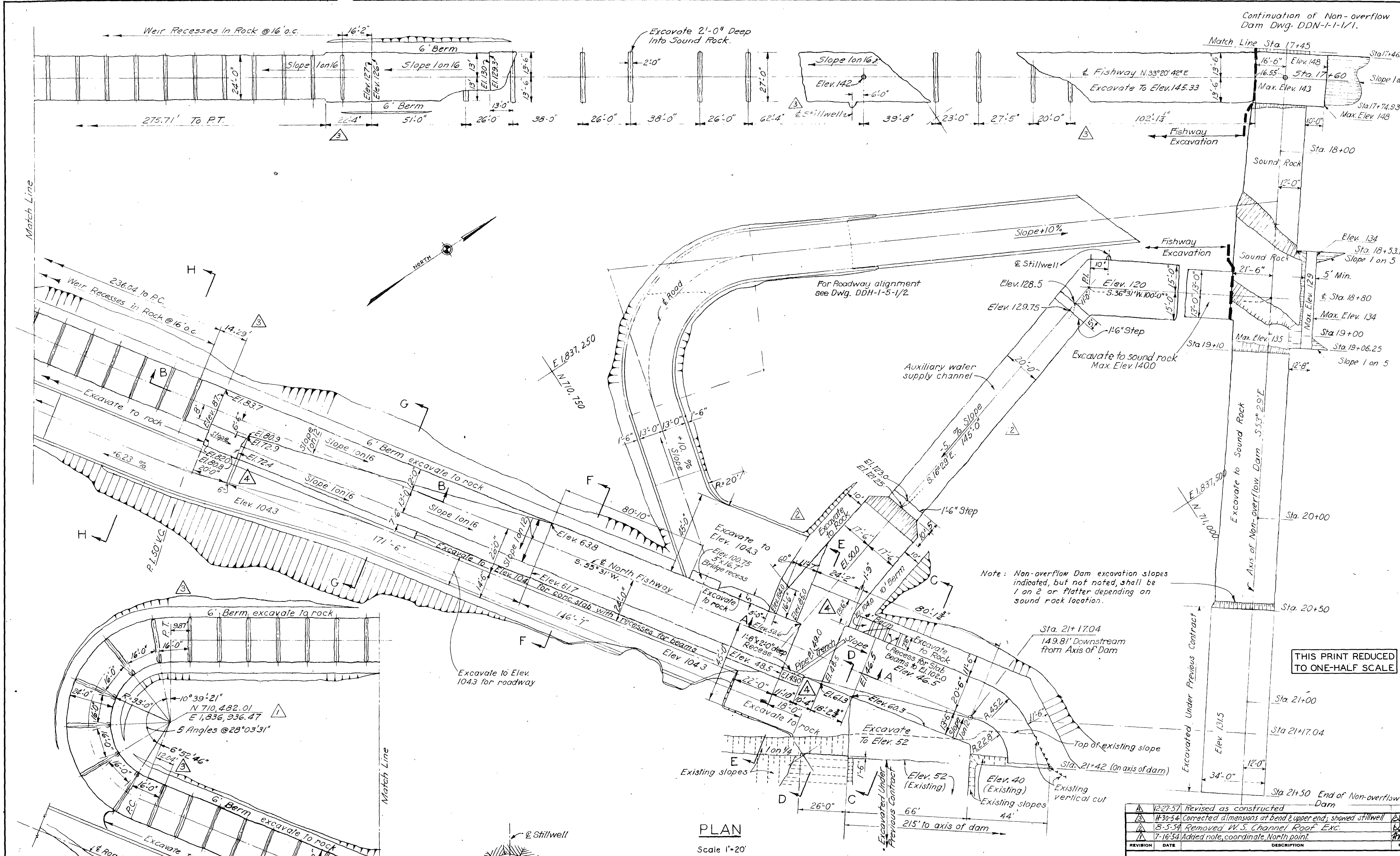
CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

DESIGNED: W.A.C.
TRACED: F.E.W.
CHECKED: D.L.S.
PREPARED:

THE DALLES DAM
COLUMBIA RIVER, WASHINGTON - OREGON
GEOLOGIC INVESTIGATIONS
NON-OVERFLOW DAM & FISH LADDER
NAVIGATION LOCK TO SPILLWAY
GEOLOGIC SECTIONS

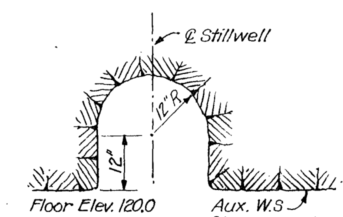
REVIEWED: [signature] CHIEF, SAFETY BRANCH
SUPERVISED: Lloyd L. Ruff CHIEF, GEOLOGY SECTION
SUBMITTED: Paul Thumber CHIEF, FOUNDATION & MATERIALS BRANCH
RECOMMENDED: Ben L. Peterson CHIEF, ENGINEERING DIVISION
APPROVED: [signature] COLONEL, C.E. DISTRICT ENGINEER
DATE 2-25-54
SCALE AS SHOWN SPEC. NO.
SHEET 32 OF
DDG-1-9-6/7

To accompany 15 March 1954 SUPPLEMENT to Design Memorandum No. 6, Navigation Lock, North Fishway, and Non-Overflow Dam between Lock & Spillway



EXCAVATION FOR STILLWELL

No Scale



Reference Drawings

North Fishway - DDF-1-4-2/1
Non-over-flow Dam - DDD-1-4-3/1
Excavation Sections - DDF-1-1-2/2

AS CONSTRUCTED
CONTRACT NO. DA-35-026-eng-20928
CONTRACTOR Atkinson Ostrander Co.
DATE OF RECEIPT OF NOTICE TO PROCEED: 24 SEPT. 1954
DATE OF COMPLETION OF CONTRACT: 20 MARCH 1957
DATE OF ACCEPTANCE: 20 MARCH 1957

NOTES:
For tolerances on excavation lines and grades see paragraph 2-11 of Specifications.
Excavation under structures shall be to elevations as shown or lower, depending on sound rock location.
The final elevations will be determined by the Contracting Officer as the progress of excavation proceeds.
△ All stations shown are measured along Axis of Dam.

REVISION	DATE	DESCRIPTION	BY
4	12-27-57	Revised as constructed	
3	11-30-54	Corrected dimensions at bend & upper end; showed stillwell	
2	8-5-54	Removed W.S. Channel Roof Exc.	
1	7-16-54	Added note, coordinate, North point.	

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DISTRICT ENGINEER, PORTLAND, OREGON

THE DALLES DAM
COLUMBIA RIVER WASHINGTON-OREGON
NORTH FISHWAY
EXCAVATION - PLAN

DESIGNED: N.T.
DRAWN: J.A.J. / E.C.D.
CHECKED: G.W.D.
APPROVED: DATE 2-25-54
SCALE AS SHOWN
SHEET 200 OF
DDF-1-1-2/1

LEGEND

- ⊕ DH80-2 — Exploratory core boring
- Traverse line for mapping fracture spacing
- FSM SITE 3 — Fracture set mapping sites for determining predominant joint orientations
- Approximate outline of proposed structures
- A — Geologic Cross Section

Notes:

1. *See Plates 4-2 through 4-4 for cross-sections.*
2. *Logs of borings are presented on Plate 4-7.*

State Plane
OR N
Nad 1927
Projected

NOTE: JOB NO. 80-57

COORDINATES: OREGON NORTH

DATUM: M.S.L., 1947 ADJ.

CONTROL: U.S.A.E.D., TRIANGULATION AND LEVELS

TOPOGRAPHY: STEREOPLOTTED FROM AERIAL PHOTOGRAPHY DATED 29 APRIL 1980

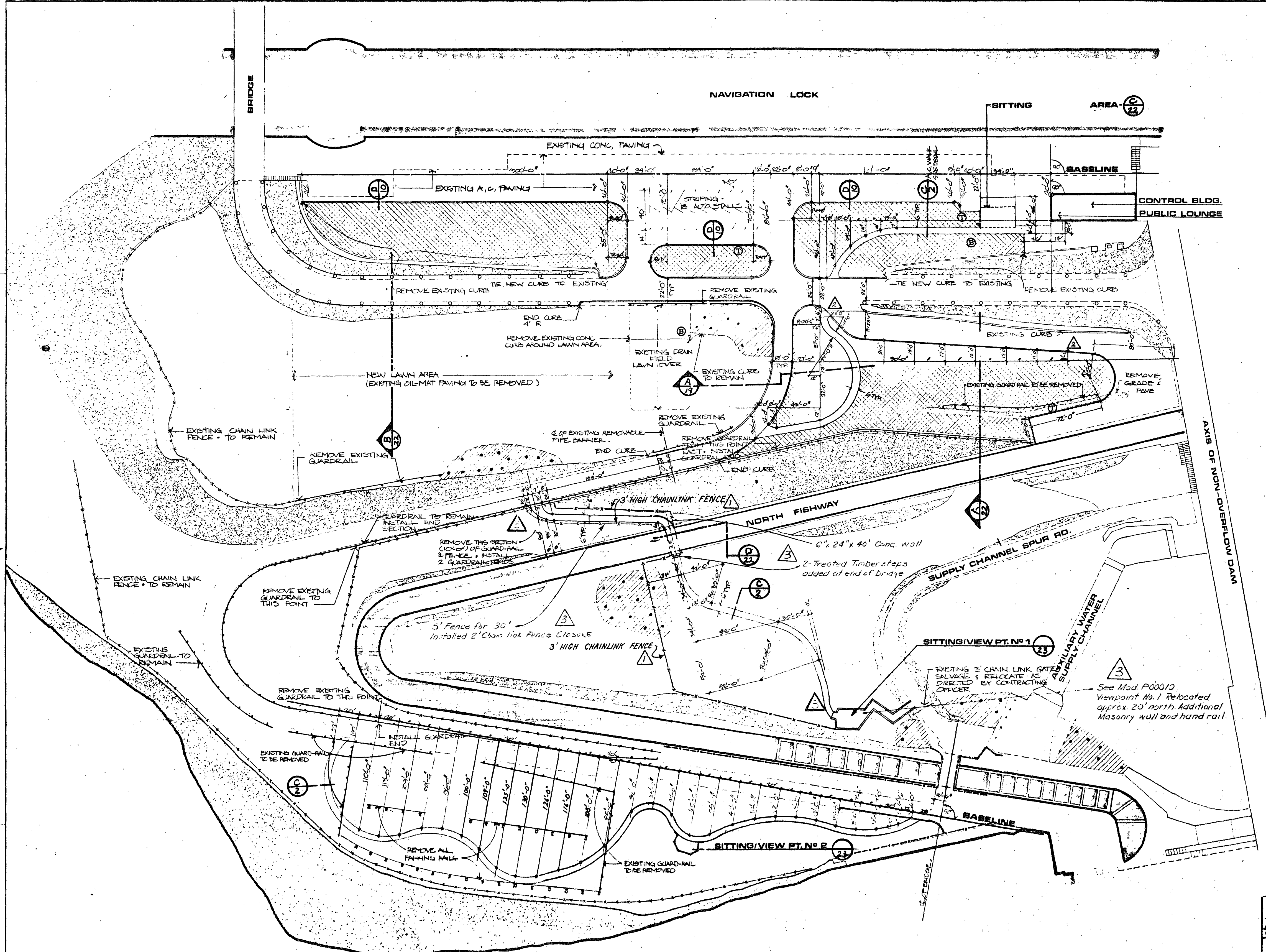
NORTH FISHWAY POWERHOUSE INTAKE

PLAN OF EXPLORATIONS

U.S. ARMY ENGINEER DISTRICT, PORTLAND

PREPARED John W. Sager — CHIEF, GEOLOGY SECTION
RECOMMENDED — CHIEF, ENGINEERING DIVISION
SUBMITTED — CHIEF, FOUNDATION AND MATERIALS BRANCH
APPROVED Terrence J. Connell — COLONEL, CORPS OF ENGINEERS DISTRICT ENGINEER
FIELD WORK JS
DRAWN
CHECKED JWS
TRANSMITTED WITH REPORT DATED

DD-20-41/2



·LEGEND·

- EXISTING PLANTING BED W/ TREES,
- EXISTING PAVING TO BE REMOVED,
- EXISTING RIP-RAP,
- NEW A.C. PATH,
- EXISTING GUIDE POSTS,
- EXISTING GUARD-RAIL,
- EXISTING HANDRAIL W/SCREEN,
- EXISTING CHAIN-LINK FENCE,
- EXISTING PARKING RAIL,
- EXISTING SAFETY FENCE,

PICNIC AREA FURNITURE SHT 36	QUANTITY	
PICNIC TABLE	5	LOCATE NEAR BARBEQUE
TRASH RECEPTICLE	3	Ⓣ
BARBEQUE GRILL & PAD	3	Ⓑ

NOTE: *ALL WALKS AND CONCRETE SURFACES SHALL SLOPE A MINIMUM OF 3/16" PER FOOT, UNLESS OTHERWISE STATED.*

AS CONSTRUCTED
CONTRACT No. DACW-75-C-0295
CONTRACTOR Hall, Gall, Landau, Young Const.
DATE OF RECEIPT OF NOTICE TO PROCEED
DATE OF COMPLETION OF CONTRACT
DATE OF ACCEPTANCE

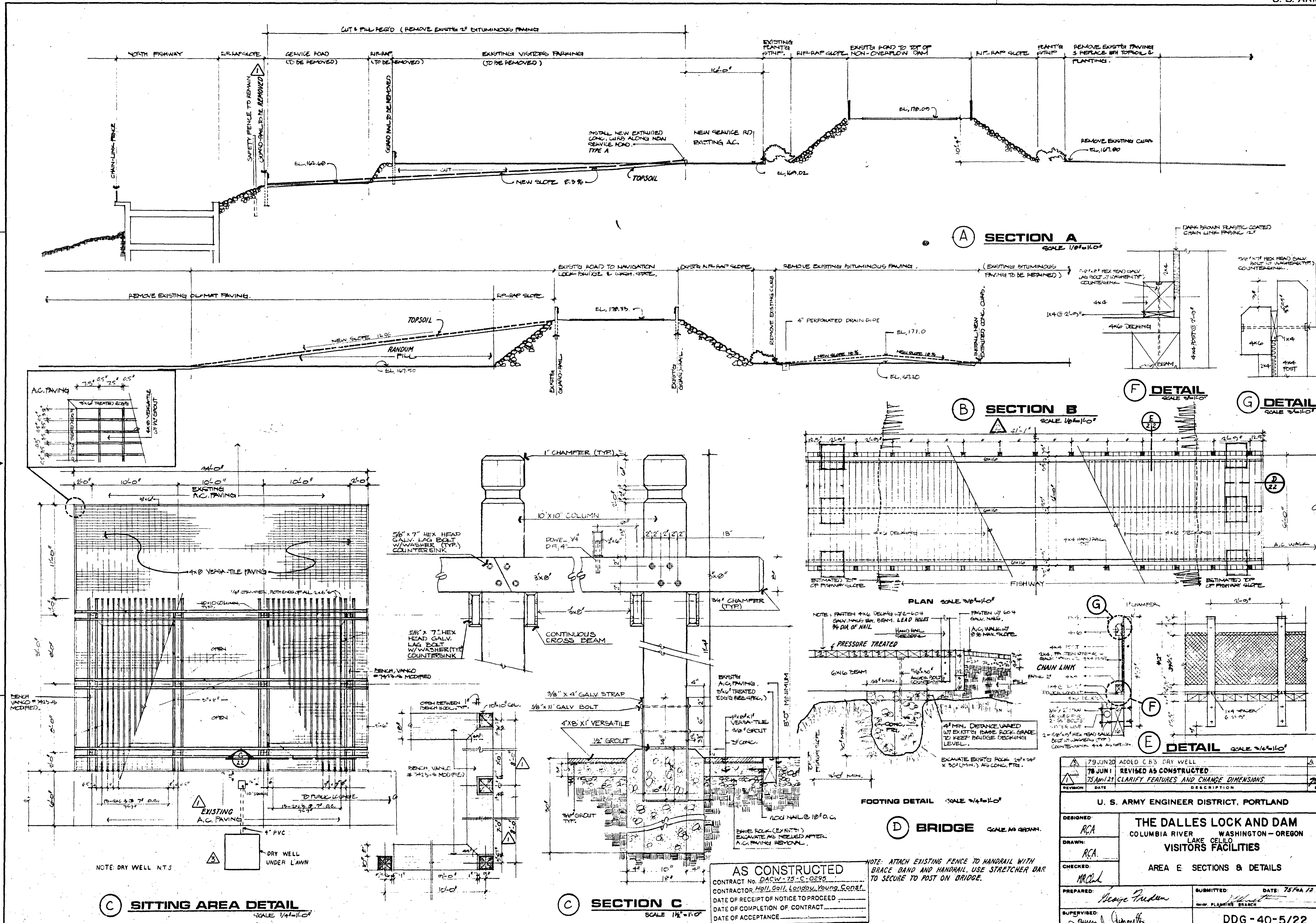
REVISION	DATE	DESCRIPTION	BY
3	78 MAY 31	REVISED AS CONSTRUCTED	
2	76 Sep. 8	Revised Road And Curb	
1	75 MAY 1	ADDED CHAINLINK FENCE	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

DESIGNED: RCA
DRAWN: RCA
CHECKED: MR Ch.

THE DALLES LOCK AND DAM
COLUMBIA RIVER WASHINGTON–OREGON
LAKE CELILO
VISITORS' FACILITIES
AREA E CONSTRUCTION PLAN

PREPARED: [signature]
SUBMITTED: [signature] CHIEF PLANNING BRANCH
DATE 75 Feb. 12
SUPERVISED: [signature] CHIEF RECREATION PLANNING SECTION
SHEET: DDG-40-5/18



AS CONSTRUCTED
CONTRACT No. DACW-75-C-0295
CONTRACTOR Hall, Gall, Landau, Young, Const.
DATE OF RECEIPT OF NOTICE TO PROCEED
DATE OF COMPLETION OF CONTRACT
DATE OF ACCEPTANCE

REVISION	DATE	DESCRIPTION	BY
3	79 JUN 20	ADDED C.B.'S DRY WELL	
	78 JUN 1	REVISED AS CONSTRUCTED	
1	75 April 21	CLARIFY FEATURES AND CHANGE DIMENSIONS.	

U. S. ARMY ENGINEER DISTRICT, PORTLAND

THE DALLES LOCK AND DAM
COLUMBIA RIVER WASHINGTON – OREGON
LAKE CELILO
VISITORS FACILITIES
AREA E SECTIONS & DETAILS

DESIGNED: RCA
DRAWN: RCA.
CHECKED: MRC
PREPARED: George Freden
SUBMITTED: DATE: 75 Feb 12
CHIEF, PLANNING BRANCH
SUPERVISED:
CHIEF, RECREATION-PLANNING SECTION
SHEET 22 DDG-40-5/22

APPENDIX C
Cost Appendix

APPENDIX D
Hydraulic Calculations

ENGINEERING DESIGN CALCULATION COVER SHEET	Office CENWP-EC-HD				
PROJECT: TDD NS Ladder Rock Wall Stabalization SUBJECT: Volume Reduction vs. Fish Passage Requirements	Calc By:	ADL	Date		8/4/2015
	Checked by	SJS			8/18/2015
Calculation Log Number:		Sheet	1	of	1

Summary:
Check volume reduction in north shore fish ladder due to shotcrete along rock wall to see how it affects flow in the ladder. Check against fish passage criteria.

Results:
The higher flow controls how much the volume of the ladder can be downsized, and the maximum decrease in volume of an individual pool is 12.7% .

Revision History:

Revision	Date:	Purpose	Checked By	Date
Original	8/4/2015		SJS	8/18/2015

ENGINEERING DESIGN SHEET

PROJECT: TDD Rock Wall Stabalization
SUBJECT: Volume Reduction vs. Passage Requirements
OFFICE SYMBOL: CENWP-EC-HD
COMPUTED BY: ADL DATE: 08/04/15
CHECKED BY: SJS SHEET: 1 OF: 3

Design head drop per ladder pool is 1.0 ft to 1.3 ft
Based on which species of fish the flow is tailored to (1 ft for salmon, 1.3 ft for shad)
Similar to the Cougar and Minto Design, weir coefficients were calculated from data presented by NHC (2000)
24 foot wide Ice Harbor ladder was chosen with a 6' foot weir length and a 18 inch by 18 inch orifice.

Design Coefficeints:
Weir Coefficient = varies
Orifice Discharge Coefficient = varies (rounded orifice)

Data acquired from Cougar Fish Facility indicated coefficients are acurate within ± 0.2%
Weir coefficients were modified using the Villemonte Equation for submerged weir flow.

Salmon Flow Conditions

H =	1 ft	Cd=	0.67
Cw=	5.07	g=	32.2 ft/s^2
L=	6.0 ft	dH=	1 ft
		height=	1.5 ft
		width=	1.5 ft
		A=	2.25 ft^2
Qweir =	30.4 cfs	Qorifice =	12.1 cfs
2 weirs =	60.84 cfs	Vorifice =	8.0 ft/s
Qtotal =	85.0 cfs	2 orifices =	24.20 cfs

Shad Flow Conditions

H =	1.3 ft	Cd=	0.67
Cw=	5.25	g=	32.2 ft/s^2
L=	6.0 ft	dH=	1 ft
		height=	1.5 ft
		width=	1.5 ft
Qweir free =	46.7 cfs	A=	2.25 ft^2
Cv =	0.956		
Qweir =	44.6 cfs	Qorifice =	12.1 cfs
2 weirs =	89.25 cfs	Vorifice =	8.0 ft/s
Qtotal =	113.4 cfs	2 orifices =	24.20 cfs

1 foot between weir crests & pools

ENGINEERING DESIGN SHEET

PROJECT: TDD Day Rock Wall Stabalization
SUBJECT: Volume Reduction vs. Passage Requirements
OFFICE SYMBOL: CENWP-EC-HD
COMPUTED BY: ADL DATE: 08/04/15
CHECKED BY: SHEET: 2 OF: 3

Volume Requirements:

The following minimum volume requirements need to be satisfied for energy dissipation in the ladder pools, per NMFS (2011):

$$V = \frac{\gamma Q H}{(4\,ft - lbs/s)/\,ft^3}$$

Where:
V = Required Volume (cubic feet)
Q = Fish ladder flow (cfs)
γ = Unit Weight of Water, 62.4 lb/cubic foot
H = Head Differential (ft)

	Flow Rate		Head Differential		Required Volume
Low Flow:	85 cfs	--------->	1 ft	--------->	1,326.6 cu ft
High Flow:	113 cfs	--------->	1 ft	--------->	1,769.8 cu ft

The following equation calculates the volume of the pool:

$$V_{act} = \left[WS_{el} - Z_i - \left(0.5 \times L_{pool} \times S\right)\right] \times W \times L_{pool}$$

Where:
Vact = Pool Volume (cubic feet)
WSel = Water Surface Elevation (ft)
Zi = Invert Elevation (ft)
Lpool = Length of Pool (ft)
S = Slope of Pool
W = Width of Pool (ft)

Lpool = 17.333333 ft W = 24 ft
S = 6.25%

	Wsel - Zi		Actual Volume
Low Flow:	7 ft	--------->	2,686.7 cu ft
High Flow:	7.3 ft	--------->	2,811.5 cu ft

Summary:

Flow (cfs)	H (ft)	Vreq (ft3)	Vact (ft3)	Difference (ft3)
85.0	1	1,326.6	2,686.7	1,360.1
113.4	1	1,769.8	2,811.5	1,041.7

* Since the difference between required volume and actual volume is smaller with the higher flow, it will most likely control.

ENGINEERING DESIGN SHEET

PROJECT: John Day Rock Wall Stabalization
SUBJECT: Volume Reduction vs. Passage Requirements
OFFICE SYMBOL: CENWP-EC-HD
COMPUTED BY: ADL DATE: 08/04/15
CHECKED BY: SHEET: 3 OF: 3

Volume Requirements (cont...):

The following tables will check how much the volumes of each pool can be decreased but still maintain compliance with the requirements:

Low Flow

Volume Reduction	Reduced Volume	Required Volume	Meets Requirement?
10%	2418.0	1326.55	YES
20%	2149.3	1326.55	YES
30%	1880.7	1326.55	YES
40%	1612.0	1326.55	YES
50%	1343.3	1326.55	YES
50.6%	1327.2	1326.55	YES
50.7%	1324.5	1326.55	NO

High Flow

Volume Reduction	Reduced Volume	Required Volume	Meets Requirement?
10%	2530.3	1769.75	YES
20%	2249.2	1769.75	YES
30%	1968.0	1769.75	YES
37.0%	1771.2	1769.75	YES
37.1%	1768.4	1769.75	NO

Conclusion:

During the low flow conditions, the pool volume can be reduced by up to 50.6%. This would still meet the NMFS requirements for energy dissipation in each pool, and allow flow conditions for salmon passage. But, when the flow is increased for shad passage (with 1.3 ft of head above the weir), the volume of the pools can only be reduced by a maximum of 37%. Even though this seems like a small amount, this would actually be a large reduction in space in the ladder. If 1 in of shotcrete was applied to both sides of the fish ladder wall, it would result in a 0.7% decrease in volume per pool. Due to the irregularities of the ladder and the excess width in most areas, it is not expected that the addition of shotcrete to the walls of the fish ladder for rock stabalization will impact the ability of the fish ladder to meet NMFS criteria, as long as the length of the weirs or size of the orifices are not changed.