FINAL REPORT

Steamboat Falls Fish Passage Evaluation and Alternatives Analysis

February 2010

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The North Umpqua Foundation

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Executive Summary

Steamboat Creek lies within the Umpqua National Forest and is a major tributary to the North Fork Umpqua River, Oregon. The stream supports runs of summer and winter steelhead and spring Chinook salmon. Steamboat Falls is located on Steamboat Creek, approximately 6 miles upstream from its confluence with the Umpqua River. The drop across the falls is between 20 and 25 feet. In 1958 the Oregon State Game Commission (later renamed the Oregon Department of Fish and Wildlife, ODFW) constructed a fishway facility along the south bank of Steamboat Falls to improve fish passage.

The fishway is prone to plugging with sediment and small debris on an annual basis and is frequently plugged by early winter. This shuts off nearly all the flow to the fishway, impeding fish passage over the falls. The fishway is typically unplugged by staff from ODFW and volunteers in late June or early July, when flows have receded to safe levels for persons to enter the fishway enclosure. The fishway is often plugged during periods when winter steelhead, and possibly summer steelhead that hold in downstream pools during the previous summer, attempt to pass over Steamboat Falls to reach spawning grounds in the upper watershed. Additionally, large numbers of summer steelhead typically arrive at the base of the falls in May and June, and must hold there until the fishway is unplugged.

This report is part of a three-phase project to improve upstream passage conditions over the falls throughout the upstream migration season for summer and winter steelhead trout and spring Chinook salmon. This report provides and assessment of current fish passage conditions within the existing structure, describes three alternatives for improving fish passage, and provides a comparative evaluation of the alternatives with respect to costs, risks and benefits.

Assuming adult salmon and steelhead are migrating nearly year-round in Steamboat Creek, low and high fish passage flows, as prescribed by ODFW, would range from 24 cfs to 1,684 cfs. This is an extremely wide range of flows for a fish passage facility to operate. Neither the existing fishway nor any of the developed alternatives will be operational across this entire flow range.

The fish migration period at Steamboat Falls is relatively continuous, but can also be divided into two distinct periods. From May through July migration is predominately summer steelhead that over-summer upstream of the falls and spring Chinook. From December through April the migrating fish are summer steelhead that over-summer downstream of the falls and winter steelhead. The lowest flows that occur at the falls from December through April are about 100 cfs during dry years, 300 cfs during average years, and 400 cfs during wet years.

Flows in June, a critical migration period for summer steelhead, are typically between 70 cfs (90 percent exceedance flow) and 300 cfs (10 percent exceedance flow), depending on both the time of month and the amount of late spring rainfall and snowpack left in the upper basin. Therefore, providing passage at streamflows from 70 cfs to 300 cfs is the focus of this project.

Three alternatives were developed and evaluated to improve fish passage at Steamboat Falls. Alternative A involves modifications to the existing fishway to improve its performance. Alternative B involves construction of a new bedrock fishway with bedrock pools and chutes, located along the north side of the falls. Alterative C also involves construction of a new bedrock fishway along the north side of the falls, but would have concrete weirs between pools. Alternative B or Alternative C could be selected as a preferred alternative in conjunction with selection of one of the Alternative A levels of modification. This would provide redundancy and increase the range of streamflows that fish passage is provided. It would also provide an opportunity to abandon the concrete fishway in the future if the bedrock pools provide adequate fish passage.

Existing Conditions

An evaluation of existing fishway performance found that the existing concrete fishway is out of current ODFW and NMFS NW fish passage criteria at all streamflows evaluated, from 21 to over 200 cfs. At lower flows, the water depths within the fishway pools are too shallow. At all fishway flows the Energy Dissipation Factor (EDF), a measure of turbulence in the pools, is extremely high. Additionally, the fishway regularly clogs with sediment in the fall or winter and becomes inoperable until it is cleaned out in the late spring or early summer. As a result, summer and winter steelhead running upstream to spawn are regularly unable to pass over the falls from December until the end of June. This likely severely reduces the number of spawning fish in the tributaries of Steamboat Creek upstream of the falls, especially when high flow events in late fall cause the fishway to become blocked.

Alternative A

Modifications in Alternative A were divided into three levels. Level 1 focuses on improved sediment routing through the fishway and improved fish passage hydraulics. Level 2 aims at reducing the amount of sediment entering the fishway. Level 3 increases fish attraction to the fishway entrance by re-establishing the auxiliary water system (AWS). Not all levels must be implemented. However, Level 2 modifications assume Level 1 is also implemented, and Level 3 assumes both Level 1 and Level 2 are also implemented.

With any level of modification, a structural inspection of the fishway should be done as part of final design, and repairs to spalled or scoured concrete should be done during construction.

Level 1

Level 1 modifications are relatively minor but provide considerable improvement to the fishway hydraulics and fish attraction at the entrance. Level 1 includes modifications to the existing weirs and slots within the fishway, modifications to the exit channel, and construction of a training wall and rooftop curb. The weir modifications in Level 1 are intended to maintain sediment transport throughout the fishway exit channel and to keep the fishway operational even with sedimentation. A sill installed at the bottom of the slot in each weir will increase pool depth and reduce turbulence. Raising the entrance weir will produce a water surface drop at the downstream end of the fishway, creating an attraction jet. The training wall and rooftop curb will prevent water from flowing onto the roof until streamflows are above 400 cfs. This will allow maintenance access inside of the fishway during winter baseflow conditions and earlier in the spring to clean out sediment and debris. The Level 1 modifications also prevent distracting flows from plunging off the roof and into the fishway entrance until streamflows reach 400 cfs. Currently this occurs at streamflows of about 140 cfs.

Level 2
Level 2 modifications include reconstruction of the spillway crest, installation of an adjustable gate on the spillway, increasing the height of the exit port openings and installing adjustable gates on the ports. Lowering of the spillway gate and raising of the exit ports during winter will decrease the amount of sediment entrained into the fishway, helping to reduce sedimentation problems. Raising the spillway gate during the lower flows in summer will maintain the headwater pool level and flow into the fishway. The use of the gates at the exit and spillway will also increase the range of fish passage streamflows during the winter from 400 cfs with Level 1 to about 600 cfs with Level 2. However, at these higher flows, the fishway conveys less than 10 percent of the streamflow, which is the recommended minimum for fish attraction. The low percentage of attraction flow and the high degree of turbulence in the pool below the falls may make it difficult for fish to locate the fishway at these increased operational flows.

Level 3
Level 3 modifications involve reestablishing the auxiliary water systems (AWS) in an attempt to remedy the problem of fish attraction at the higher operational flows, between about 400 and 600 cfs. The AWS will provide an additional 12 cfs to the fishway entrance, increasing the amount of flow discharging from the fishway. However, sedimentation and some clogging with debris is likely to occur on the AWS intake grille, requiring occasional cleaning.

Annual cleanout of sediment in the entrance bay will likely be required for Level 3 modifications. The entrance bay is prone to sedimentation caused by backwatering from the tailwater pool during large flow events. Sedimentation in the entrance bay may create surging and excessive velocities through the diffuser grate, located on the floor. If several feet of deposition occur, flow from the AWS through the diffuser could become completely blocked.

Alternative B

Alternative B proposes the most natural looking fishway. It would be constructed from bedrock, with limited to no use of concrete. It would have chutes between pools with 2 to 3-foot drops, which are beyond the ODFW and NMFS NW maximum drop criteria of 1-foot but similar to the drops found throughout Steamboat Creek upstream and downstream of the falls. However, the other fish passage criteria for pool depths and EDF are met across a wide range of streamflows. This alternative could provide suitable fish passage up to streamflows of 440 cfs, or greater. As currently proposed, it would only be functional during moderate and high flows, with the existing fishway becoming the primary fish passage facility once streamflows drop below about 75 cfs. This would generally occur in July. Making the bedrock fishway operable during lower flows may compromise operations of the existing fishway. The precise range of operational flow would be determined in final design.

The existing fracturing, or jointing, in the bedrock is expected to facilitate conventional excavation of the bedrock in 2- to 4-foot by 4-foot by 4-foot blocks. Fishway alignment carefully follows orientation of bedrock jointing. Because the jointing in the existing bedrock will be used to create the pools and pool crests, it may be difficult to obtain the exact dimensions desired for fish passage. Rock shaping with small charges and limited application of concrete could be used to obtain more accurate dimensions and address over-excavated areas.

Alternative C

Alternative C involves excavation of bedrock along the north side of the falls, similar to Alternative B. The main difference is that the bedrock fishway would use concrete weirs keyed into the excavated bedrock rather than bedrock chutes. Use of concrete weirs makes it possible to have much finer control of the fishway hydraulics and provides less restriction on the fishway alignment. The fishway would meet existing ODFW and NMFS NW fish passage criteria. Drops would be exactly 1 foot between weirs to meet passage criteria. The pools between the weirs would have a residual pool depth of 3 feet and would have adequate volume to dissipate the flow's energy up to a streamflow of about 420 cfs. Although concrete has a lower aesthetic value than bedrock, it will be easier to achieve the exact dimensions necessary to provide fish passage across a range of flows.

Recommendations

Based on findings in this study, we recommend implementing both Alternative A Level 1 modifications and Alternative C. Combined, these alternatives provide redundancy and year-round passage for winter and summer steelhead and spring Chinook. Though Alternative B would provide similar fish passage conditions with increased aesthetic qualities, it assumes an increased level of risk regarding the ability to shape bedrock to the desired dimensions during construction.

1 Background

1.1 Introduction

Steamboat Creek lies within the Umpqua National Forest and is a major tributary to the North Fork Umpqua River, Oregon. The stream supports runs of summer and winter steelhead and spring Chinook salmon. Steamboat Falls is located on Steamboat Creek approximately six miles upstream from its confluence with the Umpqua River. The drop across the falls is between 20 and 25 feet. In 1958 the Oregon State Game Commission (later renamed the Oregon Department of Fish and Wildlife, ODFW) constructed a fishway facility along the south bank of Steamboat Falls to improve fish passage (Figure 1-1).

Prior to its construction, anecdotal evidence and drawings of the fall's historic morphology suggest adult steelhead, and possibly Chinook salmon, were able to ascend the falls within a limited range of flows. The route most suited for natural fish passage over the falls was along the south bank, where a steep bedrock chute would likely have provided flow conditions suitable for adult steelhead and salmon to swim through. Following construction of the fishway along the south bank of the falls, this potential natural passageway was eliminated, forcing fish to utilize the new fishway to migrate upstream.

The fishway is prone to plugging with sediment and small debris on an annual basis. The fishway facility was modified by ODFW in 1985 to reduce problems with sedimentation. Despite these modifications, the fishway is still frequently plugged by early winter. This shuts off nearly all the flow to the fishway, impeding fish passage over the falls. The fishway is typically unplugged by staff from ODFW and volunteers in late June or early July, when flows have receded to safe levels for persons to enter the fishway enclosure (refer to **Appendix A** for site photographs).

The fishway is often plugged during periods when winter steelhead, and possibly summer steelhead that hold in downstream pools during the previous summer, attempt to pass over Steamboat Falls to reach spawning grounds in the upper watershed. Additionally, large numbers of summer steelhead typically arrive at the base of the falls in May and June, and must hold there until the fishway is unplugged. During this period steelhead are observed leaping repeatedly at the base of the falls. After the fishway is unplugged, the summer steelhead have difficulty finding the fishway entrance, presumably due to poor attraction conditions.

The fishway lies within the Umpqua National Forest but is owned and operated by ODFW. The fishway is accessed from the southern bank through the adjacent Forest Service Campground, or along the northern bank from a turnoff on Steamboat Creek Road. The pools located above and below the ladder are a popular swimming and recreational area during the summer months.

Figure 1-1. Existing enclosed fishway and spillway at Steamboat Falls.

1.2 History of Steamboat Falls Fishway: Construction, Repairs, and Modifications

In 1958 the Oregon State Game Commission constructed the fishway facility along the south bank of Steamboat Falls. The fully enclosed fishway ascends approximately 20 vertical feet, and has three switchbacks to fit within a relatively small footprint of about 100 feet long by less than 30 feet wide (Figure 1-2). Construction of the fishway required large-scale excavation of bedrock at the face of the falls. In places, bedrock was excavated to a depth of more than 20 feet.

The fishway was designed primarily as a pool and weir type ladder, with orifices at the exit (upstream end) and upper two bays to regulate flow into the fishway with changing headwater levels. To control the headwater level at the fishway exit, a concrete spillway was built on top the bedrock. An auxiliary water system (AWS), with an intake at the crest of the spillway, supplied additional water to the fishway entrance bay (downstream end) to increase fish attraction. A copy of the original design plans are provided in **Appendix B**.

During the flood of 1964, the pools throughout the fishway filled with sediment and exterior portions of the fishway were severely damaged, including the AWS, hatches, and concrete spillway. The total volume of sediment deposited within the fishway was estimated to be 300 cubic yards. Repairs were made in 1966 or shortly after. They included reconfiguration and reconstruction of the spillway, addition of a sediment sluice gate and pipe for the fishway headwater pool, and relocation of the auxiliary water system (AWS) intake. A copy of the 1966 repair plans are provided in **Appendix C**.

In 1985 the fishway was modified in an apparent effort to reduce sedimentation and improve hydraulics within the fishway. Modifications included (1) replacement of the head gates at the fishway exit with guides for stoplogs, (2) plugging of the two orifices and cutting a 1.4-foot wide vertical slot into the bulkhead separating the second and third bay from the exit, and (3) cutting a 1.5-foot wide vertical slot into weirs 6 through 18 that extends down to the fishway floor. Minor repairs were also made to the concrete spillway. A copy of the 1985 as-built drawings for the fishway modifications are provided in **Appendix D**.

ODFW continues to perform minor repairs to the concrete spillway to keep exposed rebar from becoming a public hazard (L. Jackson Per. Com., 2009). Additionally, ODFW has largely sealed off the AWS intake with a steel plate to reduce impingement of juvenile salmonids and lamprey.

1.3 Project Scope

The North Umpqua Foundation (TNUF), along with the Umpqua National Forest and Oregon Department of Fish and Wildlife (ODFW), Douglas County, and several environmental groups have initiated the "Steamboat Falls Fish Passage Project," with the goal of improving upstream passage conditions over the falls throughout the upstream migration season for steelhead trout and Chinook salmon.

Planning and preconstruction efforts leading to implementation are envisioned to occur in three phases. The first phase is development of conceptual design alternatives. The second phase is to select a preferred alternative and complete the NEPA (National Environmental Policy Act) process. The third phase is to complete final design and permitting. Following this, in-stream construction would be completed and subsequent effectiveness monitoring would be initiated.

TNUF has requested the services of Michael Love & Associates (MLA), working with Winzler & Kelly and The Galli Group, to:

- Evaluate the existing fish ladder's structural integrity and fish passage effectiveness,
- Develop at least three fish passage concept design alternatives along with associated engineering cost estimates, and
- Prepare a comparative analysis of alternatives assessing risks and benefits.

Findings from these activities are summarized in this report.

1.4 Project Goals and Objectives

The project goal is to establish reliable fish passage conditions with minimal delay during periods that adult winter and summer run steelhead and spring run Chinook salmon attempt to migrate upstream over Steamboat Falls.

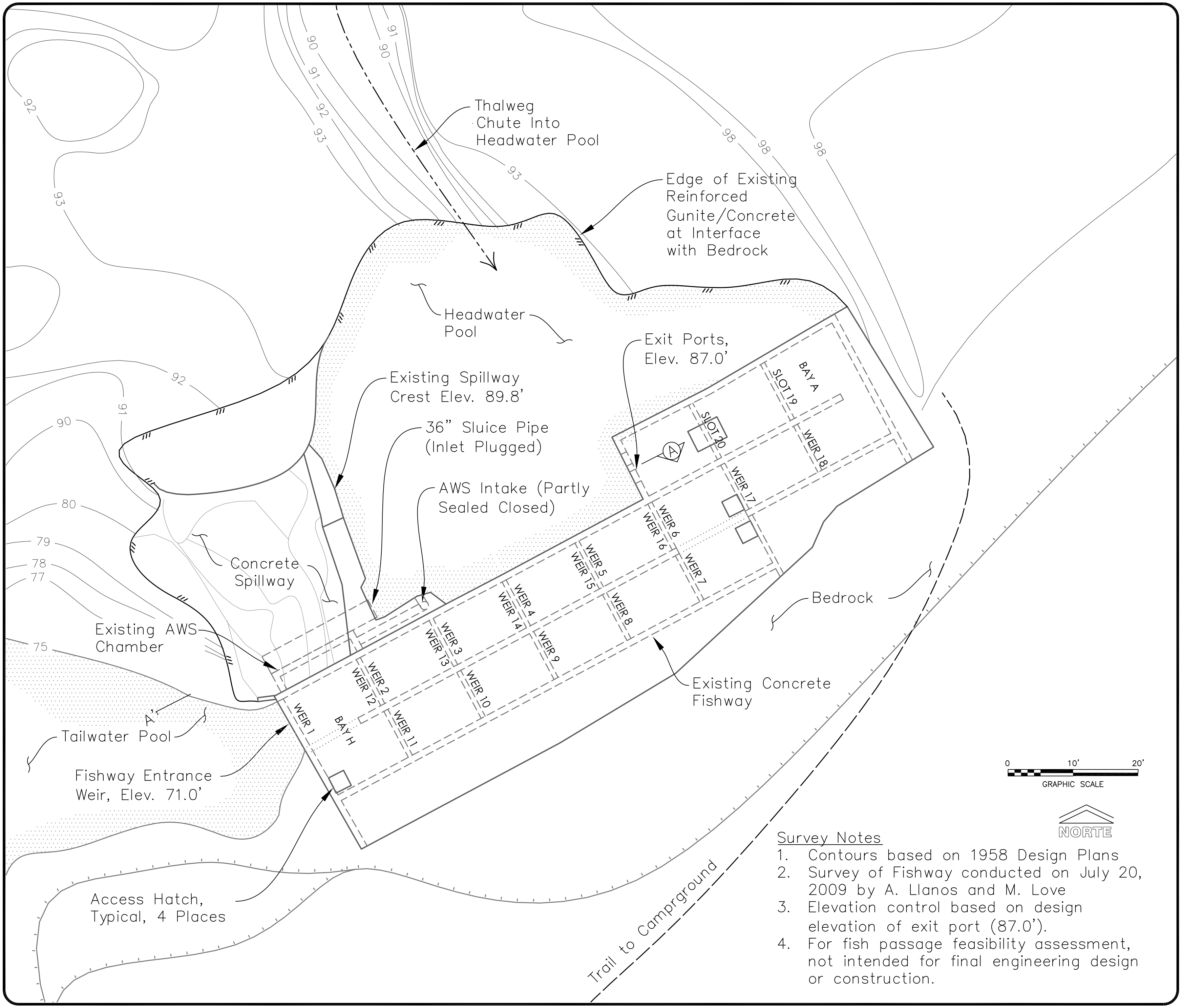
Specific objectives and considerations used to develop feasible alternatives included:

- Reducing the risk of fishway clogging with sediment and debris
- Increasing the range of operational fishway flows (i.e. passage during the winter flow regime)
- Improving fishway attraction flow
- Improving fish passage hydraulics:
    - Satisfy ODFW and National Marine Fisheries Service fish passage criteria, where possible
    - Create fish passage conditions no more challenging than conditions found within the adjacent stream channel
- Minimizing maintenance associated with debris and sediment management
- Minimizing operational requirements
- Considering public safety
- Considering recreational access to the northern portion of the falls from the campground
- Durability and a reasonable design life
- Acceptable implementation cost

1.5 Site Meeting and Field Activities

A project initiation meeting was held on July 20, 2009 and included members of TNUF and the Steamboaters (a local non-profit group), staff from the Umpqua National Forest and ODFW, Michael Love P.E. and Antonio Llanos P.E. from Michael Love & Associates, Mark Wharry P.E. from Winzler and Kelly, and Ed Busby C.E.G. and William Galli P.E., G.E. from The Galli Group. The meeting included a site visit and discussion of ongoing operations and maintenance, project goals and objectives, and project approach. At the meeting, ODFW provided copies of the original design plans and plans for subsequent repairs and modifications (**Appendices B, C, and D**).

Following the meeting, geologic field mapping was conducted by The Galli Group, and MLA staff measured fishway dimensions and hydraulic conditions. An elevation survey for use in developing design alternatives was conducted by MLA staff on the following day. The geologic field mapping and survey were used to assess current conditions and to develop and analyze various alternatives for meeting project goals, as presented in this report.



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STEAMBOAT FALLS FISH PASSAGE PROJECT
The North Umpqua Foundation

Existing Fishway

DATE	Dec. 2009
SUBMITTAL	Concept
DESIGN	Love / Llanos
DRAWN	Llanos
FIGURE	1-2

Figure 1-2. Existing fishway configuration.

2 Geology of Steamboat Falls

The project geologic and geotechnical report prepared by the Galli Group describes the bedrock geology of Steamboat Falls in detail (**Appendix E)**. This chapter summarizes the report and provides an overview of the bedrock geology at Steamboat Falls as it applies to development of alternatives that involve excavation of the bedrock.

Steamboat Falls is formed of strongly welded ash-flow tuff bedrock that is light brown on weathered surfaces and light gray on unweathered surfaces. In the project area, developed joint, or fracture, discontinuities have developed in the welded ash-flow tuff bedrock. Discontinuities are defined as semi-planer features in rock mass that form a natural weakness along which displacement can occur.

2.1 Bedrock Jointing

The project geologist mapped discontinuities in the project area and identified three distinct joint sets:

Set 1. The most strongly developed joint set, referred to as the "N25W" set, strikes along a line running southeast-northwest at approximately 25^0 west of north. It has a dip angle (measured from the horizontal) ranging from 70^o to vertical. The typical spacing between N25W joints ranges from one to four feet.

Set 2. The second joint, referred to as the "East" set, strikes along a line running southwest-northeast at 60^o to 75^o east of north, and dips at 65^o to vertical. The East set is most defined along the south side of the falls and typical spacing between East joints ranges from three and four feet.

Set 3. The third joint set is relatively horizontal, and is referred to as the "Flat set". It has an undulating dip that is most frequently between 15^o and 18^o. This set is well developed and varies in thickness.

The face of the falls north of the fishway appears to have developed parallel to the strongly developed main N25W trending fracture set (Figure 2-1). The remaining two fracture sets ("Flat" and "East") have formed small blocks that can be detached from the face, and a stepped face to develop, with 2 to 4 foot step-ups. The stepped face of the falls along this 3-set joint pattern prevents it from becoming over-steepened.

2.2 Effects of Jointing on Bedrock Excavation

It is likely the pattern of three joint sets forming detached blocks will allow excavation of the bedrock to proceed back from the face of the falls if an alternative is chosen that requires excavation. The "weakest" developed joint set north of the structure appears to be the "East" set. It has a spacing of approximately 4 feet. This set should occur frequently enough to allow the excavation of blocks. This set appears to be better developed (or exposed) south of the structure in the south bank. The "flat" set is well developed and varies in thickness; it was observed to have very thin layers north of the structure, providing smaller and/or thinner dimension blocks to be excavated. Actual joint sets may be irregularly spaced, and the size of excavated blocks can vary accordingly. It is anticipated that the largest blocks will be on the order of 4 feet x 4 feet x 4 feet. Smaller blocks, on the order of 1 foot thick x 4 feet wide x 2 to 4 feet high may be present in many locations. Excavation of the bedrock blocks will create a stepped cut face as a finished surface.

A considerable amount of bedrock was excavated when the existing fishway was constructed along the south side of the falls in 1958. Based on the original plans (**Appendix B**), the bedrock was excavated to a depth of 20 feet or more in some locations. The plans identify the disposal area for the excavated bedrock as being along the toe of the north bank, adjacent to the Steamboat Creek Road embankment. During the site visit, MLA staff noted large block-shaped "bedrock boulders" stacked in this area; presumably the spoils from excavation of the bedrock for the existing fishway. These bedrock blocks had typical dimensions along each axis ranging between two to four feet, reaffirming the feasibility of excavating bedrock along the 3-set joint pattern.

The geologic report examined rock slope stability and concluded that the bedrock does not have a significant chance of slope failure because of the steeply dipping nature of the joints. There is some change of creating an overhanging rock face that could result in a "toppling" failure if a large area of unsupported slope is excavated in the northwest or southeast facing cut. The risk of toppling failure can be reduced by removing any overhanging faces during the excavation process.

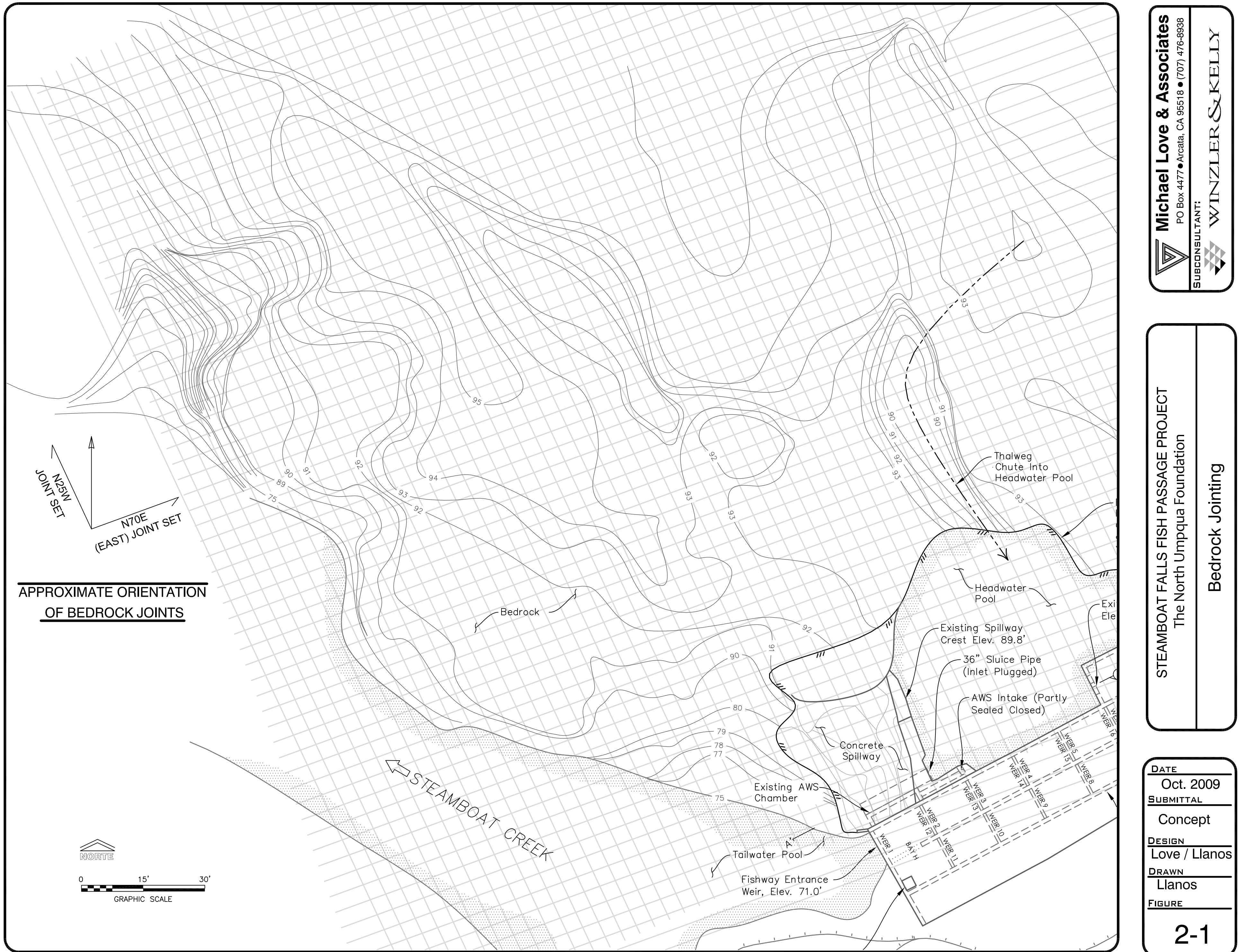


Figure 2-1. Topography of Steamboat Falls overlaid with gridlines generally oriented with the N25W and East bedrock jointing.

3 Target Fish Species and Hydrology

This project is tasked with improving upstream passage for summer and winter run adult steelhead trout (*Oncorhynchus mykiss*) and spring run Chinook salmon (*Oncorhynchus tshawytscha*).

Other aquatic organisms that may utilize a fish passage facility at Steamboat Falls include Pacific lamprey (*Lampetra tridentate*) and costal cutthroat trout (*Oncorhynchus clarki clarki*). However, they are not target species for improved passage. Pacific lamprey are presumed to climb over the face of the falls, both historically and under current conditions. Except for infrequent occurrences, costal cutthroat trout would probably have been blocked at the falls prior to construction of the fishway (See Section 3.2). They are now likely able to pass through the existing fishway under limited flow conditions.

3.1 Timing of Upstream Migration for Steelhead and Chinook Salmon

Developing and evaluating upstream passage alternatives for adult summer and winter steelhead and spring run Chinook salmon requires an understanding of the timing for upstream migration relative to season and streamflow. Information about the timing of different fish runs in Steamboat Creek includes:

(1) US Forest Service winter and spring steelhead spawner surveys in tributaries to Steamboat Creek upstream and downstream of the falls

(2) TNUF coordinated daily observations from mid-spring to mid-fall of fish in over-summer holding pools upstream of the falls

(3) Anecdotal observations and accounts of fish leaping at the falls

(4) General knowledge of fish life histories within the North Umpqua Watershed by ODFW and US Forest Service fisheries biologists, and local anglers.

3.1.1 Summer Steelhead

The primary spawning period for summer steelhead within the North Umpqua basin is believed to be in December and January. However, these fish leave the ocean the previous spring and hold in the river and in larger tributaries over the summer and fall before spawning. Based on the limited information available, it is apparent that summer steelhead in the North Umpqua basin employ multiple over-summering strategies that lead to a wide range in the timing of their arrival at Steamboat Falls.

When the existing fishway is blocked with sediment from winter high flows, as is common, summer steelhead are observed gathering in the large pool below, and repeatedly leaping at Steamboat Falls in late May and June. Once the fishway is unplugged, they migrate upstream to Lower Bend Pool and Big Bend Pool on Steamboat Creek. These pools are located near the confluence with Big Bend Creek, which produces much colder water than Steamboat Creek. As a result, these two pools have water temperatures much more suitable for over-summering steelhead than further upstream or downstream on Steamboat Creek. Additionally, low-flow barriers prevent the fish from migrating further upstream until flows increase.

Since 1999, the observer for the TNUF's FishWatch program, Lee Spencer, has resided at Big Bend Pool from mid-spring through mid to late fall to discourage potential poachers and provide educational information to visitors. His detailed notes document summer steelhead continuously arriving at the pool from as early as May (Table 3-1), and continuing to come and go throughout the summer and fall. By the end of summer, several hundred steelhead are regularly holding in pools upstream of the falls. This indicates that steelhead are readily able to migrate upstream through the existing fishway at Steamboat Falls during the low flows of late spring and summer months, when the fishway is unblocked. In 2006, as in other years, no steelhead were observed upstream of the falls until the fishway was unblocked.

Summer steelhead also over-summer in downstream pools, including those below Steamboat Falls and Little Falls on Steamboat Creek, and in pools throughout the North Umpqua River, which has more suitable water temperatures for steelhead during the summer months. Many of these summer steelhead are believed to migrate up Steamboat Creek during late fall freshets on their way to spawning grounds in the upper reaches of Steamboat Creek and its tributaries.

3.1.2 Spring Chinook Salmon

Spring Chinook generally arrive within the North Umpqua Basin in April and spawn in September and October (Jeff Dose, personal communication). The observer at Big Bend Pool regularly documents a handful of spring Chinook arriving during the summer, with occasional spawning just below the pool.

3.1.3 Winter Steelhead

Unlike summer steelhead, the common belief is winter run steelhead migrate upstream from the ocean to their spawning grounds as swiftly as flow conditions allow. They are thought to run up Steamboat Creek from late December into May, swimming upstream of Steamboat Falls when the fishway is passable.

Records of steelhead spawner surveys conducted by US Forest Service in the winter and spring of 2000 through 2006 documents spawning upstream of Steamboat Falls occurring from early January through mid-May. Although these fish are likely a combination of both summer and winter steelhead, the records help establish that steelhead are moving around and spawning in Steamboat Creek during this period.

Table 3-1. Range of summer steelhead observed in Big Bend and Lower Bend Pools upstream of Steamboat Falls (From Spencer, 2007).

MONTHLY RANGE IN STEELHEAD NUMBERS AT
BIG BEND & LOWER BEND POOLS

YEAR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1999								
Big Bend Pool	0	0	2-107	125-550	440-620	70-600	34-150	0
Lower Bend Pool	?	?	0	1?	1?	?	?	?
2000								
Big Bend Pool	0	2-9	3-63	69-125	93-242	140-401	108-198	100-228
Lower Bend Pool	?	5	37-140	2005	125-185	20-225	1-38	0
2001								
Big Bend Pool	1-2	1-16	9-97	106-145	155-619	175-700	2-225	0
Lower Bend Pool	0	2-30	24-170	97-300	120-300	50-238	4-48	0
2002								
Big Bend Pool	1-3	5-107	99-230	244-346	77-349	384-434	20-454	140-271
Lower Bend Pool	0-1	1-10	9-50	37-103	30-84	12-47	0	0
2003								
Big Bend Pool	5-8	5-101	100-241	150-615	340-591	394-439	1-391	0
Lower Bend Pool	0	0	2-30	4-39	11-28	15-37	4-81	0
2004								
Big Bend Pool	0	2-100	182-375	65-580	204-562	0-442	0-146	61-62
Lower Bend Pool	0	4-7	20-105	0-105	0-23	2-24	0-10	0
2005								
Big Bend Pool	0	3-27	43-251	302-374	329-405	322-456	1-302	1-3
Lower Bend Pool	0	2-8	4-50	55-100	120-125	35-100	1-22	—
2006								
Big Bend Pool	***ladder***	***ladder***	12-505	432-544	565-609	56-683	(5-6)-239	
Lower Bend Pool	***blocked***	***blocked***	0-8	5-23	30-(40-60)	2-67	100	

3.1.4 Summary

With both a winter and a summer steelhead run at Steamboat Falls, it is reasonable to assume that individual steelhead attempt to pass over the falls throughout the entire year. The summer steelhead attempt to pass over Steamboat Falls beginning in May, with the largest numbers arriving in June and July. Summer steelhead continue using the existing fishway move upstream throughout late summer and early, but in lower numbers. Spring Chinook also migrate over the falls during this period.

Beginning with the first fall freshets, summer steelhead over-summering downstream of Steamboat Falls may begin migrating over the falls, with increasing numbers of summer steelhead moving upstream in December. By January, both summer and winter steelhead can be migrating over Steamboat Falls. If the fishway remained operable and flows are suitable, the winter steelhead run can continue into May.

3.2 Historical Fish Passage Conditions

Prior to construction of the fishway in 1958, anecdotal evidence and drawings of the fall's historic morphology suggest that adult steelhead, and possibly Chinook salmon, were able to ascend the falls within a limited range of flows. The route most suited for natural fish passage over the falls was along the south bank, where a steep bedrock chute might have provided flow conditions suitable for adult steelhead and salmon to swim through. In a 1942 photograph of the falls (Figure 3-1), flow through this bedrock chute is clearly visible during what appears to be moderate flow conditions. At this streamflow, flow in the chute appears to be excessively turbulent, making upstream fish passage difficult to impossible.

3.2.1 Historical Bedrock Chute Passageway

The original 1958 design plans show the topography of Steamboat Falls in detail before it was altered to construct the fishway (Figure 3-2). The topography shows a bedrock chute along the south bank, where the fishway is currently located. From the eastern end of the plunge pool below the falls, fish would need to leap vertically about 8 to 10 feet, landing onto the bottom of the bedrock chute. From here, they either would have been washed back into the plunge pool or have swum up the chute, which was about 65 feet long and sloped at about 10 percent. At the top of the chute was a series of pools and small drops that lead to the top of the falls.

The leap height of 8 to 10 feet is within the leaping abilities of adult steelhead (Stuart, 1962), but may have been excessive for an adult Chinook salmon. The difficulty steelhead had swimming up the chute would depend partly on the heterogeneity of the bedrock within the chute. If the bedrock was rough with small protrusions, fish could swim through areas of lower velocities, allowing them to swim up the chute during higher flows than if it were relatively smooth. It is difficult to determine at which flows the chute may have been passable, but based on the topography, the 1942 photograph, and an understanding of streamflow variability at the site, it is reasonable to assume that passage would have been most suitable during spring and early summer baseflows, and possibly during periods in the fall following the first freshets. At higher flows, the passageway would likely have been too fast and turbulent. At the lowest flows during the year, the depth in the chute would have been quite shallow, and the steelhead may not have been able to have their bodies sufficiently submerged to gain adequate propulsion.

3.2.2 Alternative Passageway

An alternative passageway was located just to the west of the bedrock chute. A sizable bedrock pool, eleven feet deep, was located on a bedrock shelf between the base of the falls and the main plunge pool below the falls. Fish would have been able to reach this pool during lower flows. From here, they would need to leap vertically 10 feet and then swim across shallow flow over relatively flat bedrock to reach the series of pools and small drops that lead to the top of the falls. This 11-foot deep pool was filled with rock and concrete as part of the 1966 repairs to the fishway and is now the bench below the existing spillway.

This alternate passageway would have only been suitable when a small amount of flow was plunging over the falls and into this small pool. With too much flow, the pool would have become extremely turbulent. At low streamflows, during the late summer, all of the flow would have gone down the bedrock chute, drying out this passageway. Therefore, it is reasonable to assume steelhead would have only been able to utilize this passageway during late spring and early summer baseflow conditions.

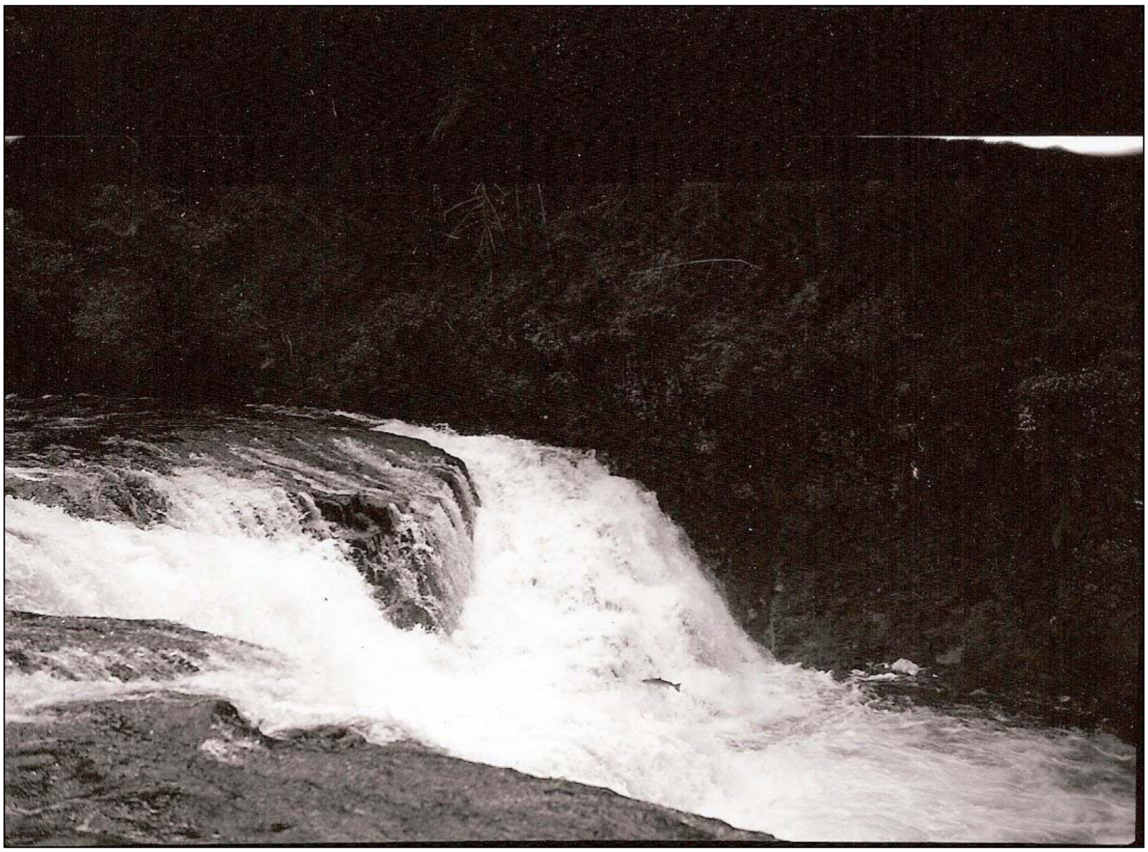


Figure 3-1. Steelhead leaping at the Steamboat Falls in 1942, prior to construction of the concrete fishway. Provide by The North Umpqua Foundation.

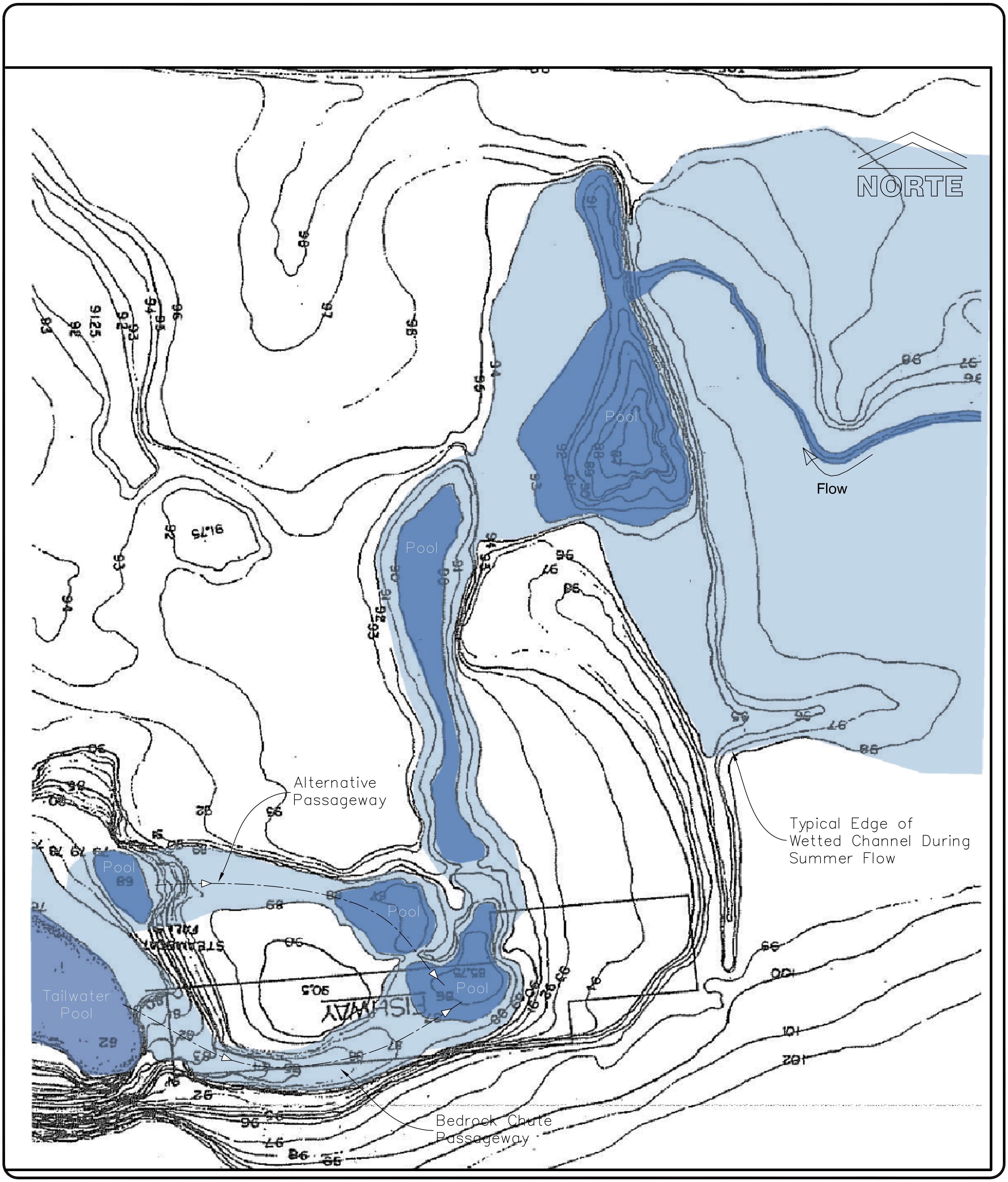


FIGURE
3-2

STEAMBOAT FALLS FISH PASSAGE PROJECT
The North Umpqua Foundation

Historical Morphology

Michael Love & Associates
PO Box 4477 • Arcata, CA 95518 • (707) 476-8938
SUBCONSULTANT:
WINZLER & KELLY

Figure 3-2. Historic topography of Steamboat Falls, from the original 1957 design survey. Approximate waters edge during summer baseflow is shaded light blue. Pools are shaded dark blue.

3.3 Hydrology of Steamboat Creek

Steamboat Creek, a tributary to the North Umpqua River, drains a relatively low elevation basin in the Western Cascades of South-Central Oregon. At its mouth, it has a drainage area of approximately 227 square miles. Steamboat Falls is located on Steamboat Creek, approximately 6 miles upstream from the confluence with the North Umpqua River. At this location, the contributing drainage area is approximately 133 square miles.

The elevations along the upper crest of the basin range between 5,400 feet and 5,500 feet, placing it in a transitional zone of snow and rain-on-snow during the winter, and rainfall during the spring and early fall. The lower portion of the basin is below 4,000 feet elevation, and the hydrology is driven predominately by rainfall. As is typical throughout this hydrologic region, little precipitation falls between June and September. Snowpack in the upper basin is typically small and melts relatively early in the spring due to its low elevation, causing baseflows in Steamboat Creek to drop significantly in July and stay low until the onset of fall rains.

Evaluation of the existing fish passage conditions and development and evaluation of fish passage alternatives for Steamboat Falls requires a detailed understanding of the seasonal variability in streamflows at the falls as it relates to the timing of fish movement. Streamflows in Steamboat Creek are gaged by the US Geologic Service (USGS) at Station No. 14316700 (Steamboat Creek near Glide), located just upstream from the confluence with the North Umpqua River. The station records both daily average and annual peak flows. The available record length is 53 years, running continuously from water year 1957 to 2009.

There are no measurements of flow in Steamboat Creek at Steamboat Falls. Instead, the streamflows at the falls were approximated using the flows recorded from the USGS gaging station scaled to the drainage area of the creek at the falls. Using these scaled flows, both daily average and peak flow conditions at Steamboat Falls were estimated.

3.3.1 Streamflows and Fish Passage

A flow duration analysis is the most common means of describing streamflow characteristics for fish passage design and evaluation. The analysis uses daily average flow data for the entire year or limited to a specific time of year. Exceedance probabilities are typically used to describe the duration of flow. For example, streamflows are greater than the 50-percent annual exceedance flow, on average, half of the time throughout the year. Exceedance probabilities and their associated flows are used to construct flow duration curves for the period of interest.

A flow duration analysis was conducted for Steamboat Creek at Steamboat Falls to aid in evaluating existing and proposed fish passage conditions. Both ODFW (2006) and NMFS NW (2008) recommend designing upstream passage facilities to provide fish passage at streamflows falling between the 95 percent and 5 percent exceedance flows during the migration period. Under these guidelines, the fishway would be operating 90 percent of the time during the migration period. Five percent of the time flows would be too low and the other 5 percent of the time flows would be too high for the fishway to operate.

For Steamboat Falls, the fish migration period is relatively continuous (See Section 3.1). However, it can be divided into two distinct periods. From May through July migration is predominately summer steelhead that over-summer upstream of the falls and spring Chinook. From December through April the fish migrating over Steamboat Falls are predominately winter steelhead and summer steelhead that over-summer downstream of the falls.

To evaluate the variability in streamflow during fish migration periods, three flow duration curves were constructed: annual, May through July for the "summer-run", and December through April for the "winter-run", which includes late-arriving summer steelhead (Figure 3-3). Based on ODFW and NMFS NW criteria, low and high fish passage flows would range from 30.5 cfs (cubic feet per second) to 638 cfs for the summer-run in May through July, and 122 cfs to 2,292 cfs for the winter-run in December through April. Using the annual flow duration curve (because fish are observed moving year-round), the range of fish passage flows would be between 24 cfs and 1,684 cfs.

These are an extremely wide range of flows for a fish passage facility to operate, especially at a "run-of-the-river" site such as Steamboat Falls. It is important to consider that these design flow guidelines are typically applied to (1) much smaller watersheds, resulting in a much narrower range of flows, and (2) passage at reservoirs and other structures where streamflows are controlled. It is not reasonable to expect the existing fishway or any of the alternatives for Steamboat Falls will be operational across this entire flow range.

Flow duration curves were constructed for each month of the year to better assess flow conditions during the height of summer steelhead migration and during late fall and winter migration periods (**Appendix F**). Variability in water years (Oct. 1 through Sept. 30) was also examined by separating years into Wet, Average, and Dry based on the annual yield. Annual yields in the highest and lowest 10 percentile were designated as Wet and Dry years, respectively. Plotting of the hydrographs for a typical year from each category demonstrates the annual and inter-annual flow variability (Figure 3-4).

Flows in June, a critical migration period for summer steelhead, are typically between 70 cfs (90 percent monthly exceedance flow) and 300 cfs (10 percent monthly exceedance flow), depending on both the time of month and the amount of late spring rainfall and snowpack left in the upper basin. By July, flow is consistently below 100 cfs, and averages between 30 cfs and 70 cfs for 65 percent of the month. Therefore, flows from roughly 30 cfs to 300 cfs were used to evaluate existing conditions and to develop alternatives for passage of summer steelhead.

For summer steelhead and winter steelhead running up Steamboat Creek between December and April, streamflows at the falls during this period typically remain above 100 cfs, 300 cfs, and 400 cfs during Dry, Average, and Wet years, respectively (Figure 3-4). Therefore, if upstream passage for these fish is desired, suitable fish passage conditions should be provided at streamflows from 100 cfs to at least 400 cfs.

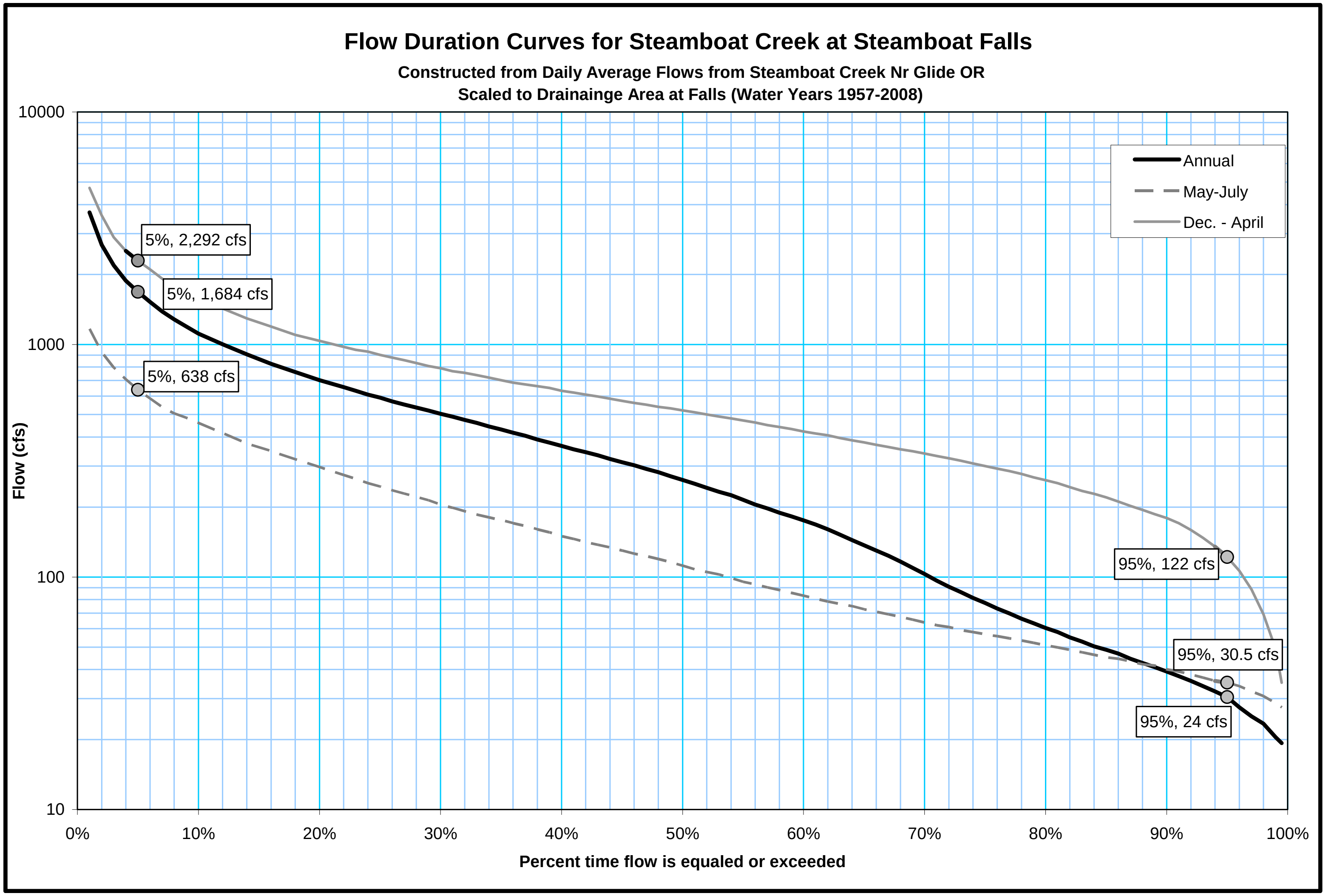


Figure 3-3. Annual, "summer-run" and "winter-run" flow duration curves for Steamboat Creek at Steamboat Falls. The 5% and 95% exceedance flows are provided for each curve.

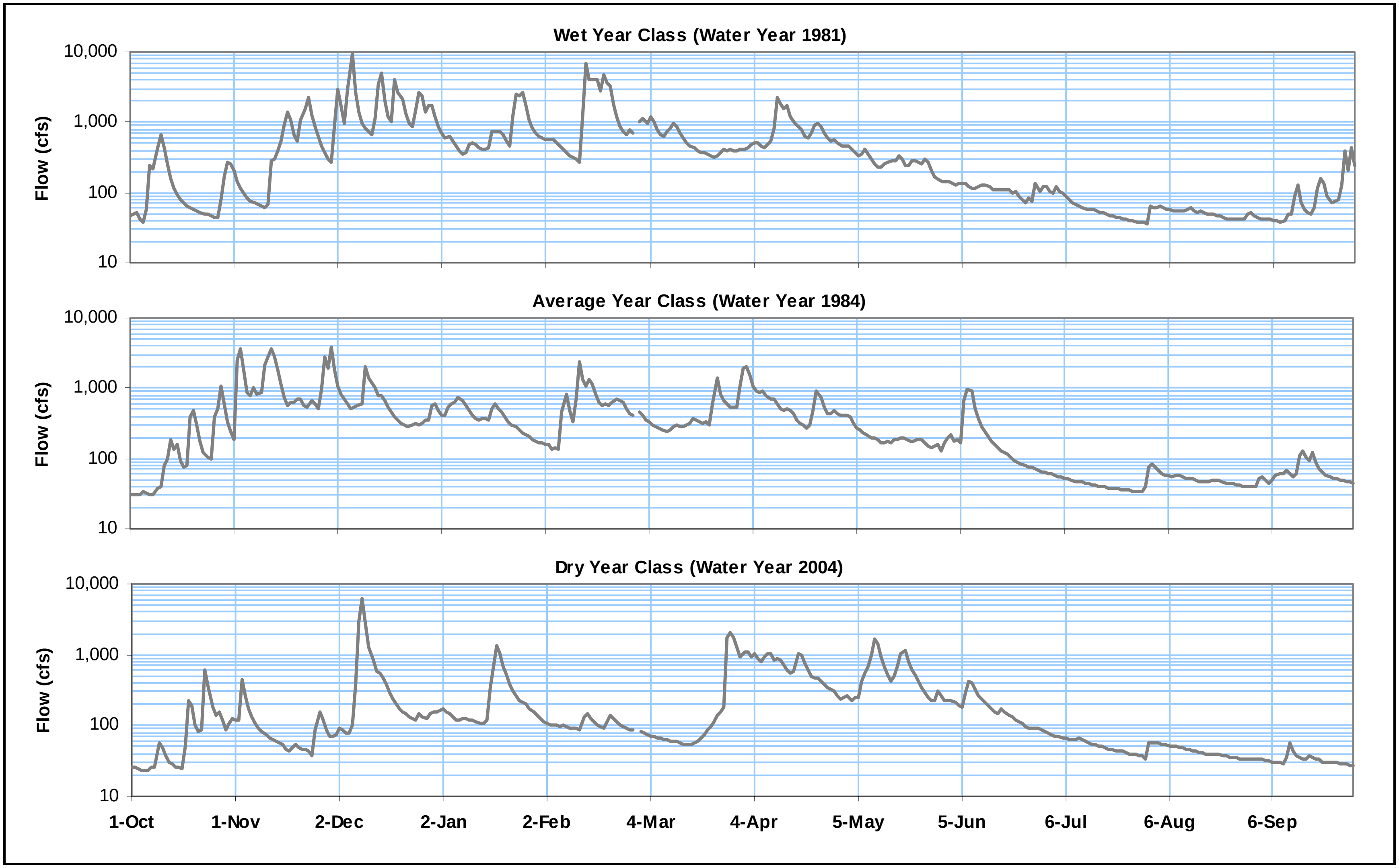


Figure 3-4. Hydrographs for flow at Steamboat Falls for statistically Wet, Average, and Dry water years. Constructed with daily average flows from USGS Station No. 14316700 (Steamboat Creek Nr Glide) and scaled to the drainage area at Steamboat Falls.

3.3.2 Peak Flows

Annual peak flows recorded at the gaging station on Steamboat Creek and scaled to the drainage area at Steamboat Falls were analyzed to characterize the frequency and magnitude of flow events at the falls. These results provide insight into the flows that likely transport the bulk of the bedload in Steamboat Creek, and how different alternatives might fare during large floods. It also adds perspective to the limited range of flow that fish passage is a concern relative to the total range of flows experienced at the site.

To estimate return periods of peak flows, a probabilistic analysis was conducted using methods outlined in Buellton 17-B (USGS, 1982). Results are summarized in Table 3-2 and calculations are provided in **Appendix F**.

Streamflows with return periods between 1.2 and 1.5-years are often geomorphically characterized as "bankfull flow" flows. At these flows the stream's larger bedload tyically becomes fully mobile (Leopold et al., 1964). It is reasonable to assume that entrainment of sediment into the fishway primarily occurs at streamflows of roughly 4,500 cfs and higher.

The estimated peak flow at Steamboat Falls during the 1964 flood, the largest flood on record in Steamboat Creek, is 29,900 cfs; greater than the estimated 100-year peak flow. This event caused severe damage to the spillway and hatches, and filled the fishway with sediment. The second largest event on record was the 1996 flood, with an estimated peak flow of 18,400 cfs, it had an approximate return period of 25 years.

Table 3-2. Peak flows and associated return flows at Steamboat Falls.

Return Period	1.2-year	1.5-year	2-year	5-year	50-year	100-year
Peak Flow	4,500 cfs	6,300 cfs	8,100 cfs	12,500 cfs	21,000 cfs	23,200 cfs

4 Parameters for Evaluation, Design and Comparison

The following section describes parameters used to evaluate performance of the existing fishway and to develop, evaluate, and compare the feasibility and performance of alternatives. General fishway features and terminology, as it applies to the existing fishway, are presented in Figure 1-2.

The Oregon Department of Fish and Wildlife (ODFW) and the National Marine Fisheries Service Northwest Region (NMFS NW) have standards and criteria for fishways (ODFW, 2006; NMFS NW 2008). ODFW commonly defers to NMFS NW standards and criteria in areas not covered by ODFW standards. Table 4-1 lists criteria used to evaluate the existing fishway and develop alternatives for this project. Other ODFW and NMFS NW criteria concerning fishway design flows, dimensions and the AWS were also used but are not listed in the table.

Table 4-1. Summary of ODFW and NMFS NW criteria for fishway design.

Parameter	Criteria	Source
Upper Design Flow	5% Exceedance Value Daily Flows During Migration Season	ODFW/ NMFS NW
Lower Design Flow	95% Exceedance Value Daily Flows During Migration Season	ODFW/ NMFS NW
Attraction Flow	Minimum 10% For Total Streamflow <1,000 cfs	NMFS NW
Maximum EDF in Fishway Pools	4.0 ft-lb/s/ft^3	ODFW/ NMFS NW
Minimum Water Depth for Swimming	12 inches Adult Salmonids	ODFW/ NMFS NW
Minimum Pool Depth	2 feet if Leaping Required	ODFW
Drop at Fishway Entrance	1.0 to 1.5 feet in Streaming Flow	NMFS NW
Maximum Drop Within Fishway	12 inches Adult Salmonids	ODFW/ NMFS NW
Maximum Water Velocity at Fishway Transitions	8 feet/second	ODFW
Minimum Slot Width	12 inches Adult Salmonids	ODFW/ NMFS NW
Turning Pools Greater Than 90 Degrees	Double the Centerline Length of Straight Pools	ODFW/ NMFS NW
Minimum Orifice Dimensions	15" High and 12" Wide	NMFS NW

4.1 Fish Attraction

Providing suitable attraction conditions for adult steelhead to find the entrance of the fishway is a key design parameter. Attraction is important throughout the entire fish passage design flow range. For this project, fishway attraction depends on the percentage of the total streamflow that is contained within the fishway, the location and orientation of the fishway entrance (downstream end of the fishway), and potential for distraction or confusion generated from flow that plunges over the falls, spillway, or fishway roof, rather than from the flows contained in the fishway. A water surface drop across the fishway entrance can be used to produce a jet of water that penetrates into the tailwater pool to help fish locate the entrance. An auxiliary water system (AWS) can also be used to supply additional flow to the fishway entrance to improve attraction at higher flows.

In larger stream systems, such as Steamboat Creek, fishways can provide suitable attraction if at least 10 percent of the total streamflow discharges from the fishway entrance. However, the larger the proportion of flow from the fishway, the more likelihood fish will find the fishway entrance with minimal delay.

4.2 Turbulence and Energy Dissipation Factor (EDF)

Turbulence is associated with the dissipation of the flow's energy. In fishways containing weirs, slots, or orifices, energy is dissipated through turbulence within the pool below each water surface drop. Turbulence can become a migration barrier by causing fatigue and disorientation to the fish. The Energy Dissipation Factor (EDF) is a measure of turbulence, and is the calculated rate energy is dissipated within a discrete volume of water. The EDF is dependent on the fishway flow, height of the water surface drop, and the volume of the pool. Turbulence can also be beneficial for scouring and transporting sediment within a fishway. A low EDF at higher flows can indicate areas that may be prone to sedimentation.

4.3 Water Surface Drop Heights

Recommended maximum water surface drop over each weir, or across a slot or orifice, should not exceed 12 inches for adult salmon and steelhead. However, they are known to leap much higher than 12 inches to pass over both natural and artificial obstructions, including numerous small drops and falls on Steamboat Creek and the North Umpqua River. If suitable conditions exist, it is not uncommon for steelhead to leap over drops as high as 8 feet or more, but at these higher drops it often takes several attempts before being successful (Stuart, 1962). Drops of 12 inches generally minimize the number of failed attempts and allow adult salmon and steelhead to swim through the drop rather than leap.

4.4 Water Depths and Velocities

Water depth for a swimming fish should be sufficient to fully submerge their body. For salmon and steelhead, the recommended minimum water depth for a swimming fish is 1 foot. If the fish must leap, water depth within the pool they leap from should be greater than 2 feet.

Salmon and steelhead generally swim in three modes: sustained, prolonged, and burst (Bell, 1991). They may maintain sustained speeds for an indefinite period. Burst swimming achieves their highest speeds and can only be maintained for short periods; typically less than a minute. Prolonged speeds fall between sustained and burst and can be maintained for a limited period that typically ranges between 10 and 60 minutes. Actual swim speeds depend on species, body size, and physical condition.

Water velocities within a fishway should not exceed the fish's swimming abilities. For short hydraulic transitions in fishways, such as at the entrance (downstream end), exit (upstream end), or through a slot or orifice, salmon and steelhead are assumed to use burst swimming. In longer channels they are expected to swim at prolonged speeds. To allow resting, velocities within a pool should be low enough for them to hold position while swimming at sustained speeds.

4.5 Flow Control

Ability to control and adjust the amount of water entering the fishway is critical to obtaining the desired conditions. This involves controlling the headwater pool level (pool at upstream end of fishway) and the amount of flow entering the fishway as streamflows change. Approaches may include using stoplogs or gates at a spillway on the headwater pool and/or fishway exit, contouring the crest of the spillway to create the desired stage-discharge relationship, carefully sizing exit orifices, slots or weirs to control the amount of flow entering the fishway, using an AWS to increase flow discharging from the fishway entrance, or a combination of these methods. Ability to make operational adjustments to flow control elements allows for adaptive management of the fishway after construction.

4.6 Project Cost

A planning level Opinion of Probable Construction Cost was completed for each conceptual design alternative to allow for comparison of alternatives and to pursue funding sources. The itemized construction costs include an estimating contingency that accounts for material and construction cost volatility and uncertainties associated with the current conceptual level of this project.

Construction costs were developed with consideration of the challenges associated with site access and working within the confined space of the existing fishway structure. In addition to developing probable construction costs, costs associated with final engineering and design, bid assistance, and construction management were prepared. The final engineering and design would include preparation of the final bid package comprised of final construction plans, specifications, and the engineer's estimate of construction cost.

Preparation of the final engineering plans would include a structural assessment of the existing fishway to determine structural repairs that could increase its service.

5 Existing Fishway Conditions

An evaluation of the existing fishway was conducted to characterize fish passage conditions relative to current standards, identify areas needing maintenance or repair, and guide development of modifications to improve conditions. Activities included:

- Studying the original design drawings from 1958 (**Appendix B**), and the modification plans from 1966 (**Appendix C**) and 1985 (**Appendix D**)
- Surveying fishway elevations and measuring fishway dimensions to verify they match the design drawings
- Modeling fishway hydraulics
- Measuring hydraulic conditions during the site visit on July 20th, 2009
- Interpreting flow patterns at Steamboat Falls at varying flows using photographs
- Identifying areas of sedimentation and resulting effects on fishway performance
- Identifying portions of the fishway in disrepair

Results from these activities were then compared to current ODFW and NMFS NW standards for fish passage facilities.

5.1 Existing Fishway Configuration

The existing concrete fishway is located along the south side of Steamboat Creek (Figure 5-1). The entrance is located at the base of Steamboat Falls and discharges into the upstream end of the plunge pool below the falls (referred to as the tailwater pool). The exit is located in a concrete headwater pool near the top of the falls.

The fishway has three 180 degree turns within it, allowing it to spiral upwards while maintaining a small footprint. The fishway is fully enclosed with a sloping roof surfaced with grouted cobbles. Access into the fishway is through three hatches with fixed steel rebar rung ladders leading down to the fishway floor. Alternatively, access can be gained through the fishway entrance.

The original concrete structure was a pool-and-weir fishway. The 18 weirs are 8 feet long and 4 feet tall, and are horizontal across the crest. Each weir contains a 12 inch wide by 8 inch tall orifice at its base. The concrete weirs are 8-inches thick and have tapered crests. Drop from weir to weir is 1-foot. The bays between the weirs are 12 feet long and 8 feet wide, and have a sloping floor. The fishway contains a sediment sluice gate in Bay H, discharging directly above the entrance, to sluice sediment out of the fishway upstream of

Weir 11. The gate is actuated using a removable handle inserted through a hole in the fishway roof.

During the 1985 fishway modifications, a 1.5-foot slot extending to the fishway floor was cut into Weirs 6 through 18 (Figure 5-2), presumably to improve sediment transport. The slots are located 0.5 feet from the left wall (looking upstream) and the edges are square to the weir rather than following the standard shape and dimensions for vertical slots, as described in NMFS NW (2008) and Rajaratnam (1992). With these modifications, the existing fishway is best described as a hybrid between a vertical slot and pool-and-weir fishway.

At the top of the fishway is the exit channel, which has a level floor, two bulkheads with vertical slots cut through them (Slots 19 and 20), and two exit ports (Figure 5-2). The two orifices in the bulkhead for Slot 19 were plugged with concrete in 1985. The orifices in the bulkhead for Slot 20 were not located during the site visit and assumed to be either plugged with concrete or coarse sediment. The fishway exit consists of two adjacent 2-foot wide by 2-foot tall ports, or orifices, through the fishway wall (Figure 5-4). They connect to the headwater pool and are positioned 2 feet above the fishway floor and 1-foot above the bottom of the headwater pool. The original downward-closing slide gates on the upstream side of the exit ports, used to control flow into the fishway, were replaced with stoplog guides as part of the 1985 modifications.

Construction of the fishway required excavating into the existing bedrock to depths of 20 feet, or more. As part of the 1966 repairs, the existing headwater pool and spillway were constructed with a combination of grout with steel mesh and reinforced concrete. The concrete is shaped to blend with the bedrock. However, there is a clear interface between the two. The spillway for the headwater pool is about 30 feet wide. The low portion of the spillway crest is nearly 10-feet wide and positioned 3 feet higher than the bottom of the exit ports. The rest of the spillway crest is at the same elevation as the adjacent roof of the fishway.

To improve fish attraction, the fishway contains an auxiliary water system (AWS) designed to take water from the headwater pool and deliver it into the entrance bay between Weirs 1 and 2 to increase the amount of flow discharging from the fishway. The AWS intake is located along the outer fishway wall immediately upstream of the spillway. The intake grille has been sealed partially shut with a steel plate, making the system inoperable.

The headwater pool has a floor that slopes downward from the fishway exit toward the spillway, forming a "sediment sink" (Figure 5-3). A sediment sluice gate and pipe are located at the bottom of this sink, adjacent to and below the AWS intake. The pipe is a 36-inch diameter corrugated culvert. The actuator for the Waterman slide gate on the inlet of the pipe is located at the crest of the spillway. The pipe goes through the base of the spillway and discharges into the tailwater pool next to the fishway entrance. Installation of the sluicing system was part of the 1966 repairs, along with relocation of the AWS intake to its current location. The sluicing system was presumably installed to prevent sediment buildup in front of the AWS intake grille.

Surveyed elevations and measurements during the July 20, 2009 site visit found only minor discrepancies between the design plans and existing conditions. The most notable are the width of the slots in each weir, which are 1.5 feet wide rather than 1.4 feet. The other discrepancy was the slope and elevation of the fishway roof downstream of the exit ports. The actual roof elevation in this area is higher than shown in the 1958 design plans.

Photographs of the site are provided in **Appendix A.**

5.2 Photographic Interpretation of Flow Conditions at Steamboat Falls

Photographic interpretation of flow patterns over Steamboat Falls and in the tailwater pool provided insight into flow patterns and fishway performance, and helped guide siting of the new fishways described in Alternatives B and C. A limited number of photographs taken at varying streamflows were obtained from different sources. To use a photograph in the interpretation required knowing the time and date it was taken, to allow the corresponding streamflow to be obtained from the downstream flow gaging station (USGS No. 14316700) and scaled to the drainage area at Steamboat Falls. Photographs show a range of streamflows at Steamboat Falls between roughly 32 cfs and 744 cfs. These captioned photographs are provided towards the end of **Appendix A**.

From the photographs, it appears that at streamflows above roughly 100 cfs, a substantial amount of water goes over the falls to the north and does not reach the fishway headwater pool (Photograph 19 Appendix A). Additionally, the water level in the creek immediately upstream of the fishway is sufficiently high to begin overtopping a bedrock outcrop, allowing water to flow onto the upstream end of the fishway roof. At about this same streamflow, the headwater pool begins to overtop the fishway roof near the spillway, allowing flow to sheet across the roof and plunge into the pool at the fishway entrance. From the photographs, it appears that once streamflow is at above roughly 150 cfs, nearly half the flow bypasses the headwater pool on its route over the falls (Photograph 20 Appendix A). There is a gap in the photographs from 150 cfs and 400 cfs. At streamflows of 400 cfs and above, there is considerable flow over the spillway and adjacent bedrock falls, as well as plunging over the downstream edge of the fishway roof (Photographs 21 through 26 Appendix A). Additionally, the tailwater pool below the spillway appears to be extremely turbulent.

Interpretation of conditions at these flows provided insight into the following areas:

- The headwater pool level remains relatively unchanged with increasing streamflows above 100 cfs

- Water flowing across the upstream end of the fishway roof at streamflows of 120 cfs and greater prevents access to the fishway for inspection and maintenance until late spring or early summer (also See Section 5.4.2)

- Fish distraction or confusion could be created by the plunging flow from the fishway roof into the tailwater pool at the fishway entrance

- At flows of 450 cfs and greater, turbulence in the tailwater pool from the flow over the spillway and falls may make it difficult for fish to get close enough to the fishway entrance to locate it.

The photographic interpretation also showed that little to no flow is conveyed over the northern portion of the falls at flows of 450 cfs and lower (Photograph 23 Appendix A). Flow that does go over the northern portion of the falls comes from water spilling out of the bedrock pool immediately upstream of the fishway headwater pool.

5.3 Fishway Hydraulics

5.3.1 Measured Fishway Hydraulics

On July 20, 2009, as part of the field measurements, the water surface profile within the fishway was measured using a stadia rod. The fishway floor, with and without sediment, and the water surface were measured relative to the elevation of the fishway roof. Elevation of the roof was then surveyed with a total station on the following day. These measurements, and resulting water surface drops and EDF were used to verify the original design and as-built drawings and to calibrate the hydraulic modeling for the existing fishway.

The fishway flow and flow over the spillway were estimated from the water surface profile and validated using the recorded hourly streamflow at the downstream USGS gage. The approximate flows through the fishway and over the spillway on July 20, 2009 were 26.4 cfs and 5.0 cfs, respectively. Measurements showed the water surface drop over each weir varied considerably, ranging from 0.6 feet to 2.9 feet (Figure 5-4). Five of the pools had minimum depths less than 2 feet. EDF in the pools was extremely high, exceeding 8 ft-lb/s/ft^3 in 9 of the pools. The high EDF is a result of the large water surface drops into the pools and reduced pool volume from sedimentation.

The variability in water surface drop and EDF arises from (1) large cobbles plugging the bottom of some of the slots, (2) the inconsistent plugging of the orifices, and (3) loss of pool volume from sedimentation causing kinetic energy to be carried to the next downstream pool rather than being dissipated.

5.3.2 Modeled Fishway Hydraulics

Summary of Hydraulic Modeling Methods

The fishway performance was evaluated through a range of flows using hydraulic modeling. A numerical model for predicting fishway hydraulics was developed for this project using standard methods (Love and Bates, 2009; Bates 2001; Bates and Love, *in press*). The model was set up in a spreadsheet and the built-in solver was used to iterate a solution.

Flow through slots and orifices were modeled using standard discharge coefficients (Rajaratnam, 1992). The weirs were modeled assuming a sharp-crested horizontal weir. Discharge over the weirs was adjusted to account for submergence by the downstream pool, when applicable (Villemonte, 1947). Flow through slotted Weirs 6-18 was assumed to be uniform (equal water surface drops between weirs) and out of the influence of the tailwater pool, while water surface drops through Slots 19 and 20 and the exit ports were individually calculated and varied with flow. Weir coefficients were verified based on field measurements of the existing fishway dimensions and hydraulic conditions (See Section 5.3.1).

Computations neglected sedimentation within the bays between weirs and within the exit channel. Flow over the spillway was estimated assuming it functions as a broad crested weir during fish passage flows. The same spreadsheet model was also used to develop and evaluate proposed modifications to the existing fishway (Alternative A).

Modeled flows included a range of streamflows from 21.4 cfs to 200 cfs. The lower value encompasses the lower end of flows during the fish migration season. The higher value corresponds to when the roof is overtopped. Once the flow begins sheeting across the fishway roof, the headwater pool level and fishway flow remain relatively constant. This is beneficial for extending the operational flow range for a fishway, but limits the flow and turbulence available in the fishway to scour and transport sediment.

Model results included water surface drops, minimum pool depths, velocity through slots, EDF in each bay, headwater elevation, and attraction flow (Table 5-1 and Table 5-2). Model input and results for existing conditions are provided in **Appendix G.**

Predicted Fishway Hydraulics

The hydraulic model demonstrated that the existing slotted weirs within the fishway fail to meet current fish passage standards at all flows evaluated. At fishway flows below 25 cfs, the minimum depth in each pool, neglecting sedimentation, falls below the ODFW recommended 2 feet. At all flows evaluated, the EDF, a measure of the turbulence, exceeds the recommended maximum of 4.0 ft-lb/s/ft^3. The model predicted velocity through each slot is consistently 4.8 ft/s and the water surface drop across each weir is 1 foot, which satisfies ODFW and NMFS NW criteria. Above 32.2 cfs, the flow depth exceeds the height of the slots and flows begin to spread out on the weirs. For the flows evaluated, flows within the fishway were greater than 10% of total stream flow, thus the ODFW attraction flow criteria is met.

At a low streamflow of 21.4 cfs, close to the lowest flows expected to occur at Steamboat Falls, the headwater pool level is about 8 inches below the spillway and all of the streamflow enters the fishway (Table 5-2). At a streamflow of about 25 cfs (the 95% annual exceedance flow) water begins to flow over the spillway. At a streamflow of 140 cfs, 32.2 cfs is conveyed in the fishway and the EDF between the slotted weirs is at its lowest value, of 6.0 ft-lb/s/ft^3.

At higher streamflow, water begins going over the falls to the north, and does not reach the headwater pool. This spilt in flow makes estimation of total streamflow more difficult (See Section 5.2). The amount of flow entering the headwater pool was estimated based on photographic observations and iterative computations of headwater pool elevation, fishway flow, weir flow over the spillway and total stream flow. When the fishway flow is about 32.2 cfs, the calculated flow going through the headwater pool is 89 cfs and the total streamflow is approximately 140 cfs. At this flow, the headwater pool is sufficiently high enough to overtop the fishway roof and plunge across the fishway entrance. This could create a distraction for fish attempting to locate the entrance.

Table 5-1. Predicted performance for existing Weir 1 through Weir 18, neglecting sedimentation. Italicized values fail to meet the ODFW fish passage criterion.

Fishway Flow	21.4 cfs	25.1 cfs	28.6 cfs	32.2 cfs	33.6 cfs
Depth in Bay Upstream of Slot[1]	2.5 ft	3.0 ft	3.5 ft	4.0 ft	4.1 ft
Minimum Water Depth in Bay	*1.5 ft*	2.0 ft	2.5 ft	3.0 ft	3.1 ft
EDF (total fishway flow)	*7.0 ft-lb/s/ft^3*	*6.5 ft-lb/s/ft^3*	*6.2 ft-lb/s/ft^3*	*6.0 ft-lb/s/ft^3*	*6.1 ft-lb/s/ft^3*

[1] Water velocity through the vertical slot is 4.8 ft/s at all fishway flows.

Table 5-2. Predicted performance of existing fishway exit and headwater pool. Italicized values indicate conditions that do not meet ODFW fish passage criterion.

Total Streamflow	21.4 cfs	25.1 cfs	47cfs	140 cfs[1]	200 cfs[1]
Streamflow Entering Headwater Pool	21.4 cfs	25.1 cfs	47 cfs	85 cfs	109cfs
Fishway Flow	21.4 cfs	25.1 cfs	28.6 cfs	32.2 cfs	33.6cfs
Headwater Elevation	89.2 ft	89.8 ft	90.5 ft	91.2 ft	91.4 ft
Streamflow in Fishway	100%	100%	61%	38%	17%
Exit Port & Receiving Pool:					
Water Surface Drop	0.29 ft	0.39 ft	0.52 ft	0.65 ft	0.71 ft
Velocity through Ports	2.7 ft/s	3.1 ft/s	3.6 ft/s	4.0 ft/s	4.2 ft/s
Minimum Pool Depth	3.9 ft	4.4 ft	5.0 ft	5.5 ft	5.7 ft
EDF	0.8 ft-lb/s/ft^3	1.1 ft-lb/s/ft^3	1.5 ft-lb/s/ft^3	2.0 ft-lb/s/ft^3	2.2 ft-lb/s/ft^3
Slot 20 & Receiving Pool:					
Water Surface Drop	0.58 ft	0.61 ft	0.63 ft	0.66 ft	0.68 ft
Velocity through Slot	3.7 ft/s	3.8 ft/s	3.8 ft/s	3.9 ft/s	4.0 ft/s
Minimum Pool Depth	3.3 ft	3.8 ft	4.3 ft	4.8 ft	5.0 ft
EDF	2.4 ft-lb/s/ft^3	2.6 ft-lb/s/ft^3	2.7 ft-lb/s/ft^3	2.8 ft-lb/s/ft^3	3.0 ft-lb/s/ft^3
Slot 19 & Receiving Pool:					
Water Surface Drop	0.80 ft	0.82 ft	0.83 ft	0.85 ft	0.87 ft
Velocity through Slot	4.3 ft/s	4.4 ft/s	4.4 ft/s	4.4 ft/s	4.5 ft/s
Minimum Pool Depth	2.5 ft	3.0 ft	3.5 ft	4.0 ft	4.1 ft
EDF	*4.5 ft-lb/s/ft^3*	*4.4 ft-lb/s/ft^3*	*4.4 ft-lb/s/ft^3*	*4.4 ft-lb/s/ft^3*	*4.7 ft-lb/s/ft^3*

[1] Total streamflow is estimated assuming a portion of the streamflow bypasses the headwater pool at streamflows greater than approximately 100 cfs.

The hydraulics through the exit ports and vertical slots in the exit channel (Slots 19 and 20) were examined in detail (Table 5-2). Most notable is that the water surface drops across the exit ports and Slot 20 and resulting EDF are relatively low. For example, at an approximate streamflow of 200 cfs, the EDF is only 2.2 ft-lb/s/ft^3 downstream of the exit ports due to the small drops and deep water in these pools.

5.4 Sedimentation

Sedimentation is an ongoing issue at the Steamboat Falls fishway. Sediment has filled the headwater pool near the AWS intake and is jamming the sluice gate. Each winter, sedimentation within the exit channel frequently leads to the complete plugging of the fishway, blocking fish passage until it is cleaned. When operational, coarse sediment clogs the slots and orifices in the fishway weirs and reduces volume of the pools in the bays between the weirs, which increases turbulence.

5.4.1 Entrainment of Sediment into the Fishway

At fish passage flows, water enters the headwater pool perpendicularly to the exit ports. This results in a strong jet that passes across the face of the exit ports and into the fishway wall. The jet sours the headwater pool in front of the exit and prevents any sediment buildup in this area, but sediment accumulates in other parts of the headwater pool (Section 5.4.4).

A substantial amount of coarse sediment still enters the fishway through the exit ports. It is difficult to predict the flow patterns in the headwater pool during sediment transport events, which likely occur at streamflows exceeding 4,500 cfs (See Section 3.3.2). However, one primary factor leading to entrainment of coarse sediment through the fishway exit ports is likely related to their elevation. Within the headwater pool, the most direct route for coarse sediment in transport at the bottom of the water column is through the exit ports, which are 3 feet lower than the spillway crest and one foot above the pool bottom. The turbulence in the pool likely keeps sediment entrained and eddies push it into the exit ports.

5.4.2 Sedimentation in the Fishway Exit Channel

Sedimentation within the fishway leads to excessive deposition and regular plugging of the vertical slots in the exit channel. Inflow becomes blocked by the sediment and the fishway becomes inoperable.

The sedimentations appears to first built up in the bay between Slots 19 and 20, and then in the bay between the exit ports and Slot 20. Some of the cobbles are greater than 18 inches in length, as measured along their longest axis. It is also common for small woody debris to partially plug the slots. This likely causes backwatering upstream of the plugged slot that leads to sedimentation of the upstream pool. Water is unable to flow into the exit ports and Slot 20 at normal fish passage flows once the top of the deposited sediment is above the normal elevation of the headwater pool.

The fishway becomes blocked by sediment and debris within the exit channel on nearly an annual basis. ODFW and volunteers regularly clean out the fishway in the late spring or early summer, once water stops flowing across the fishway roof and conditions become safe to enter the fishway. Table 5-3 lists the cleanout dates for 2001 and 2005 through 2009, along with the approximate streamflow at Steamboat Falls during the cleanout. The highest flow that the cleanout was conducted was 121 cfs, which coincided with a small amount of water flowing over the fishway roof. The average flowrate that cleanout occurred was 84 cfs. This relatively low flow is generally exceeded continuously from mid-December through mid-June, preventing fishway maintenance during the winter months.

Table 5-3. Date and streamflow when sedimentation was cleaned out of the fishway.

Clean Out Date	Daily Ave. Flow[1] (cfs)
6/18/2009	85 cfs
7/1/2008	121 cfs[2]
6/20/2007	61 cfs
7/3/2006	65 cfs
6/24/2005	98 cfs
6/13/2001	71 cfs
AVERAGE:	**84 cfs**

[1] Daily average streamflow from USGS NO. 14316700, scaled to drainage area at Steamboat Falls.

[2] Water flowing over upstream end of fishway roof

5.4.3 Sedimentation between Fishway Weirs

Once the exit channel is cleaned out, flow in the fishway scour and transport much of the sediment between the Weirs 6 and 18. However, problems with sediment within the fishway persist.

During the July 20, 2009 site visit, the bays between Weir 6 and the entrance were nearly filled with sediment, likely from a backwatering effect from the tailwater pool. These weirs are not slotted, and retain much more sediment than the slotted weirs. There was also considerable amount of sedimentation throughout the exit channel and in the turnbays (Bays A, H, and M).

Over half of the orifices at the base of the weirs were plugged with coarse sediment. Additionally, two of the slotted weirs had large cobbles jammed across the bottom of the slots. The bays directly between the slots were relatively clear of sediment, but contained a substantial amount of coarse sediment in line with the slots. The result of this sedimentation was varying drops between weirs and increased turbulence in some pools.

5.4.4 Sedimentation in Headwater Pool

The headwater pool floor slopes downward towards the sediment sluice pipe inlet. Looking upstream through the pipe, it is apparent that the sluice gate is about half open but completely jammed with sediment (Figure 5-3). Additionally, the actuator to open and close the sluice gate is damaged and inoperable. It is not clear if ODFW left the gate “cracked” open during the winter to sluice incoming sediment but was overwhelmed by the delivery rate, or if they attempted to open it once sediment was deposited in front of the gate and it got jammed.

The top of the sediment within the headwater pool is currently approximately 5 feet below the spillway and covers the lower portion of the AWS intake, which is sealed shut. The sediment level is likely at a quasi-equilibrium state, fluctuating a small amount on an annual basis. The flow velocities into the headwater pool and resulting turbulence during large flows probably prevent sediment from further filling-in the pool.

5.5 Repairs to the Existing Fishway

This study did not include a detailed structural assessment of the existing fishway structure to determine locations for specific repairs. Rather, a general structural inspection was conducted and recommendations were provided by the project's geotechnical engineer, Bill Galli P.E. with The Galli Group.

In general, the fishway appeared in good condition. As mentioned above, the sluice gate is damaged and inoperable and there is some leakage through the steel plate on the AWS intake that can cause injury to fish and lamprey ammocoetes. Minor areas of spalled concrete were observed inside the fishway, and some leakage through joints in the concrete between the upper and lower levels was noted. A considerable amount spalling and scoured concrete was observed in the headwater pool and on the spillway, exposing the underlying rebar and steel matting.

The geotechnical report prepared by The Galli Group (**Appendix E**) recommended several items to inspect and repair as necessary to increase the service life and structural integrity of the fishway. These recommendations include inspection of the bedrock stability near the structure, inspection of the bolting of the fishway to the bedrock, repairs of spalled/scoured concrete, and inspection of the tailwater pool to ensure that scour has not undermined the fishway structure. Any indentified repairs should be implemented in conjunction with the modifications proposed in this study.

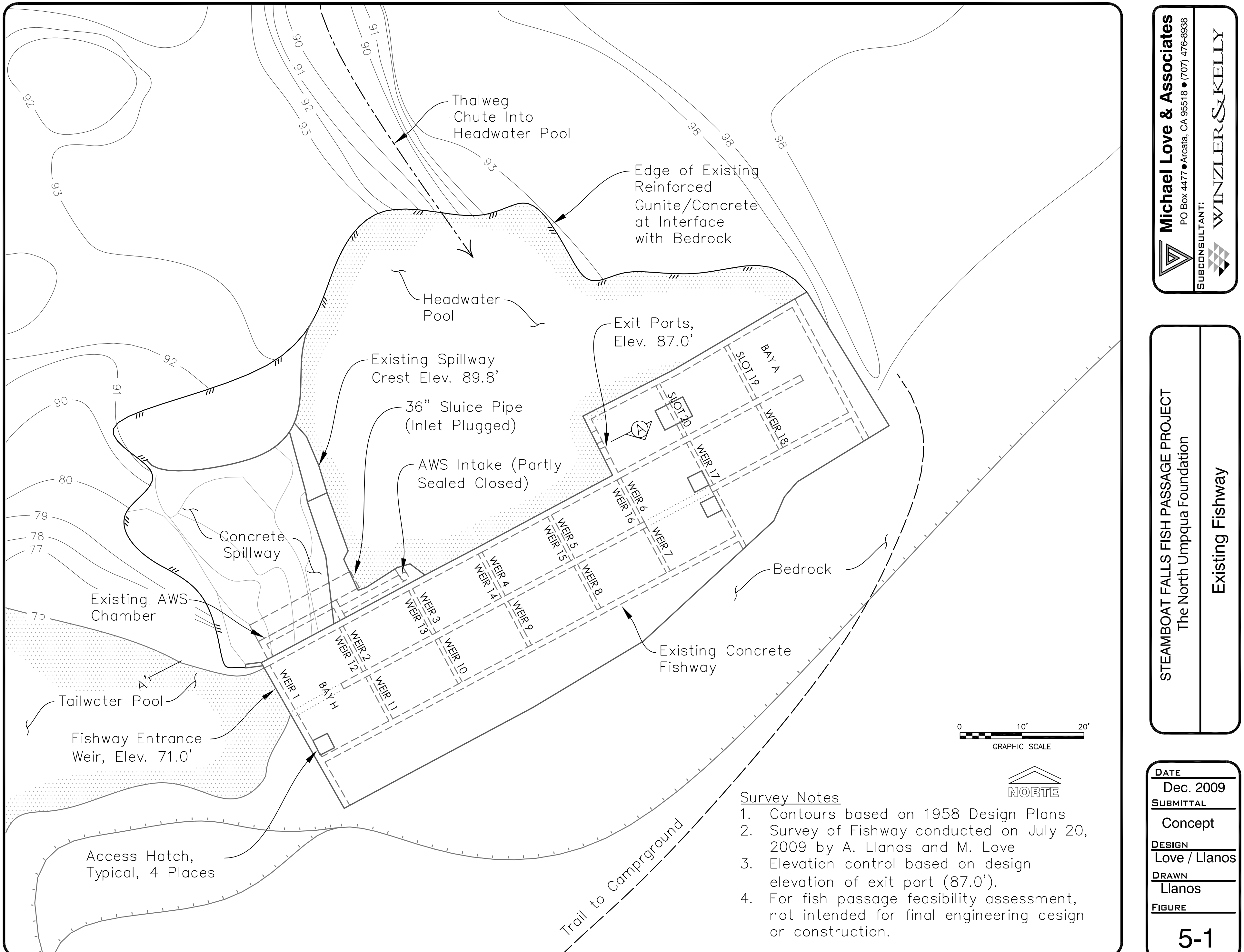


Figure 5-1. Plan view of the existing concrete fishway at Steamboat Falls.

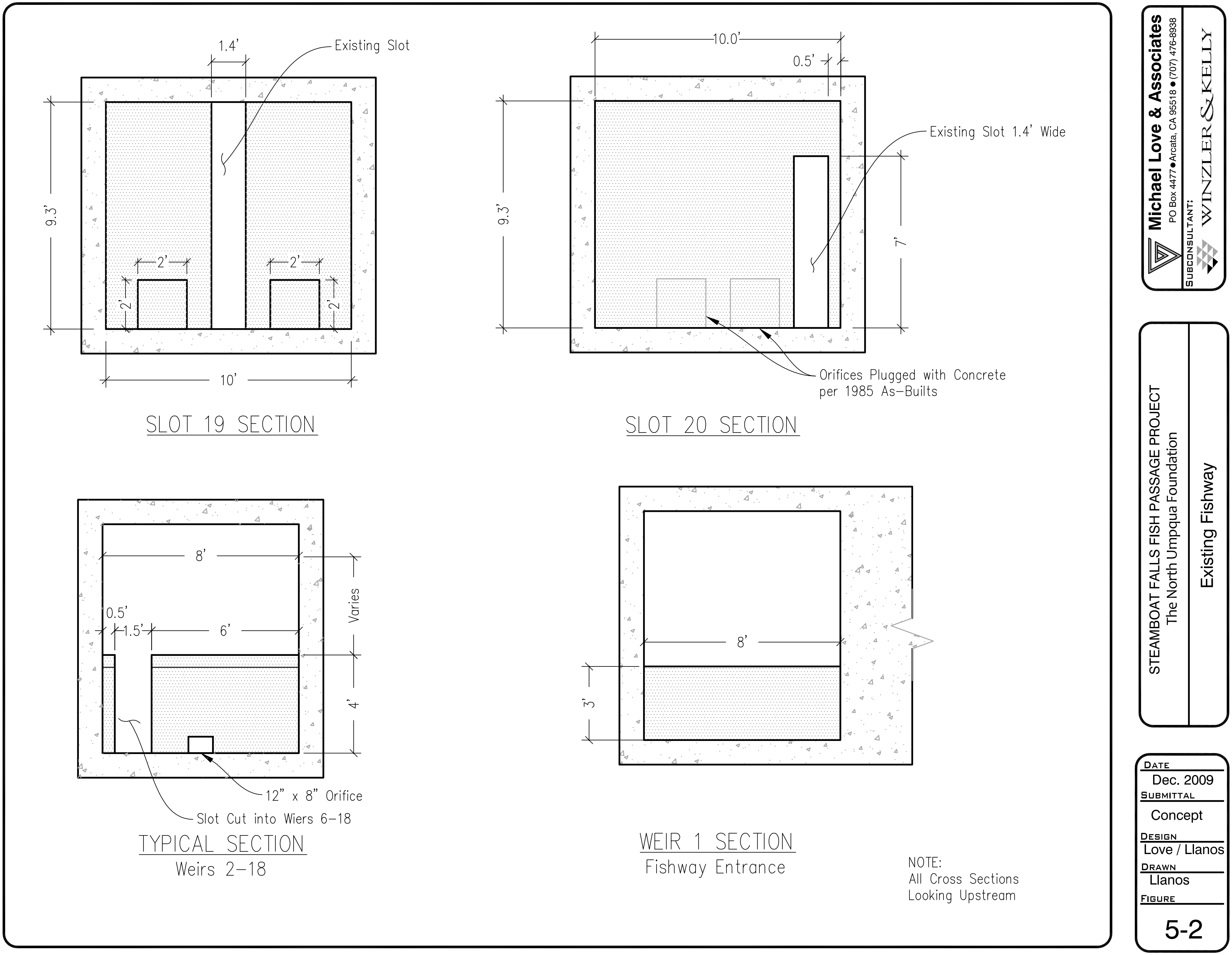


Figure 5-2. Section view of slotted weirs and vertical slots in existing concrete fishway.

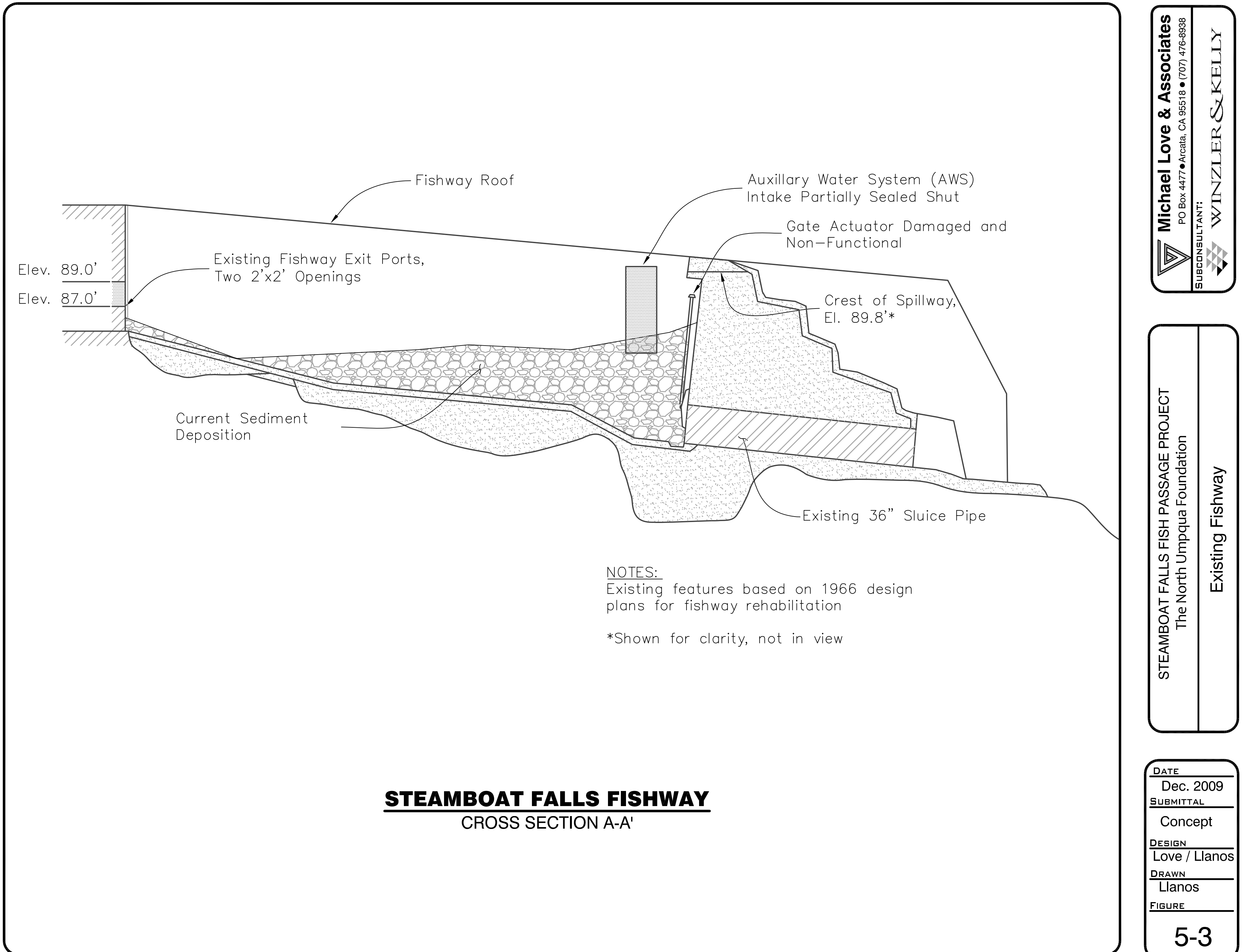
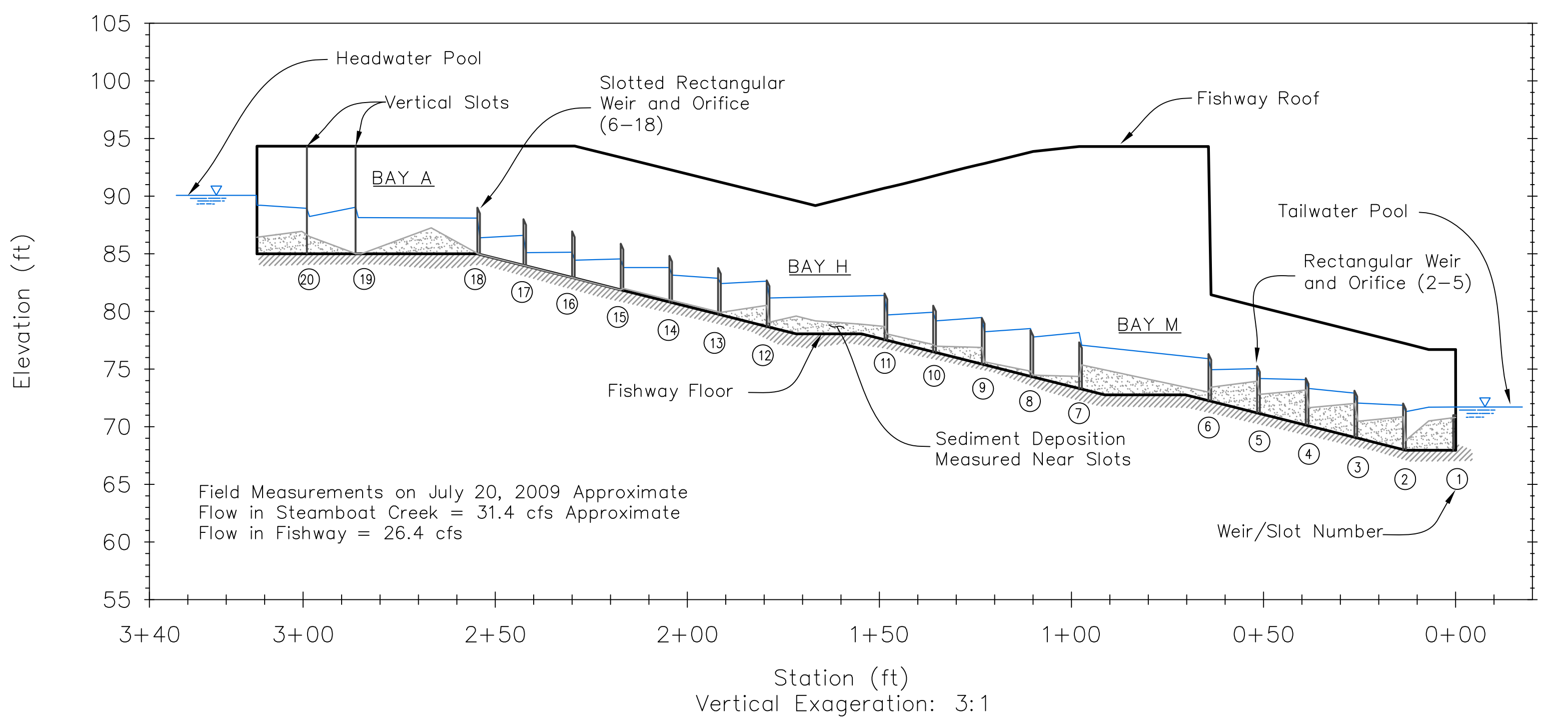


Figure 5-3. Section through the headwater pool showing exit ports, sluice pipe, AWS intake, and sedimentation within the pool.



HYDRAULIC CONDITIONS

WEIR / SLOT No.	WATER SURFACE DROP (ft)	MIN POOL DEPTH (ft)	EDF (ft–lb/s/cf)
20	0.9	4.2	4.2
19	0.9	3.2	3.8
18	1.8	1.5	14.7
17	1.4	1.4	13.3
16	1.2	1.7	9.4
15	1.2	2.8	7.4
14	0.9	2.2	6.1
13	0.5	2.9	3.4
12	1.9	2.1	13.6

HYDRAULIC CONDITIONS (cont.)

WEIR	DROP	POOL DEPTH	EDF
11	1.8	1.7	13.4
10	1.0	2.2	6.4
9	1.3	2.6	7.0
8	0.6	3.3	2.9
7	1.0	1.7	7.5
6	0.9	2.1	10.7
5	0.8	2.0	9.5
4	1.0	2.8	9.3
3	0.8	2.8	7.2
2	1.0	2.5	9.3
1	0.0	--	N/A

STEAMBOAT FALLS FISHWAY
MEASURED WATER SURFACE PROFILE

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STEAMBOAT FALLS FISH PASSAGE PROJECT
The North Umpqua Foundation

Existing Water Surface Profile

DATE	Dec. 2009
SUBMITTAL	Concept
DESIGN	Love / Llanos
DRAWN	Llanos
FIGURE	5-4

Figure 5-4. Measured water surface profile and hydraulic conditions within the existing concrete fishway.

6 Alternative A: Modifications to Existing Fishway

Alternative A involves modifications to the existing fishway at Steamboat Falls to improve its performance. Alternative A modifications have been divided into three levels. Level 1 focuses on improved sediment routing through the fishway and improved fish passage hydraulics. Level 2 aims at reducing the amount of sediment entering the fishway. Level 3 increases fish attraction to the fishway entrance by re-establishing the auxiliary water system (AWS).

Level 2 modifications assume Level 1 is also implemented, and Level 3 assumes both Level 1 and Level 2 are implemented. Improvements associated with each level are identified in Figure 6-1. Modifications are categorized by level based on the certainty of their anticipated performance, benefit, and cost. At each increasing level, the benefit-cost ratio and certainty of performance decreases.

Because this is a retrofit of an existing fishway, there are numerous physical limitations imposed by the existing structure that make meeting existing agency criteria infeasible. Alternative A improvements are evaluated relative to existing ODFW and NMFS NW criteria as well as to the degree that conditions are improved relative to existing.

To minimize dewatering and fish removal costs, construction of Alternative A is suggested to occur during low streamflow periods after a majority of the summer steelhead have migrated upstream. These conditions typically occur during the months of July through early October. Some steelhead are anticipated to arrive at the falls during the latter part of construction and will likely hold in the large pool below the falls until the construction is completed. However, elevated water temperatures in the tailwater pool may necessitate relocating late arriving steelhead to more suitable holding habitat during construction.

6.1 Level 1 Modifications (Alternative A-1)

Level 1 modifications focus on improving:

(1) fish passage hydraulics within the bays between the existing slotted weirs,
(2) sediment routing through the lower five bays nearest to the fishway entrance,
(3) sediment routing through the exit channel between the exit ports and Weir 18,
(4) access for maintenance into the fishway during higher flows, and
(5) fishway entrance conditions by reducing distraction flows originating from atop the fishway roof.

The following Sections describe each modification and their predicted effect on fishway performance. The hydraulic model developed to assess performance of the existing fishway (See Section 5.3.2) was used to develop, evaluate, and refine each proposed modification. The results are presented in detail in **Appendix H** and summarized in the following sections.

6.1.1 Modify Weirs 1-18

Modifications to the weirs include plugging the existing orifices in the weirs with concrete, cutting slots into the lower five weirs to match the other slotted weirs, and adding a 1 foot tall sill to the bottom of each slot (Figure 6-2). These modifications will improve fish passage hydraulics throughout and transport of sediment within the lower portions of the fishway.

Weir Orifices

Each of the weirs in the fishway has a small (12 inch wide by 8 inch tall) single orifice that would be plugged with concrete to eliminate problems resulting from jamming with cobbles. Currently, the proportion of the fishway flow going over each weir and through the slot varies depending on if the orifice is plugged, partially plugged or open. This results in variable pool depths and water surface drops from weir to weir. When unplugged, approximately 3.3 cfs is conveyed through each orifice.

Orifices are commonly used to improve pool and weir fishway hydraulics and sediment transport. However, the need for the orifices was eliminated when slots were cut into the weirs in 1985 and the orifices are no longer necessary. Gates to close off the orifices, as shown in the original design drawings (**Appendix B**) are no longer present, therefore we recommend plugging the orifices.

Weir Slots

Vertical slots would be cut into the lower 4 weirs (Weirs 2-5) at the fishway entrance. The vertical slots would have identical dimensions to those cut into Weir 6 through Weir 18 during the 1985 fishway modifications. The vertical slots will be located 0.5 feet from the wall, 1.5 feet wide, and extend down 4 feet, to the fishway floor.

Adding slots in the weirs will reduce sediment deposition in the lower bays. Currently, the bays between these weirs are completely filled with sediment, likely due to backwatering by the tailwater pool during large flows and a lack of slots to allow sediment movement. The upstream weirs, which have slots, are able to transport sediment much better, as evidenced by the limited deposition.

Slot Sills

A one-foot high steel sill plate will be installed at the bottom of each vertical slot at Weirs 2-18. This will reduce the effective height of the slot to 3 feet. The sill will increase water depth in each bay by one foot and significantly reduce turbulence in the pools.

The sill would be constructed of a steel plate fastened to the downstream face of the weir. Grout would be used upstream of the plate to form a ramp that facilitates sediment transport. For Weir 18, the sill height will only be 0.5 feet to maintain an adequate water surface drop that improves sediment transport within the exit channel.

Entrance Weir (Weir 1)

The entrance weir crest (Weir 1) is currently lower than the summer tailwater pool level, and produces no drop or jet at the entrance to help attract fish. To improve attraction, the entrance weir will be slotted with the same dimensions as Weirs 2-5. Additionally, the weir crest will be raised 2 feet (Figure 6-2) to generate a drop across the entrance and to create a jet of streaming flow into the tailwater pool at varying tailwater levels.

6.1.2 Modify Fishway Exit Channel

The fishway exit channel consists of a level fishway floor extending from the exit ports to Weir 18. Within this section of the fishway, Weirs 19 and 20 are walls that were retrofitted in 1985 with 1.5-foot wide vertical slots that help regulate the fishway flow as the level in the headwater pool changes (Figure 6-3). This area is prone to severe sedimentation on an annual basis, which routinely blocks flow from entering the fishway and effectively makes it inoperable until the sediment is manually cleaned out by ODFW personnel and volunteers in late spring or early summer (See Section 5.4.2). Unlike the downstream slotted weirs, these slots extend to the roof. Once plugged, fish passage is completely blocked. The suspected causes of sedimentation between the vertical slots is clogging of the slots (including the slot in Weir 18) with small debris and cobbles, along with insufficient turbulence and scouring (low energy dissipation) in the pool immediately downstream of the exit ports.

To reduce sedimentation in the exit channel and keep the fishway functional in the event of debris clogging and sedimentation, the two vertical slots in Weirs 19 and 20 would be demolished and replaced with concrete slotted weirs. Weir 19 would be 4 feet tall with a 1.5 foot wide by 4-foot tall slot through the center of the weir. Weir 20 would be 4.5 feet tall with a 1.5 foot wide by 3.5-foot tall slot through the center of the weir. The shape of the new slotted weirs will allow water to continue flowing (at a reduced rate) over the weirs in the event the slots become clogged with debris and sediment. This will improve conditions by providing for limited passage through the fishway when currently all passage would be blocked.

The fishway floor would be raised 1-foot between the fishway exit ports and Weir 19 to increase water surface drops and decrease the pool volume, thus increasing scour (Figure 6-3). A grouted ramp and 1-foot steel sill plate mounted at the bottom of the slot in Weir 20 would maintain adequate pool volume and regulate flow into the fishway. A ramp and plate is not necessary at Weir 18 because of the raised fishway floor at this location.

A new access ladder will be included on the left side of Weir 20, replacing the existing access ladder. To fit the access ladder and maintain sufficient weir length requires re-locating the ladder approximately 2 feet towards the wall from where it is currently located. To access the ladder, the existing hatch opening needs to be widened by 2.5 feet. A new 6-foot by 5-foot prefabricated aluminum hatch cover will be installed to accommodate this larger opening.

6.1.3 Construct Upstream Training Wall

At streamflows above approximately 100 cfs, water overtops the existing bedrock immediately upstream of the fishway, allowing water to sheet across the fishway roof and access hatch near the fishway exit. Accessing the fishway to perform maintenance during these conditions is extremely hazardous. Streamflow typically remains above 100 cfs throughout most of the winter and spring, which prevents ODFW from cleaning sediment out of the fishway until late spring or early summer.

A five-foot tall training wall would be built across the upstream edge of the fishway (Figure 6-1). The training wall will butt-up against and protrude 1 to 2 feet above the bedrock outcrop that currently blocks lower flows from sheeting across the fishway roof. The training wall will shunt flows from upstream into the headwater pool, keeping them from sheeting across the fishway roof. This will keep the fishway roof dry and allow ODFW personnel safe access to the fishway hatches during baseflow conditions throughout the entire year, facilitating inspection and maintenance. The upstream face of the new training wall should conform to, and be doweled into, the existing bedrock outcrop. This should provide adequate strength to withstand forces associated with large floods and associated debris.

6.1.4 Install Fishway Roof Curb

At streamflows above approximately 85 cfs, the level of the headwater pool at the spillway is elevated sufficiently for water to sheet across the downstream end of the fishway roof and plunge into the pool at the entrance. This plunging flow is suspected of creating a distraction that may interfere with attracting fish to the fishway entrance.

A curb would be constructed that has a level crest and runs on top of, and along, the outer wall of the fishway (Figure 6-1 and Figure 6-4). At the location of the existing spillway, the curb would be one-foot tall (top of curb elevation of 92.0 feet). With the new curb, water at the spillway would be prevented from flowing over the fishway roof until streamflow well exceeds 300 cfs. Conditions at high flows are difficult to quantify given the large proportion of water that goes over the falls upstream of the headwater pool during these flows.

6.1.5 Decommission and Plug Sluice Pipe

The existing sediment sluice pipe that discharges at the base of the spillway is inherently prone to plugging with sediment, as indicated by its current condition (See Section 5.4.4). Additionally, the existing actuator for the Waterman slide-gate at the sluice pipe inlet is damaged and nonfunctional. The sluice pipe would be permanently plugged with concrete and the slide-gate and operator would be removed (Figure 6-4).

6.1.6 Seal AWS Intake (except with Level 3 Modifications)

If Level 3 modifications to restore the auxiliary water system (AWS) are not implemented, the AWS intake should be completely sealed-off with a steel plate, such that no water is able to leak through the plate (Figure 6-1). Elimination of the leakage will eliminate the risk of impinging juvenile fish and lamprey ammocoetes.

6.1.7 Fish Passage Performance for Level 1 Modifications

The proposed Level 1 modifications to the weirs and fishway floor in the exit channel are designed to self-regulate flow into the fishway with changing levels in the headwater pool. The proposed modifications for Weirs 2 through 17 will increase water depth and decrease turbulence (as measured by the Energy Dissipation Factor, EDF, See Section 4.2) within the fishway. Hydraulic calculations indicate that fish passage conditions within the fishway will be substantially improved with the proposed Level 1 modifications. The results of the hydraulic calculations are summarized in Table 6-1 and Table 6-2.

Definition of Operational Fishway Flows and Low and High Passage Streamflows
At the Steamboat Falls fishway, only a portion of the total streamflow is conveyed in the fishway. The "operational fishway flows" refers to the range of flows conveyed in the fishway that provide fish passage, and are defined by the lower and upper fishway flow. The "low passage streamflow and "high passage streamflow" defines the range of streamflows in Steamboat Creek in which the fishway is operable. The low and high passage streamflows coincide with the lower and upper fishway flows.

Lower Fishway Flow
For evaluation purposes, a fishway flow of 18 cfs was designated as the lower operational flow for the fishway. Based on the flow record, this is close to the lowest flows believed to occur at Steamboat Falls (See Section 3.3). At this fishway flow, minimum water depth in each bay between the modified weirs would be about 2.5 feet and the EDF would be 3.9 ft-lb/s/ft^3, which satisfy ODFW fishway criteria. For comparison, under existing conditions the same fishway flow results in a minimum water depth in each bay of 1.1 feet and EDF of 7.6 ft-lb/s/ft^3.

Upper Fishway Flow
The upper fishway flow was set based on the headwater pool level and Level 1 modifications. At fishway flows above 36 cfs, the headwater pool begins to overtop the new curb and sheet across the fishway roof, reducing fish attraction at the fishway entrance. **For the purposes of evaluating the performance of modified fishway, the upper operational fishway was set at 36 cfs.**

At the upper fishway flow of 36 cfs, the overall EDF in each bay is 5.7 ft-lb/s/ft^3. For comparison, the same fishway flow under existing conditions results in an overall EDF of 6.3 ft-lb/s/ft^3, with all of the flow conveyed in the slot.

Operating Headwater Pool Levels and Exit Channel
With Level 1 modifications to the exit channel, the water surface in the headwater pool ranges between elevations 90.0 feet (elevation of the spillway crest) at the lower fishway flow of 18 cfs and 92.0 feet (top of new fishway roof curb) at a fishway flow of 36 cfs (Table 6-2). At higher fishway flows, the headwater pool overtops the fishway roof curb and water begins to sheet across the fishway roof.

Evaluation of Turbulence
The modified slot in each weir becomes full at a fishway flow of about 22 cfs. At this flow the minimum water depth in each bay is 3.0 feet and the EDF is at the recommended ODFW threshold of 4.0 ft-lb/s/ft^3. At the upper fishway flows, the EDF rises to 5.7 ft-lb/s/ft^3, greater than the recommended ODFW threshold. At any given fishway flow, reducing the EDF requires increasing the pool volume. Further increasing the proposed sill height in the slot would accomplish this to some extent, but would compromise the ability of the fishway to transport sediment. Increasing the width or length of the pools is not practical within the existing fishway.

Even though the turbulence is high, summer steelhead still readily traverse the fishway and successfully reach the upstream channel in large numbers (Table 3-1). The effect of turbulence on passage is not just a function of the overall EDF, but of the shape and volume of the pools and where in the pool turbulence occurs relative to the migration pathway (i.e. does the fish have to swim through the turbulence to ascend the fishway). Given that the current EDF between the slotted weirs within the fishway is always above 6 $ft\text{-}lb/s/ft^3$ and fish still readily pass through it, a reasonable assumption is that summer steelhead can pass through or over the slotted weirs at EDF values greater than 4.0 $ft\text{-}lb/s/ft^3$.

With Level 1 modifications, at fishway flows greater than 22 cfs water will begin to spill over the horizontal weir crest. At this same flow, the EDF reaches 4.0 $ft\text{-}lb/s/ft^3$. Once flow overtops the weir, fish will be able to leap or swim over the weirs rather than swimming through the slot. Under both current and proposed conditions, most of the turbulence is focused on the left side of each bay (looking upstream). Most of the turbulence that does exist along the right side of the bay originates from the flow plunging over the weir rather than the jet discharging from the slot.

By assuming that most of the energy from the slot flow is dissipated as turbulence in the left side of each bay, close to the slot, then the turbulence in the right side of the bay is generated from the plunging flow over the weir and can be calculated separately. The EDF calculated for the right side of the bay is more representative of the turbulence fish would encounter when fishway flows are above 22 cfs and they are able to swim or leap over the weirs rather than having to swim through the slots. Using this method, the EDF in the right side of the bay ranges from 0.3 to 1.6 $ft\text{-}lb/s/ft^3$, well below the ODFW and NMFS NW threshold.

Low and High Passage Streamflows
With the addition of the curb on the fishway roof and modifications to the weirs and exit channel, the operational fishway flow range is 18 cfs to 36 cfs, and the corresponding streamflows entering the headwater pool range between 21 cfs and 213 cfs (Table 7-2). At streamflows above approximately 100 cfs, a substantial amount of the water goes over the falls upstream of the headwater pool, and is not accounted for in these model results. From photographs of the falls, it appears that at flows above roughly 150 cfs, half or more of the streamflow bypasses the headwater pool (See Section 5.2). Based on this, the total streamflow is approximately 400 cfs when the streamflow entering the headwater pool is 213 cfs. **Therefore, the fishway is predicted to function at operational fishway flows (18 cfs to 36 cfs) when streamflows range between 21 cfs and about 400 cfs.**

The low passage streamflow of 21 cfs is close to the lowest flow predicted to occur at Steamboat Falls (approximately the 99 percent annual exceedance flow, See Section 3.3.1), making the modified fishway suitable for fish passage throughout the summer. The high passage streamflow at Steamboat Falls of 400 cfs is exceeded about 35 percent of the time throughout the year, and about 65 percent of the time during December through April. This falls far below the ODFW and NMFS NW criteria, which recommend using the 5 percent exceedance flow of 1,684 cfs for the migration period (See Section 3.3.1). However, the Level 1 modifications substantially increase the amount of time throughout the year that passage would likely be suitable for adult winter and summer steelhead and Chinook salmon.

Table 6-1. Predicted fishway performance between Weir 1 and Weir 17 with Level 1 modifications[1]. Italicized values fail to meet the ODFW fish passage criterion. Values in parenthesis indicate existing conditions.

Fishway Flow	18 cfs	22 cfs	25 cfs	30 cfs	36 cfs
Depth in Bay Upstream of Slot[2]	3.5 ft (2.1 ft)	4.0 ft (2.6 ft)	4.2 ft (3.0 ft)	4.4 ft (3.7 ft)	4.6 ft (4.2 ft)
Minimum Water Depth in Bay	2.5 ft (*1.1 ft*)	3.0 ft (*1.6 ft*)	3.2 ft (2.0 ft)	3.4 ft (2.7 ft)	3.6 ft (3.2 ft)
EDF (total fishway flow)	3.9 ft-lb/s/ft^3 (*7.6 ft-lb/s/ft^3*)	4.0 ft-lb/s/ft^3 (*6.8 ft-lb/s/ft^3*)	*4.4 ft-lb/s/ft^3* (*6.5 ft-lb/s/ft^3*)	*5.0 ft-lb/s/ft^3* (*6.1 ft-lb/s/ft^3*)	*5.7 ft-lb/s/ft^3* (*6.3 ft-lb/s/ft^3*)
EDF (right side of bay)	N/A	N/A	*0.3 ft-lb/s/ft^3*	0.9 ft-lb/s/ft^3 (N/A)	1.6 ft-lb/s/ft^3 (N/A)

[1] Drop between Weirs 1-17 is 1.0 feet.

[2]Water velocity through the vertical slot is 4.8 ft/s at all fishway flows for both existing and proposed conditions.

Table 6-2. Predicted performance of fishway exit with Level 1 modifications. Italicized values indicate conditions that do not meet ODFW fish passage criterion.

Total Streamflow	**21 cfs**	**47 cfs**	**72 cfs**	**250 cfs[1]**	**400 cfs[1]**
Streamflow Entering Headwater Pool	**21 cfs**	**47 cfs**	**72 cfs**	**130 cfs**	**213 cfs**
Fishway Flow	18 cfs	22 cfs	25 cfs	30 cfs	36 cfs
Headwater Elevation	90.0 ft	90.6 ft	91.1 ft	91.5 ft	92.0 ft
Streamflow in Fishway	86%	46%	35%	9%	12%
Exit Port & Receiving Pool:					
Water Surface Drop	0.21 ft	0.30 ft	0.39 ft	0.56 ft	0.81 ft
Velocity through Ports	2.3 ft/s	2.7 ft/s	3.1 ft/s	3.7 ft/s	4.5 ft/s
Minimum Pool Depth	3.8 ft	4.3 ft	4.7 ft	5.0 ft	5.2 ft
EDF	0.5 ft-lb/s/ft^3	0.8 ft-lb/s/ft^3	1.1 ft-lb/s/ft^3	1.8 ft-lb/s/ft^3	2.9 ft-lb/s/ft^3
Weir 20 & Receiving Pool:					
Water Surface Drop	0.80 ft	0.82 ft	0.89 ft	0.91 ft	0.92 ft
Velocity through Slot	4.3 ft/s	4.3 ft/s	4.3 ft/s	4.3 ft/s	4.3 ft/s
Minimum Pool Depth	3.0 ft	3.5 ft	3.9 ft	4.2 ft	4.4 ft
EDF	2.5 ft-lb/s/ft^3	2.6 ft-lb/s/ft^3	2.6 ft-lb/s/ft^3	3.0 ft-lb/s/ft^3	3.4 ft-lb/s/ft^3
Weir 19 & Receiving Pool:					
Water Surface Drop	0.70 ft	0.72 ft	0.79 ft	0.86 ft	0.86 ft
Velocity through Slot	3.3 ft/s	3.8 ft/s	4.1 ft/s	4.3 ft/s	4.5 ft/s
Minimum Pool Depth	3.3 ft	3.8 ft	4.1 ft	4.3 ft	4.5 ft
EDF	3.0 ft-lb/s/ft^3	2.5 ft-lb/s/ft^3	2.7 ft-lb/s/ft^3	3.9 ft-lb/s/ft^3	*4.4 ft-lb/s/ft^3*
Weir 18 & Receiving Pool:					
Water Surface Drop	0.80 ft	0.82 ft	0.89 ft	0.91 ft	0.92 ft
Velocity through Slot	4.3 ft/s	4.4 ft/s	4.5 ft/s	4.6 ft/s	4.6 ft/s
Minimum Pool Depth	2.5 ft	3.0 ft	3.2 ft	3.4 ft	3.6 ft
EDF	2.7 ft-lb/s/ft^3	2.9 ft-lb/s/ft^3	3.4 ft-lb/s/ft^3	4.0 ft-lb/s/ft^3	*4.7 ft-lb/s/ft^3*

[1] Total streamflow is estimated assuming approximately half of the streamflow bypasses the headwater pool en route over the falls at flows greater than approximately 100 cfs.

Fish Attraction
Attraction to the fishway is influenced by the amount of flow discharging from the fishway entrance relative to the total streamflow. At the lower fishway flow of 18 cfs and a streamflow of 21 cfs, the fishway would convey about 86 percent of the total streamflow. At the upper fishway flow of 36 cfs and a streamflow of 400 cfs, the fishway would convey about 9% of the total streamflow. These conditions are close to meeting the NMFS NW minimum criteria of 10% attraction flow.

Cutting a slot and raising the entrance weir (Weir 1) will create a hydraulic drop across the entrance. The slot will ensure the flow is streaming, as recommended by NMFS NW. This will produce a jet that penetrates the tailwater pool to aid fish in locating the fishway entrance. The tailwater pool level is believed to range about 2 feet between the low passage streamflow and the high passage streamflow. The drop across the entrance weir will vary depending on the fishway flow and the level of the tailwater pool, but will generally be between 0.3 feet and 1.5 feet (**Appendix H**). To better quantify the drop across the entrance at varying streamflows would require an improved understanding of how the tailwater pool level varies with streamflow and could be examined during the final engineering phase of the project.

Sedimentation within the Exit Channel
Modifications to the exit channel will increase scour and sediment transport while still meeting water surface drop criteria. Water surface drops across Weirs 18 through 20 range from 0.80 feet to 0.92 feet at operational fishway flows (Table 6-2). These drop heights would improve sediment scour, while still satisfying ODFW and NMFS NW maximum water surface drop criteria of 1-foot. At higher flows, the drops across the exit ports and Weirs 18 through 20 continue to increase, along with the turbulence and associated scouring forces.

The slot at Weir 20 will inevitably clog with small debris during winter flows, leading to sediment deposition between the exit ports and Weir 20. Sediment would likely build up to the top of the new weir crest, which is at elevation 90.5 feet, approximately 0.5 feet higher than the top of the existing exit ports. If the sediment or debris does not fully close-off the exit ports, water will continue to flow over the crest of Weir 20 and through the fishway when the headwater pool is above elevation 90.5 feet. With the slot in Weir 20 completely clogged with debris and sediment, the fishway flow would reach 18 cfs when the headwater pool elevation is at 91.4 feet, and would be about 26 cfs when the headwater pool reaches elevation 92.0 feet and begins overtopping the fishway roof (assumes exit ports are free from debris, refer to **Appendix H** for calculations).

Operations and Maintenance
There are no operational requirements associated with Level 1 modifications. Maintenance should be reduced due to improved sediment transport within the fishway. However, it is likely that sediment will still need to be cleaned out of the fishway to some extent on an annual basis.

The addition of the training wall on the upstream end of the fishway roof will allow for access to the fishway hatches to clean out sediment during higher flows than under current conditions. As a result, ODFW staff will be able to clean out the fishway earlier in the spring, when summer steelhead first begin to arrive at Steamboat Falls, rather than having to wait until late June or early July. By late June, large numbers of summer steelhead have gathering in the pool below the falls, and many of the individual fish can become relatively exhausted and injured from their repeated leaps at the face of the falls. It may be necessary to install stoplogs in front of the exit ports, using the existing guides, to seal off some or all of the flow and ensure a safe work area inside the fishway.

6.1.8 Anticipated Design Performance

Hydraulic Calculations
The results of the hydraulic calculations assume that the bays and slots are not clogged with sediment. Sediment deposition would change the results of the computations, including the amount of flow in the fishway relative to streamflow and EDF in each bay, which is dependent on pool volume.

The fishway hydraulic model relies on estimations of discharge coefficients, which can range considerably with small changes to the shape of the slots, orifices, or weirs. Additionally, sedimentation in the bays can change the discharge coefficient. Therefore, the hydraulic results presented here are approximations and the actual fishway discharges may vary by as much as 15 to 20 percent. Variation could be higher in the case of severe sedimentation or debris clogging the slots.

Sedimentation
The Level 1 modifications will not reduce the amount of sediment entering the fishway. Rather, the modifications attempt to improve transport of sediment within the exit channel and maintain limited fish passage in the event that sedimentation continues to occur. There is considerable uncertainty regarding the rate and flows at which coarse sediment is entrained into the fishway and if the proposed modifications to the exit channel will be able to transport the sediment. Additionally, there is some uncertainty to whether the sedimentation immediately downstream of the exit ports could completely block flow through the ports and into the fishway making the fishway inoperable at all headwater pool levels.

Concern may arise regarding the 1-foot tall sills placed at the bottom of the slots in Weirs 2 though 18 and 20 and the potential to exacerbate sedimentation within the bays. However, with the ramp placed on the upstream side of the sill and given the slope of the fishway floor, it is unlikely that they will increase sedimentation. The sills also increase the frequency of flow plunging over the weir crest, which will help scour sediment from the pools and away from the slots.

Flow Over Steamboat Falls and Fish Attraction
At higher streamflows, the flow patterns over Steamboat Falls is complex, with much of the flow going over the falls before reaching the headwater pool. There is a considerable amount of uncertainty regarding the magnitude of the total streamflow when only a portion of the flow enters the headwater pool (Table 6-2). The total streamflow could be more or less than the estimated 400 cfs at the upper fishway flow of 36 cfs, which would alter the ratio of flow in the fishway to total flow used in evaluating fish attraction.

The variability of the tailwater pool level with changes in flow is not well characterized. An improved understanding of this relationship would better quantify the hydraulic drop across the entrance at varying streamflows. This could be accomplished by installing a staff plate in the tailwater pool and recording pool levels at varying flow conditions.

6.1.9 Cost and Constructability

The feasibility level cost estimate for Alternative A Level 1 modifications is $255,000. A detailed breakdown of the cost estimate is provided in **Appendix I**.

Construction of Level 1 modifications will require the removal of streambed material present in the fishway prior to construction. This work could be included in the construction documents as a responsibility of the contractor, or conducted by ODFW prior to construction. For the purpose of this conceptual design document and budgeting project costs, the construction costs for Level 1 modifications includes the anticipated cost to remove the deposited streambed material.

Once the deposited material has been removed from the existing fishway, the structure would be drained and closed off by placing temporary stop logs in the existing guides at the fishway entrance and exit ports.

Once the fishway structure is drained, modifications to the internal weirs can be completed. This would include plugging the existing orifices with a non-shrink grout or concrete, saw-cutting for reforming of the new vertical slots, and constructing the slot sills and ramps. The modifications also include the demolition and removal of Weirs 19 and 20. Weirs 19 and 20 will be reformed per the concept plans and cast-in-place, along with the proposed slab at the base of the two weirs.

Level 1 modifications also include the construction of an upstream training wall, fishway roof curb, and plugging of the existing sluice pipe. The volume of concrete necessary to implement Level 1 is anticipated to justify the need for the concrete to be transported to the site in a mixing truck, tailgated into a hopper at the terminus of the access road, and pumped down to the fishway. Some mixing of concrete and grout onsite may be necessary for small miscellaneous work.

To avoid detrimental effects on water quality, the fishway would need to be kept drained for a minimum of 30 days after concrete installation to allow the concrete to fully cure. If operation of the fishway is necessary in sooner than 30 days, a concrete sealant could be applied to the finished surfaces that would minimize impacts to water quality during the curing process.

Level 1 modifications also include the enlargement of the hatch opening and replacement of the hatch cover over Weir 20. These modifications will require saw-cutting the concrete roof structure to enlarge the opening to accommodate a new hatch cover. The proposed hatch cover will consist of a double panel aluminum hatch with a recessed locking unit to prevent unauthorized access and vandalism.

The cost of any repairs was not included in the cost estimates. During the final engineering and design phase, it is suggested that an assessment be conducted to identify and specify any necessary structural repairs.

6.2 Level 2 Modifications (Alternative A-2)

Level 2 modifications focus on decreasing the amount of sediment entering the fishway and increasing the range of streamflows the fishway operates. The changes focus on modifications to the fishway exit ports and spillway at the headwater pool. Level 2 modifications assume that Level 1 modifications will be implemented and the hydraulics within the fishway will be as described in Section 6.1.7.

To develop changes to the spillway configuration and evaluate resulting affects on fish passage streamflows, the hydraulic model used to assess Level 1 modifications was updated and used for the Level 2 modifications. The results are presented in detail in **Appendix H** and summarized in the following sections.

6.2.1 Approach to Reducing Sediment Entering the Fishway

The two existing exit ports are 2 feet wide by 2 feet tall, and the bottom of each port is 3 feet below the crest of the existing spillway of the headwater pool (Figure 5-3). This keeps the ports submerged at all flows, which is beneficial for conveying sufficient flow into the fishway and minimizing entrainment of floating debris. However, given the elevation of the ports relative to the spillway crest, coarse sediment is much more likely to go into the fishway rather than over the spillway.

Raising the exit ports and/or lowering the spillway crest would likely decrease the rate of coarse sediment entrainment into the fishway while not changing flow patterns in the headwater pool. However, it would cause the exit ports to become unsubmerged during summer low flows, which would substantially decrease the amount of flow entering the fishway and increase the risk of clogging with floating debris during low flow periods. Additionally, a lower spillway crest would increase the water surface drop across the chute that flows into the headwater pool, making it more challenging for fish to exit the headwater pool during low flows. One means of overcoming these issues is to install manually operated gates at the exit ports and on the crest of the spillway that would have a "winter" setting for higher flows and a "summer" setting for lower flows.

6.2.2 Modify Exit Ports and Add Stoplog Headgate

The concrete at the top of each exit port would be saw-cut to make the ports 1 foot taller, but maintain the same bottom elevation. A stoplog placed in the existing guides along the face of the exit ports would be used to keep a 2-foot by 2-foot opening through each port (Figure 6-4). In the fall a board would be placed in the bottom of the stoplog guides, effectively raising the bottom elevation of the port by 1 foot, this should reduce the amount of sediment entering the ports while keeping the fishway hydraulics the same as with Level 1 modifications. In late spring, a board supported on a 2-foot tall riser would be placed across the top of the opening. In this setting, the ports would be the same as existing conditions.

The use of the stoplogs in this manner is equivalent to a gate with a 2 foot by 2 foot opening that slides up and down. The stoplog gates would be mounted on rigid steel frames designed for easy removal. The same stoplog gate could be used for both the winter and summer settings by simply removing it from the guides, flipping it end over end, and then reinserting it.

These changes to the exit ports could be included in Level 1 modifications if reconstruction of the spillway is not desired. However, without the Level 2 modifications to the spillway, changes to the exit ports would not be as effective at reducing sediment entrainment into the fishway. Fishway and spillway hydraulics and fish passage flows would be the same as described for Level 1 modifications (See section 6.1.8).

6.2.3 Reconstruct Spillway with Flow Control

The spillway crest would be reconstructed with the concrete crest placed 1 foot lower than the current spillway crest. The new crest would have a compound shape, with the lowest part of the crest being 10 feet wide, then stepping up 2 feet on both sides, with a 15-foot wide horizontal weir that extends to the fishway wall and a 5 foot wide horizontal weir the extends to the north (Figure 6-5). A manually operated gate would be recessed into the 10-foot wide spillway crest. The gate would be a hinged crest gate consisting of a single stainless steel gate panel that hinges on a lateral torque bar recessed in the re-formed concrete spillway. In the downward position, the gate would lay flush along the invert of the crest to minimize bed material and debris accumulation. In the upward position, the top of the gate would be 1 foot above the spillway crest. The gate would be manually actuated from the fishway side of the spillway crest and would be designed to be operated by a single adult. The gate would be lowered in the fall and raised in the spring. The exit port stoplogs would be adjusted at the same time as the spillway gate to maintain design pool levels in the headwater pool.

The operation controls for the gate would be located inside the fishway and would be actuated using a removable handle inserted into the operator through a small hole in the fishway roof. Access to the controls for maintenance would be through a new hatch in the fishway roof.

The reconstructed spillway and new gate would be designed to maintain pedestrian access across the spillway crest during summer months. The point of crossing the spillway would likely be upstream of the raised gate. Velocities would be low but the water depth would be roughly 1 foot deeper than under existing conditions.

6.2.4 Fish Passage Performance for Level 2 Modifications

Combined, these two modifications would place the bottom of the exit ports only 1 foot (currently 3 feet) below the crest of the spillway and 2 feet (currently 1 foot) above the floor of the headwater pool during winter operations, which would likely increase the amount of coarse sediment going over the spillway rather than entering the fishway. During summer operations, the headwater pool, exit ports, and spillway would function similarly to existing conditions.

Increases in the High Passage Streamflow
Hydraulics within the fishway would remain the same as with Level 1 modifications, aside from improvements due to a decrease in sediment deposition in the exit channel. The fishway flow associated with a given headwater level would be the same as with Level 1 modifications. The Level 2 modifications, when the spillway gate is set in its down-position, would significantly increase the range of streamflows the fishway would be operational. The streamflow entering the headwater pool would be approximately 282 cfs at the upper operational fishway flow of 36 cfs (Table 6-3). Given that much of the streamflow bypasses the headwater pool at these flow magnitudes, the actual high passage streamflow would like exceed 600 cfs (25% annual exceedance flow).

Table 6-3. Predicted fish passage flows with Level 1 and 2 modifications. Italicized values do not meet fish passage design criterion.

Headwater Pool Elevation	**90.0 ft**	**90.6 ft**	**91.1 ft**	**91.5 ft**	**92.0 ft**
Fishway Flow	18 cfs	22 cfs	25 cfs	30 cfs	36 cfs
Winter Operational Settings					
Total Streamflow	**52 cfs**	**94 cfs**	**150 cfs**[1]	**400 cfs**[1]	**600 cfs**[1]
Streamflow Entering Headwater Pool	52 cfs	94 cfs	128 cfs	198 cfs	282 cfs
Proportion of Total Streamflow Discharging from Fishway	35%	23%	17%	*8%*	*6%*
Summer Operational Settings					
Total Streamflow	**18 cfs**	**39 cfs**	**64 cfs**	**150 cfs**[1]	**400 cfs**[1]
Streamflow Entering Headwater Pool	18 cfs	39 cfs	64 cfs	124 cfs	201 cfs
Proportion of Total Streamflow Discharging from Fishway	100%	55%	39%	20%	*9%*

[1] Approximation of total streamflow. At streamflows greater than approximately 100 cfs, a substantial proportion of the water flows over the falls upstream of the headwater pool.

The attraction flow at the fishway entrance does not correspondingly increase with the increase in the high passage streamflow. Although Level 2 modifications increase the high passage streamflow from about 400 cfs to 600 cfs, the upper operational fishway flow remains at 36 cfs. As a result, at the high passage streamflow the fishway would convey only about 6 percent of the total flow, which is less than the NMFS NW recommended threshold of 10 percent. In comparison, with only Level 1 modifications, the high passage streamflow is about 400 cfs and the fishway conveys nearly 10 percent of the total flow.

With Level 2 modifications, the high passage streamflow of 600 cfs at Steamboat Falls is exceeded about 25 percent of the time throughout the year, and about 40 percent of the time during December through April. This falls far below the ODFW and NMFS NW high passage design flow criteria but would greatly increase the window of opportunity for adult winter and summer steelhead and Chinook salmon to use the fishway.

Operations and Maintenance
The operational requirements associated with Level 2 modifications would involve two visits to the site. These visits would occur once in the fall to set the exit ports and spillway gates to their down position, and once in the summer to lower the spillway gate and raise the exit port gates. Currently, ODFW performs maintenance on the fishway each spring to clean sediment out of the exit channel. With Level 1 modifications, sediment cleanout would occur earlier in the spring. Operational adjustments to the gates could occur during this visit. Only one additional site visit, occurring in the fall before the onset of winter rains, would be required by ODFW personnel to set the exit ports and operate the gates. Personnel should be able to perform the gate operations in less than an hour.

6.2.5 Anticipated Design Performance

Hydraulic and sediment transport conditions within the fishway would remain the same as with Level 1 modifications, aside from there potentially being less sediment deposition because less sediment is entering the structure. Less sediment deposition would make fishway hydraulics more closely match those predicted by the hydraulic model and would increase the likelihood that the fishway would remain functional throughout the winter.

The main benefit of reducing the supply of coarse sediment into the fishway is to reduce the risk of rapid sedimentation in the exit channel during large flow events, which could block the exit ports and prevent sufficient flow from entering the fishway to transport the sediment. However, areas throughout the fishway that remain prone to sedimentation due to insufficient scouring forces will continue to experience sedimentation, even if sediment supply is reduced.

It is extremely difficult to quantify the reduction in coarse sediment entrainment into the fishway resulting from Level 2 modifications. Flow patterns in the headwater pool are complex and change dramatically as streamflows increase. Additionally, the flows and rates that coarse sediment enters the headwater pool are unknown. These complications make modeling of sediment transport within the headwater pool infeasible.

Modifications to the spillway would increase the high fish passage streamflow to approximately 600 cfs. However, based on photos of the falls at similar flows, fish may have difficulty locating the fishway entrance. The flow over the falls creates considerable turbulence throughout the tailwater pool. Fish must swim through the entire tailwater pool, with its turbulent waters created by the falls, before reaching the fishway entrance. The flow conveyed in the fishway is less than 10 percent of the total streamflow, further reducing the likelihood that fish will find the entrance at these high flows.

The stoplog gate would be easy to operate and the opening could be modified, if needed. The selected type of spillway gate is designed to withstand the environmental conditions present at the site. The gate would be in its lowered positioned during the highest flows, which keeps it out of the way of the water, sediment and debris traveling over the spillway. The operational life of the gate would need to be considered, such that it has a similar lifespan as the reformed concrete spillway. Both would like need to be repaired and/or replaced before the life of the existing concrete fishway is exhausted.

Fall Transition

Level 2 modifications assume the gates on the exit ports and spillway would be adjusted in late fall, before the onset of persistent high flows. If a period of low flows (streamflow less than 52 cfs) occur after the gates have been adjusted to their winter setting, the flow in the fishway could be too low for passage. It the flows receded even lower, top of the exit ports could become unsubmerged, increasing risk of plugging by small woody debris.

Risks Associated with an Inoperable Spillway Gate

There is a risk that at some point the proposed spillway gate could become inoperable and repairs could not be made until the return of summer low flows. If the spillway gate became stuck in the up-position when attempting to lower it in late fall, then the fishway would function throughout the winter as described under Summer Operational Settings in Table 6-3. The main affect is that the high fish passage streamflow would be reduced to 400 cfs.

If the spillway gate became stuck in the down-position in the spring and summer the fishway would operate as described under the Winter Operational Setting in Table 6-3. This would raise the low fish passage streamflow from 18 cfs to 52 cfs. At summer streamflows lower than 52 cfs, which often occur in July, August, and September, summer steelhead may be unable to pass upstream due to insufficient flow in the fishway. Additionally, at lower flows the top of the exit ports would no longer be submerged and could be more prone to catching debris.

6.2.6 Cost and Constructability

Level 2 modifications can be implemented in addition to the modifications presented in Level 1. The feasibility level cost estimate for implementing both Levels 1 and 2 modifications is $414,000. A detailed breakdown of the cost estimate is provided in **Appendix I**.

Level 2 modifications include enlarging both fishway exit ports by saw-cutting and removing the upper 1-foot of concrete above each port opening. The existing stoplog guides mounted on the exterior of the fishway ports will continue to be utilized, however new stoplogs and frames to accommodate the winter and summer positions depicted in Figure 6-4.

Level 2 modifications also include the re-construction of the existing concrete spillway and addition of a new flow control gate. Several alternatives to providing flow control over the spillway were explored to increase control of the water surface elevation in the headwater pool during low flow periods. The best flow control option appears to be a hinged crest gate consisting of a single stainless steel gate panel hinged on a lateral torque bar recessed into the reformed concrete spillway. In the downward position, the gate would lay flush along the invert of the crest to minimize bed material and debris accumulation. The gate would be manually actuated from the fishway side of the spillway crest and, following industry standards, could be actuated by a single adult. For the purpose of this conceptual design and developing opinion of probable construction costs, the hinged crest gate was used.

Other considered flow control systems for the spillway include an Obermeyer weir, a slide gate, and an inflatable dam. An obermeyer weir operates similarly to the hinged crest gate, but is actuated with an inflatable device. There is a concern that this type of gate may be more subject to vandalism than a hinged crest gate. A slide gate could be mounted to the downstream face of the spillway and would consist of a downward opening single panel gate that would be manually actuated from the fishway structure. The external mounting of the gate makes it vulnerable to guide and gear box fouling.

Stoplogs were not considered because of the dangers associated with stoplog installation and removal in the high flow conditions at the site. A catwalk that could be used for stoplog installation did not appear to be feasible due to high flow elevations and accessibility. Inflatable dams are a proven technology for applications requiring impoundment of low headwater depths and providing operational control. However, they require a large amount of space, have a large surface area exposed to flows and vandalism, and require continuous monitoring.

These options all have similar costs, but the adjustable crest gate was selected as most feasible because it is safe to access and operate, the least susceptible to vandalism, and requires less space. During subsequent design efforts, other systems to control spillway flow can be considered. Various aspects of each system should be evaluated, including cost, long term durability, safety, operating personnel needs, and maintenance.

Reconstruction of the spillway will include demolishing the upper portion of the existing concrete spillway and removal from the site. The volume or concrete necessary to re-construct the spillway and cast the hinged weir gate would likely warrant the need for the concrete to be delivered to the site in a mixing truck and pumped to the spillway.

Reconstruction of the concrete spillway will require a temporary streamflow diversion to keep this area dewatered during construction. Dewatering could be accomplished with the use of sand bags temporarily placed in one of the pools upstream of the headwater pool to divert water to the other section of the falls. The headwater pool could then be dewatering with use of the existing sluice gate before it is plugged, or with a siphon or pump.

6.3 Level 3 Modifications (Alternative A-3)

Level 3 modifications focus on improving attraction of fish to the fishway entrance by re-establishing the auxiliary water system (AWS); a component of the original fishway. The AWS increases the flow discharging form the fishway, which is intended to improve the ability of fish to locate the entrance. Level 3 modifications assume that Level 1 and Level 2 modifications will be implemented and the hydraulics within the fishway will be as described in Section 6.1.7.

6.3.1 Install New AWS Intake Grille and Flow Control

A new intake grille, also referred to as a fine trash rack, would be placed across the existing AWS intake, which is located on the outer wall of the fishway immediately upstream of the spillway (Figure 6-1 and Figure 6-4). The grille would fit into the existing opening, which is

2.5 feet wide by 7.0 feet tall. The grille would be constructed of vertical flat bars with maximum 7/8 inch spacing between bars, per NMFS NW criteria. The top of the grille would be at the elevation of the modified spillway crest. Given the small size of the AWS and site configuration, the grille would be placed vertically, rather than being inclined at a 1:5 (H:V) slope, as recommended by NMFS NW.

ODFW does not have standards for auxiliary water systems, but refers to NMFS NW standards which state that the maximum approach velocity for the intake should not exceed 1.0 foot/second. The effective area of the grille would be approximately 14.4 square feet. Therefore, the maximum discharge through the AWS intake e would be 14.4 cfs. Higher AWS flowrates would exceed the maximum approach velocity criteria.

To control the AWS flowrate, a control valve would be added to the intake pipe located behind the grille. The valve would be designed to provide porosity control, which would facilitate drawing of water uniformly across the face of the entire grille. The operator for the flow/porosity control valve would be located behind the intake grille, adjacent to the intake pipe. Access to the control valve would be through a new hatch located behind the intake grille.

6.3.2 Replace Diffuser Grates

The original diffuser grate is located along the floor of the entrance bay and was constructed of 1-inch by 4-inch wooden boards. The existing floor under the diffuser is stepped laterally, which helps uniformly distribute flow through the diffuser. During the site inspection, the existing diffuser grate was buried by 3 feet of coarse sediment, and its condition is unknown. However, it is reasonable to assume that the grate and associated hardware will need replacement as part of Level 3 modifications.

6.3.3 Fish Passage Performance for Level 3 Modifications

The proposed Level 3 modifications will increase the flowrate discharging from the fishway entrance, but will not increase flows in the fishway upstream of the entrance bay. Restoring the AWS, combined with the addition of the curb on the fishway roof and raising of the entrance weir included in Level 1, should improve the ability of fish to locate the fishway entrance.

Energy Dissipation of Auxiliary Flow

After going through the intake, the AWS flow would be conveyed through an existing 15-inch diameter corrugated metal pipe that discharges into a pool in the AWS chamber. The overall hydraulic drop from the intake to the AWS chamber is about 20 feet. If adequate energy dissipation is not provided, there can be surging out of the chamber and through the diffusers in the floor of the fishway entrance bay. A general guidance provided by NMFS NW is to avoid an EDF greater than 16 ft-lb/s/ft^3 in the AWS chamber (Aaron Beavers, NMFS NW, Personal Communications). The pool in the existing AWS chamber is 12 feet long by 2.25 feet wide and would typically have a depth between 6 feet and 7 feet. With an AWS flow of 14.4 cfs, the pool EDF could be as high as 25 ft-lb/s/ft^3, which could create undesirable surging through the diffusers in the entrance bay. **To meet the recommended maximum EDF of 16 ft-lb/s/ft^3 requires limiting the AWS flowrate to about 12 cfs.**

Increased Attraction Flow
With the addition of 12 cfs from the AWS to the entrance pool, the percent of streamflow discharging from the fishway entrance relative to the streamflow entering the headwater pool remains above 10% at operational fishway flows (Table 6-4). At the high passage streamflow, the addition of the auxiliary flow to the fishway flow increases the attraction flow by a third (from 36 cfs to 48 cfs). Assuming total streamflow is about 600 cfs when the flow entering the headwater pool is 282 cfs, (more than half the streamflow bypasses the headwater pool), the fishway attraction flow with the AWS is 8 percent of the total streamflow. This is close the NMFS NW recommended minimum of 10 percent.

Water velocities through Diffuser Grate
The diffuser grate is 8 feet wide by 12 feet long, with an area of 96 square feet. At a AWS flowrate of 12 cfs the average velocity through the diffuser grate in the entrance bay floor would not exceed 0.13 feet/second, which is below the NMFS NW recommended diffuser velocity criteria of 0.5 feet/second. Sedimentation along the floor of the entrance bay could lead to non-uniform flow and areas of increased velocity through the diffuser grate. Severe sedimentation could also reduce the AWS flowrate.

Operations and Maintenance
Operational requirements for Level 3 modifications are limited to identifying the appropriate setting for the flow control valve behind the AWS intake to ensure the appropriate intake flowrate is achieved at all flows. The AWS flowrate will vary to some degree based on the level of the headwater pool. During operational flows, the headwater pool level only ranges two feet. At even higher flows, the headwater pool only rises a small amount more, except during extreme flow events. These conditions should facilitate identification of a suitable setting for the flow control valve. Once the setting is identified, no other operations are required. As part of identifying the correct setting, some monitoring of flow conditions across the diffuser grate should be conducted. If excessive surging of velocities through the grates occurs, the AWS flowrate should be decreased.

Table 6-4. Predicted fish passage flows with Level 1, 2 and 3 modifications. Percent streamflow discharging from fishway entrance assumes the restored AWS conveys the maximum allowable rate of 12 cfs, when available.

Headwater Pool Elevation	**90.0 ft**	**90.6 ft**	**91.1 ft**	**91.5 ft**	**92.0 ft**
Fishway Flow	18 cfs	22 cfs	25 cfs	30 cfs	36 cfs
Fishway Entrance Flow (with AWS)	30.0 cfs	33.7 cfs	37.0 cfs	42.0 cfs	48.0 cfs
Winter Operational Settings					
Total Streamflow	**52 cfs**	**94 cfs**	**150 cfs**[1]	**400 cfs**[1]	**600 cfs**[1]
Proportion of Streamflow Discharging from Fishway	58%	36%	25%	11%	8%
Summer Operational Settings					
Total Streamflow	**18 cfs**	**39 cfs**	**64 cfs**	**150 cfs**[1]	**400 cfs**[1]
Proportion of Streamflow Discharging from Fishway	100%	86%	58%	28%	12%

[1] Approximation of total streamflow. At streamflows greater than approximately 100 cfs, a substantial proportion of the water flows over the falls upstream of the headwater pool.

The AWS may require routine maintenance to clear debris from the intake grille. The debris would be removed using a manual rake designed for such use. It is difficult to determine the amount of debris that would accumulate or frequency of cleaning necessary to keep the AWS operating. If the required frequency of debris cleaning was found to be excessive, the AWS flowrate could be decreased using the flow control valve at the intake. This would decrease approach velocities, reducing the likelihood of debris accumulation. It would also allow for a considerable amount of debris accumulation while maintaining approach velocities that satisfy the 1 foot/second criteria. For example, if the AWS flowrate was reduced by half, to 7.2 cfs, then half of the intake grille surface area could become clogged with debris before the approach velocities become excessive. The disadvantage is that attraction flows at the fishway entrance would be decreased.

The AWS may require annual maintenance to control sedimentation at the intake grille and along the floor of the entrance bay where the diffuser grate is located. The bottom of the intake grille would be 6 feet below the new spillway crest, making it prone to sedimentation.

The entrance bay floor is located about 3 feet below the surface of the tailwater pool at its lowest level. This makes it prone to sedimentation. It is likely that the entrance bay would need to be cleaned each spring, as part of the annual sediment cleanout and resetting of the spillway and exit port gates.

6.3.4 Anticipated Design Performance

Hydraulics within the fishway would remain the same as with Level 1 modifications. The only difference is the additional flow added to the entrance bay by the AWS for increased fish attraction. The main areas of uncertainty are decreased performance due to debris and sedimentation.

Debris and Sedimentation at AWS Intake
The rate of debris accumulation on the AWS intake grille could be substantial during winter months, when access is intermittent. This would lead to decreased AWS flows and increased approach velocities at the intake grille.

Even though the Level 2 modifications will lower the spillway crest by 1 foot, there is substantial risk that the bottom portion of the intake grill will be routinely buried in sediment. This is evident when examining existing sediment levels in front of the intake (Figure 5-3). If this occurs, the AWS flowrate will have to be reduced proportional to the amount of surface area blocked by sediment to continue satisfying approach velocity criteria.

Sedimentation in Entrance Bay
The entrance bay is currently filled with coarse sediment to the top of the entrance weir. This area of the fishway experiences substantial backwatering by the tailwater pool during larger flows. The entrance bay, with the raised slotted weir from Level 1 modifications, is also at a hydraulic slope break, making it a natural place for sediment moving through the fishway to accumulate. The Level 1 slotting of the entrance weir will likely reduce sedimentation in the entrance bay to some degree. Given the coarse nature of the sediment, auxiliary water would likely be able to effectively flow through a foot or so of sediment deposited on the diffuser grate. However, if sedimentation in the entrance bay remains as

severe as under existing conditions, the AWS flowrate through the diffuser grate would likely be reduced, which would decrease the effectiveness of the AWS. If slotting of the entrance weir leads to non-uniform sedimentation, the velocities through the diffuser could be concentrated, and could exceed the 0.5 feet/second criteria in some locations.

6.3.5 Cost and Constructability

Level 3 modifications can be implemented in addition to the modifications presented in Level 1 and 2. The feasibility level cost estimate for implementing Levels 1 through 3 is $656,000. A detailed breakdown of the cost estimate is provided in **Appendix I**.

Level 3 modifications include the rehabilitation of the existing AWS, specifically the replacement of the intake grille (fine trash rack) and the addition of a porosity flow control valve and access hatch. The diffuse plate may also need to be reconstructed or replaced. The existing piping will remain in place and utilized. To reconstruct or replace the diffuser plate, existing sediment within the AWS chamber will need to be hand excavated and placed in the tailwater pool.

These modifications would be implemented while the headwater pool was dewatered to accommodate implementation of Level 2 modifications.

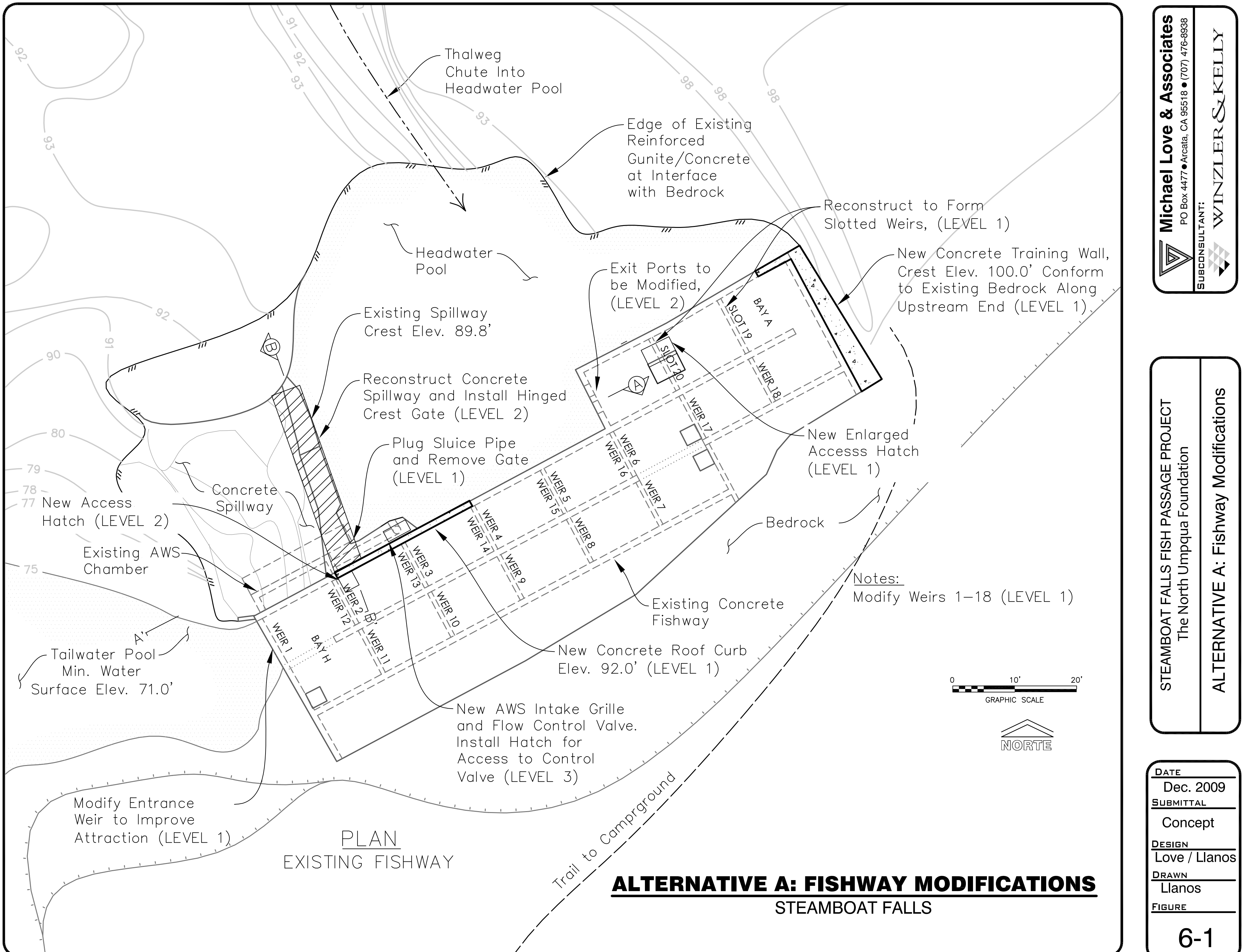


Figure 6-1. Alternative A - Level 1-3 modifications identified on plan view of fishway.

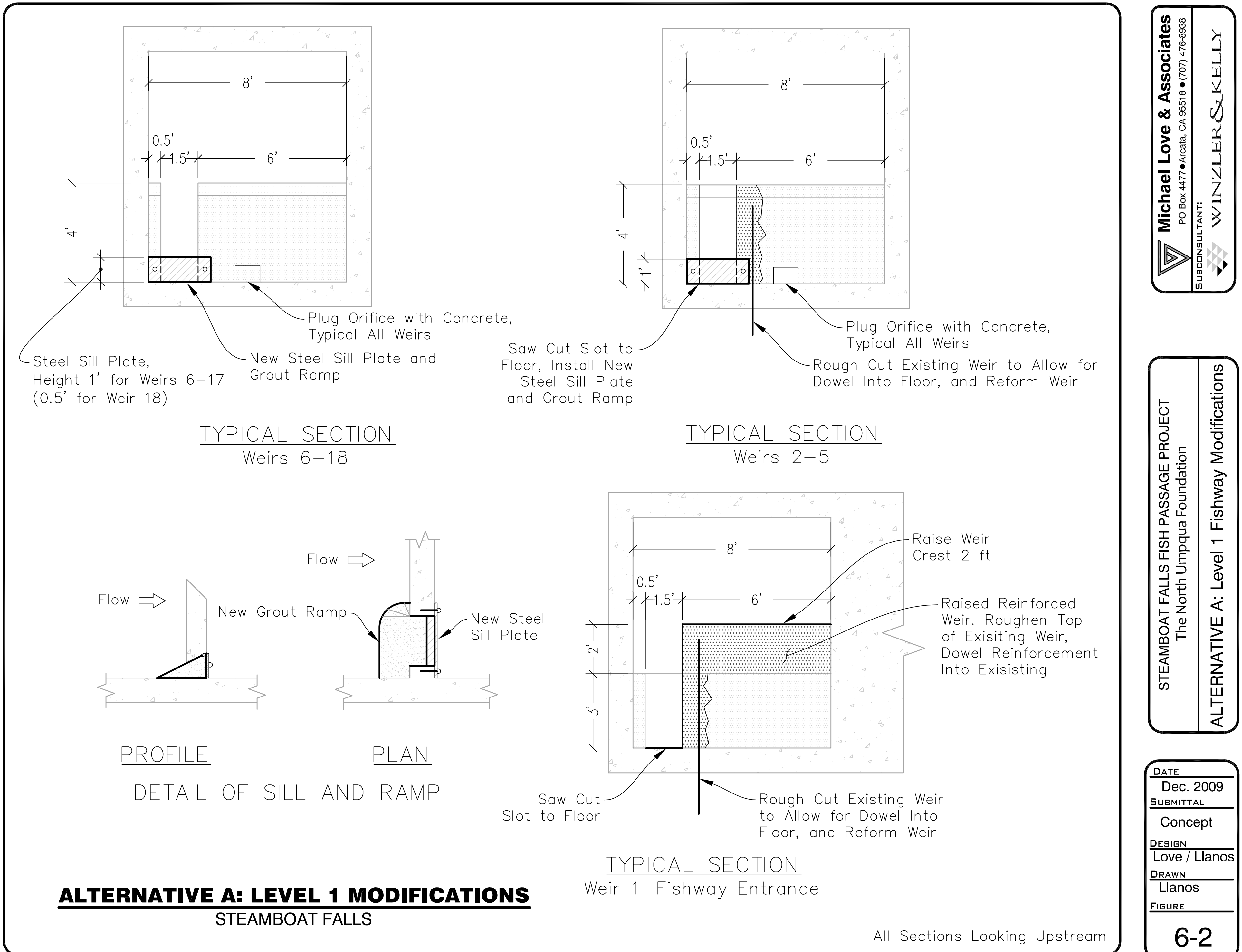


Figure 6-2. Alternative A Level 1 modifications to the existing fishway weirs.

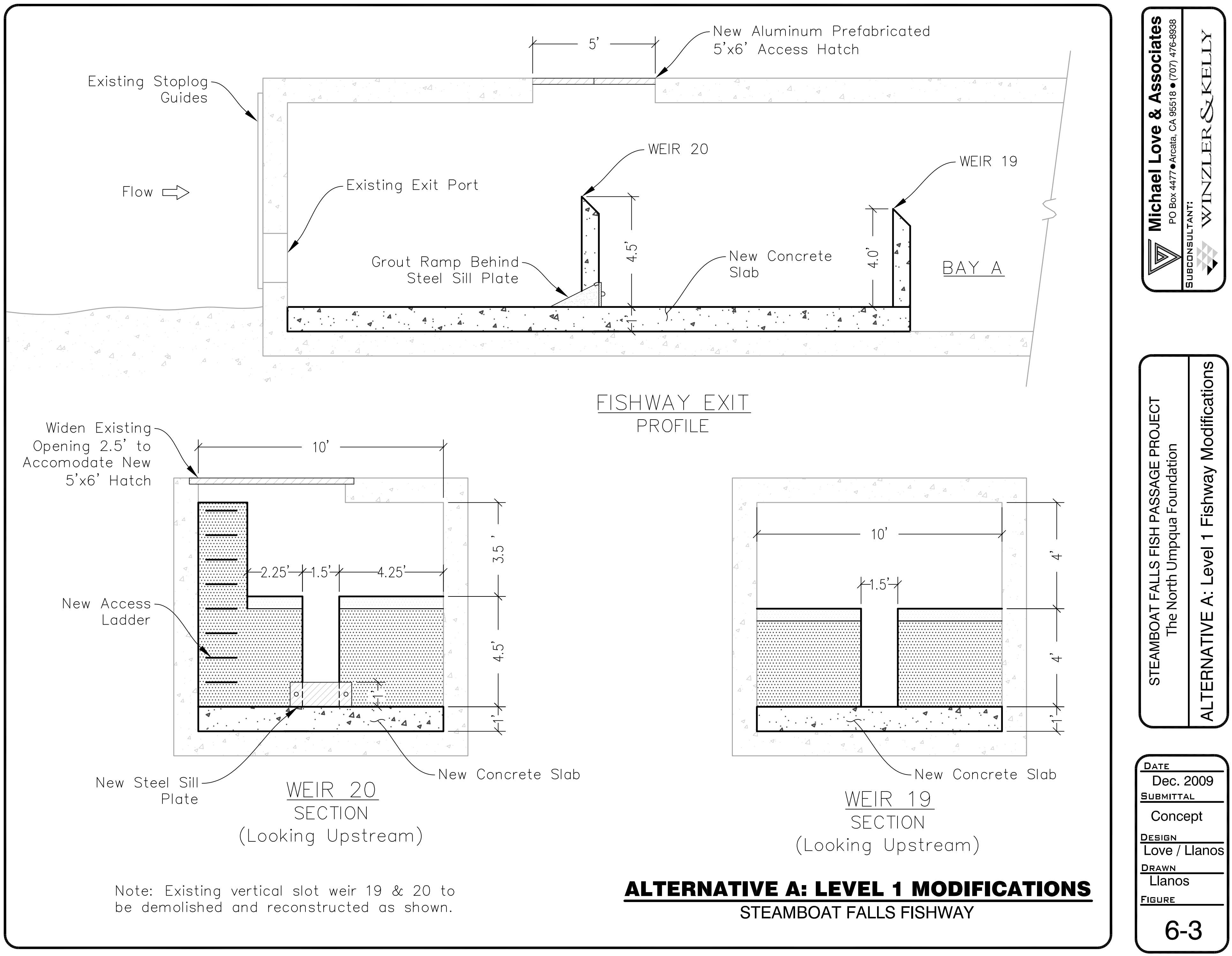
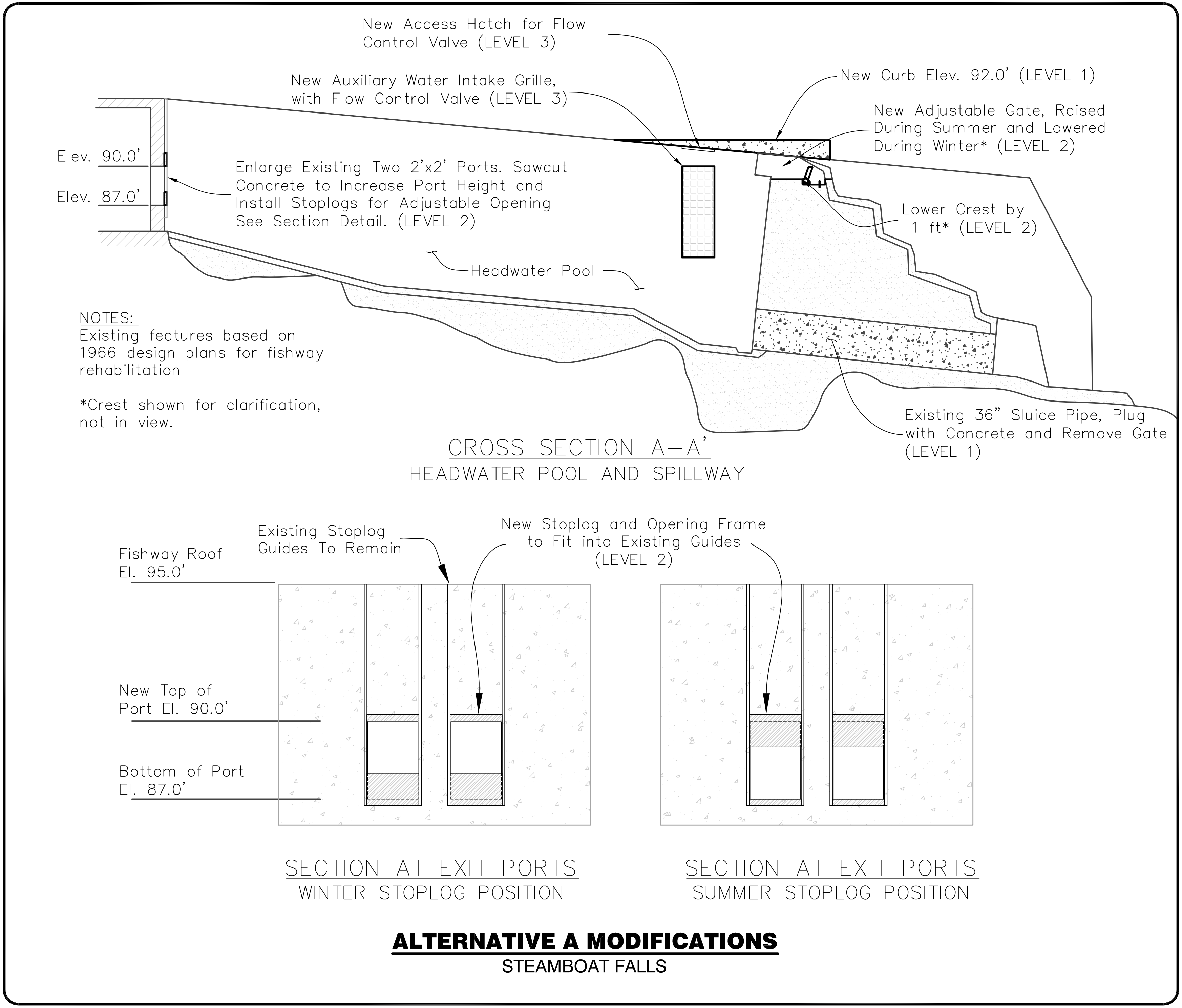


Figure 6-3. Alternative A - Level 1 modifications to fishway exit channel.



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STEAMBOAT FALLS FISH PASSAGE PROJECT
The North Umpqua Foundation
ALTERNATIVE A: Modifications

DATE: Dec. 2009
SUBMITTAL: Concept
DESIGN: Love / Llanos
DRAWN: Llanos
FIGURE: 6-4

Figure 6-4. Alternative A - Level 1-3 modifications to the existing exit port, spillway and AWS.

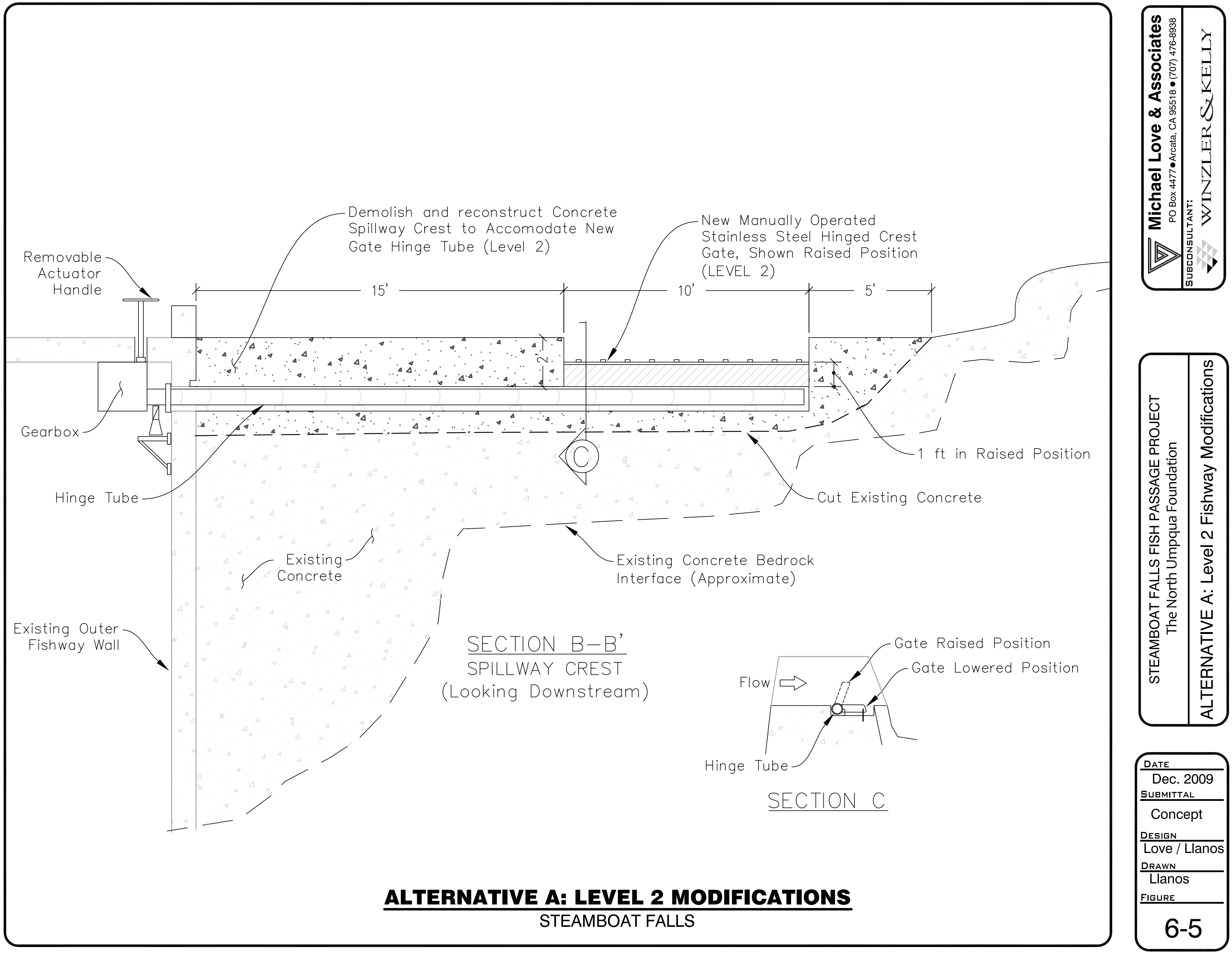


Figure 6-5. Alternative A - Level 2 modifications to existing spillway.

7 Alternative B: Bedrock Fishway

Alternative B proposes construction of a new fishway out of bedrock along the northern side of Steamboat Falls, opposite of the existing fishway. It would consist of a series of pools carved into the existing bedrock and broad crested weirs formed from bedrock (Figure 7-1). The existing fishway would either be left as-is or modified as recommended in Alternative A (See Chapter 0).

7.1 Bedrock Fishway Concept

Topography of Steamboat Falls before construction of the existing concrete fishway suggests there was a passageway along the south bank (where the fishway is currently located) that provided limited steelhead passage during certain flow conditions (See chapter 3). Restoration of this passageway is not possible because much of the bedrock was excavated to build the existing concrete fishway. If the fishway were removed, a large hole would be left in its place, and the face of the falls in that area would be 15 to 20 feet tall and very steep, creating a fish passage blockage.

An alternative concept is to excavate a bedrock passageway through the falls that would simulate a natural passageway. This native bedrock fishway could be designed to operate effectively during moderate stream flows that occur during the winter and spring, when both winter and summer steelhead migrate over Steamboat Falls. The bedrock fishway would contain a series of excavated pools divided by in situ bedrock crests. Dimensions of the fishway would vary to meet geologic site conditions, and would not necessarily follow standard fishway design criteria. Rather, fishway conditions would be evaluated in comparison to downstream natural obstructions that steelhead and possibly Chinook salmon currently negotiate to reach Steamboat Falls.

7.2 Geologic Constraints

Layout of the bedrock pools and weir crests would utilize the existing bedrock jointing (fracturing), which is briefly summarized in Chapter 2 and below, and detailed in the project geologic and geotechnical report (**Appendix E**). The project geologist identified three sets of joints in the bedrock. The "N25W" set runs in a northwest-southeast direction at approximately 25^0 west of north with a nearly vertical dip angle. The "East" set runs northeast-southwest direction at 60^o to 75^o east of north with a nearly vertical dip angle. The third joint set is nearly horizontal. Together, the three joint sets form discrete blocks that typically range between two and four feet in size. To facilitate excavation, the bedrock fishway should be designed to follow the vertical jointing in the bedrock.

The resulting face of excavated bedrock should also be stepped based on the spacing of the joints and resulting size of the excavated blocks. Geotechnical recommendations for bedrock excavation includes keeping the overall cut-slope between 1:1 (H:V) and ¾:1 (H:V). For this concept level development, the cut-face steps above the crests were assumed to be 4 feet wide by 4 feet tall.

7.3 Siting

The bedrock fishway should be strategically placed to avoid being in the main path of streamflow and bedload going over the falls. There must be enough room available to fit a fishway with adequately sized pools to dissipate the water's energy at fish passage flows. During fish passage flows, the entrance should be accessible to fish holding in the tailwater pool and the exit should be placed to control the amount of water flowing into the fishway. Additionally, there are a number of small bedrock drops and pools in the channel upstream of the main drop over the falls. Therefore, the further upstream the fishway exit and headwater pool is located, more overall drop the fishway must overcome.

The most suitable site identified for the bedrock fishway is along the northern side of the falls, opposite of the concrete fishway. At low and moderate flows, the channel thalweg passes through two pools before entering the existing concrete fishway or cascading down the concrete spillway (Figure 7-1). The downstream pool currently functions as the headwater pool for the existing fishway. The upstream pool would function as the headwater pool for the bedrock fishway. This pool is well suited for the bedrock fishway since its level does not fluctuate much with flow.

At fish passage flows, the northern area of the falls is somewhat sheltered from the main flow path of the stream by an elevated bedrock area. The sheltering effect created by the elevated bedrock will limit the amount of water flowing into the bedrock fishway.

At the bedrock fishway site, the existing bedrock is lower than in adjacent areas and a section of the existing falls in this area has a sloping bedrock face. Placement of the fishway in this area was carefully selected to take advantage of the sloping face and reduce the amount of excavation required. Below the sloping face, a bedrock bench is overlain by large "boulder blocks" stockpiled here during construction of the existing fishway (See Section 2.2). The bench and boulder blocks slope gradually into the tailwater pool and can be rearranged to form an entrance channel from the tailwater pool.

7.4 General Fishway Dimensions

A range of dimensions for the bedrock fishway were developed to encompass the variability of bedrock jointing patterns found at the site. Schematic drawings of typical fishway pool and crest shapes and dimensions are provided for general guidance for construction, with the expectation that the final shape will be determined onsite during excavation, as subsurface geologic conditions are revealed.

7.4.1 Pool Crests

Each pool crest would consist of a raised section of bedrock that creates a chute. The pool crests would be roughly 4 to 6 feet long in the streamwise direction and relatively horizontal. (Figure 7-2). The crest would have a notch that is roughly 4 feet wide and 2 to 3 feet deep that contains lower fishway flows. At fish passage flows, the crests between pools would function as bedrock chutes. The drop from crest to crest would range between 2 and 3 feet, which is well within the leaping abilities of adult steelhead and Chinook salmon. At most fishway flows steelhead will likely swim into and through the chute.

There is risk that some of the pool crests will become over-excavated due to bedrock jointing. In such cases, a limited amount of reinforced concrete keyed into the bedrock could be used to rebuild the crest. For aesthetics, the concrete could be shaded to match the color of the bedrock.

7.4.2 Pools

The cross sectional shape of the pools was based on the anticipated size of the bedrock blocks and the shape resulting from the excavated step cut-slope (Figure 7-2). The shape was also determined by the pool volume needed to dissipate the flow's energy. The residual depth of the pool downstream of each crest would be a minimum of four feet to ensure the jet from the plunging water will not impact the bottom of the pool during fish passage flows, which could harm fish. At low-flows, the top width of the residual pool would range between 10 and 14 feet. Spacing between pools ranges from 18 to 24 feet, with pool lengths ranging between 14 and 18 feet (Figure 7-3). At turns in the fishway, the centerline length of turn-pools range between 20 and 24 feet. There are also two switchback pools, each with a centerline length of roughly 40 feet.

7.5 Fishway Layout

Layout of the bedrock fishway was guided by the orientation of the bedrock jointing and the existing bedrock topography along the northern portion of the falls. The preferred route connects the fishway exit channel to an existing pool at the upstream end of the fishway that would serve as the fishway headwater pool (Figure 7-1). From the exit, the fishway follows the East joint set for about 50 feet, before turning approximately 95 degrees towards the northwest to follow the orientation of the N25W joint set for 50 feet. It then turns towards the southeast and follows the East joint set. In this section, the fishway contains two switchbacks to increase the fishway length and exploit the lower bedrock elevations on the stepped face of the falls. The overall length of the fishway measured along its centerline from entrance to exit crest is 260 feet. The overall slope of the fishway is 7.35%, with a total of eight pools. Depth of bedrock excavation, measured from the pool bottom to existing ground, ranges between 4 and 20 feet.

7.5.1 Headwater Pool, Exit Channel and Flow Control

The proposed headwater pool at the exit of the bedrock fishway is approximately 4 feet deep and 75 feet long. At low and moderate streamflows its water level only varies slightly.
A small exit channel, roughly 4 feet wide, 2 feet deep and 15 feet long, would connect the headwater pool to a pool crest of the fishway exit. The pool crest at the fishway exit would be used to control flow into the fishway. It would be constructed with different dimensions than the other pool crests within the fishway.

7.5.2 Turnbays

Turns in the fishway were necessary to fit within the site constraints. The upstream most turn, at Pool 7, places the fishway downstream of elevated bedrock, shadowing it from the main flow path of the stream during fish passage flow. The second turnbay, at Pool 5, turns the fishway back towards the tailwater pool. The turn bays are designed to dissipate energy from the plunging flow from the upstream crest before the flow turns.

7.5.3 Switchbacks

The switchback section of the fishway at Pools 2 and 3 increases the number of drops over a short length, allowing the fishway to "climb" up the face of the falls. The switchback section was located along the northern edge of the falls, which receives little to no flow except during flow events greater than fish passage flows. This area of the falls has a sloping stepped face, reducing the required depth of excavation at this location. The height of the existing bedrock dividing the switchback pools would be lowered to allow the switchback to become overtopped during high flows. Once overtopped, the switchback section would function as one large chute, allowing the water to flow in a straight line from Pool 5 to the entrance.

7.5.4 Entrance

The fishway entrance is connected to the tailwater pool of Steamboat Falls, about 130 feet north of the main portion of the falls. The entrance pool crest would be roughly 2 to 3 feet above the level of the tailwater pool. Discharge from the fishway entrance would flow through the existing boulder field for approximately 30 feet and into the tailwater pool. The boulders could be arranged to form a "roughened channel" that fish could swim through to reach the entrance crest.

7.6 Fish Passage Performance

7.6.1 Fishway Design Flows

Alternative B was developed assuming it would not be the primary low-flow passageway, but the existing fishway would provide passage during summer months. However, if low flow passage in a new fishway becomes a primary objective, the flow control at the fishway exit could be shaped, or modified after construction, to have either bedrock fishway operate at low flows

The bedrock fishway should be designed to operate during the winter and early spring, when the existing concrete fishway is most likely to be inoperable due to plugging with sediment and debris (See Section 5.4.2). The streamflows that the bedrock fishway would be operable depend on the amount of flow entering the fishway. This is controlled by the geometry of the pool crest at the bedrock fishway exit and the water level in the headwater pool.

Low Fishway Design Flow

The low fishway design flow was defined as the flow that provides 1 foot of depth across the upstream end of each pool crest, which occurs at 8 cfs. Table 7-1 summarizes fish passage hydraulics for the bedrock fishway at a range of fishway design flows. Because each crest acts as a broad crested weir, the minimum depth in each notch would occur at the downstream end. At 8 cfs, the depth and velocity at the downstream end of the notch, assuming flow goes through critical depth, would be about 0.5 feet and 4.0 feet/second, respectively.

Water will accelerate and depth decrease as flow goes through the notch before plunging into the receiving pool. Fish will either swim or leap to enter the notch. Because of the streamwise length of the notch, fish will most likely swim through the notch rather than leap over it entirely. While minimum water depth in the notch does not meet ODFW minimum depth requirements of 1 foot until 21 cfs, adult salmon and steelhead have the capability to swim short distances in shallower flows. The proposed bedrock fishway is similar to the natural shallow bedrock chutes in downstream reaches of Steamboat Creek that fish currently swim though.

Other fish passage criteria, such as velocity and EDF, are well within fish passage criteria at 8 cfs. **Therefore, to maximize the operational range of the bedrock fishway, 8 cfs was defined as the low fishway design flow.**

Table 7-1. Predicted bedrock fishway performance.[1] Italicized values indicate conditions that do not meet ODFW fish passage criterion.

Fishway Flow	**8 cfs**	**14 cfs**	**21 cfs**	**44 cfs**
Depth over Crest[2]	1.0 ft	1.5 ft	2.0 ft	2.7 ft
Minimum Depth in Notch[2]	*0.5 ft*	*0.7 ft*	1.0 ft	1.6 ft
Maximum Velocity in Notch[3]	4.0 ft/s	4.9 ft/s	5.5 ft/s	6.5 ft/s
Minimum Pool Depth	5.0 ft	5.5 ft	6.0 ft	6.7 ft
EDF in Pool	0.9 ft-lb/s/ft^3	1.4 ft-lb/s/ft^3	1.9 ft-lb/s/ft^3	4 ft-lb/s/ft^3

[1] Drops between weirs crests range from 2 to 3 feet, averaging 2.3 feet.

[2] Measured at upstream face of crest.

[3] At downstream end of crest, assuming critical flow depth.

High Fishway Design Flow

The high fishway design flow was determined by the flow that creates an EDF of 4 ft-lb/s/ft^3, which is the maximum recommended by ODFW.

At high flows, water will exceed the capacity of the notch and begin overtopping the weir on the pool crest. This will concentrate flow down the center notch while providing a small amount of plunging flow along the edges. Assuming the entire receiving pool volume is effective at dissipating the energy of the flow entering the pool, the recommended maximum EDF of 4 ft-lb/s/ft^3 would be reached at a flow of about 44 cfs. **Therefore, 44 cfs was defined as the high fishway design flow.** At this flow, the maximum water velocity in the notch would be about 6.5 ft/s; lower than the ODFW recommended maximum of 8 ft/s for notches, and well within the swimming abilities of adult steelhead and Chinook salmon (Bell, 1991).

Streamflow at Fishway Design Flow

For the purposes of evaluating this alternative, the streamflows corresponding to the operable bedrock fishway flows were assumed to be between **75 cfs and 440 cfs**.

NMFS NW recommends that a fishway convey at least 10 percent of the total streamflow to provide suitable attraction flow to a fishway. Therefore, at the high fishway design flow of 44 cfs, the bedrock fishway could provide adequate attraction flow up to a streamflow of 440 cfs (35 annual exceedance flow, See Section 3.3.1) if the exit crest can be designed to prevent excessive flow from entering the fishway. This seems feasible based on interpretation of flow conditions from photographs of Steamboat Falls at streamflows around 500 cfs.

During the summer, nearly all of the streamflow below about 75 cfs is conveyed into the headwater pool of the existing concrete fishway. The bedrock fishway should be designed to avoid capturing too much flow during the summer, which would make the concrete fishway inoperable. Therefore, the bedrock fishway should be designed to become operable (fishway flow of at least 8 cfs) at a streamflow of about 75 cfs or greater. At a streamflow of 75 cfs and a low fishway design flow of 8 cfs, the recommended NMFS NW criteria of 10% attraction flow is satisfied.

Final design of the bedrock fishway exit and determination of its operable streamflows requires collection of additional topographic information, and possibly some direct measurements of water levels in the proposed headwater pool at various flows.

7.6.2 Drop Heights

The average pool crest-to-crest drop across the fishway is 2.3 feet, but would vary between 2 and 3 feet, depending on bedrock conditions at each pool crest. Although this is greater than the recommended maximum 1-foot water surface drop height for salmon and steelhead, it is well within the leaping ability of adult steelhead and Chinook salmon and is less than some of the naturally occurring drops fish must pass over to reach Steamboat Falls. For example, downstream on Steamboat Creek is Little Falls, which has several distinct drops that fish must overcome; each exceeding 3 feet in height.

7.6.3 Operations and Maintenance

The bedrock fishway is not expected to have any operational or maintenance requirements. It is expected to self-maintain similarly to the natural falls within the area. Sediment is expected to be scoured out of the pools during large flow events (See Section 7.7.3). There is a small risk that a piece of large woody debris could occasionally become jammed in the fishway in a manner that would adversely affect fish passage. If this occurs, it may be necessary to cut or remove the wood to restore fish passage.

7.7 Anticipated Design Performance

7.7.1 Structure Shaping

It is expected that the bedrock fishway can be shaped within the face of the existing falls by removing the blocks formed along the bedrock joints (See Chapter 2). Some uncertainty exists regarding the subsurface bedrock jointing, which will govern the shape of the fishway pools and crests. This will likely create a natural variability within the fishway and may cause some portions of the fishway to not meet fish passage criteria. Fine tuning during construction may be necessary and post construction monitoring and adaptive management is recommended (Section 7.7.4). Fine tuning of the pool crest shape will likely be achieved using an excavator or small explosives. Concrete may be needed to change the shape of the pool crest in locations where coarse excavation the bedrock does not create the desired shape.

During construction, there is also the potential to over-excavate the crest, which could create an excessive drop at the next upstream crest. These issues would need to be addressed during excavation through frequent inspection by the project's geologist and onsite design modifications by the project geotechnical engineer and fish passage engineer. Concrete keyed into the bedrock may be needed to raise the weir crest should over excavation occur during construction.

7.7.2 Fish Passage Streamflows

As previously discussed in Section 7.6.1, there is uncertainty regarding the range of streamflows the bedrock fishway would be operable. Collection of additional field information during final design would help better define the range.

In the hydraulic calculations of EDF, the entire pool volume was considered effective at dissipating turbulence. However, these pools are relatively long and it is likely that most of the energy would be dissipated as turbulence close to the pool crest. Therefore, the true effective pool volume may be substantially less than assumed. This could result in excessive turbulence close to the weir crest, which could create a fish barrier at flows less than 44 cfs. As a result, the actual range of fish passage streamflows could be less than stated.

7.7.3 Sedimentation

The proposed bedrock fishway pools are not expected to experience any significant sedimentation. The large drops from crest to crest will scour and transport most of the sediment. Additionally, during large flow events, when the stream is transporting large amounts of bedload, flows are expected to cascade into the fishway from upstream, providing a tremendous amount of scouring force that should dislodge any deposited sediment.

7.7.4 Adaptive Management to address Uncertainty

If constructed, physical and biological monitoring should be conducted to verify that the fishway performs as designed. Modifications to the bedrock fishway could be made if post project monitoring identifies problem areas. Modifications could involve removal of additional bedrock or use of concrete to build up crests.

Over time, it is reasonable to expect some of the bedrock blocks forming the crest may shift along a joint or erode, which could impede fish passage. At that point, it may be necessary to use concrete to stabilize the bedrock blocks and/or reshape the crests.

If passage conditions through the bedrock fishway were found to be insufficient, one remediation would be to remove the bedrock crests and construct a series of concrete weirs to create a more standard pool and weir fishway, similar to the concept proposed for Alternative C.

If in the future, the existing concrete fishway is no longer functional and decommissioned or demolished, the bedrock fishway could serve as the sole passageway over the falls. Additionally, if the existing concrete spillway is severely damaged or destroyed, such as during the 1964 flood, the bedrock fishway will continue to function. In either situation, modifications may be required to the bedrock fishway exit crest to ensure it receives sufficient flow during low summer flows.

7.8 Cost and Constructability

The feasibility level cost estimate for Alternative B modifications is $411,000. The existing fishway can either be left as-is or modified as recommended in Alternative A. A detailed breakdown of the cost estimate is provided in **Appendix I**.

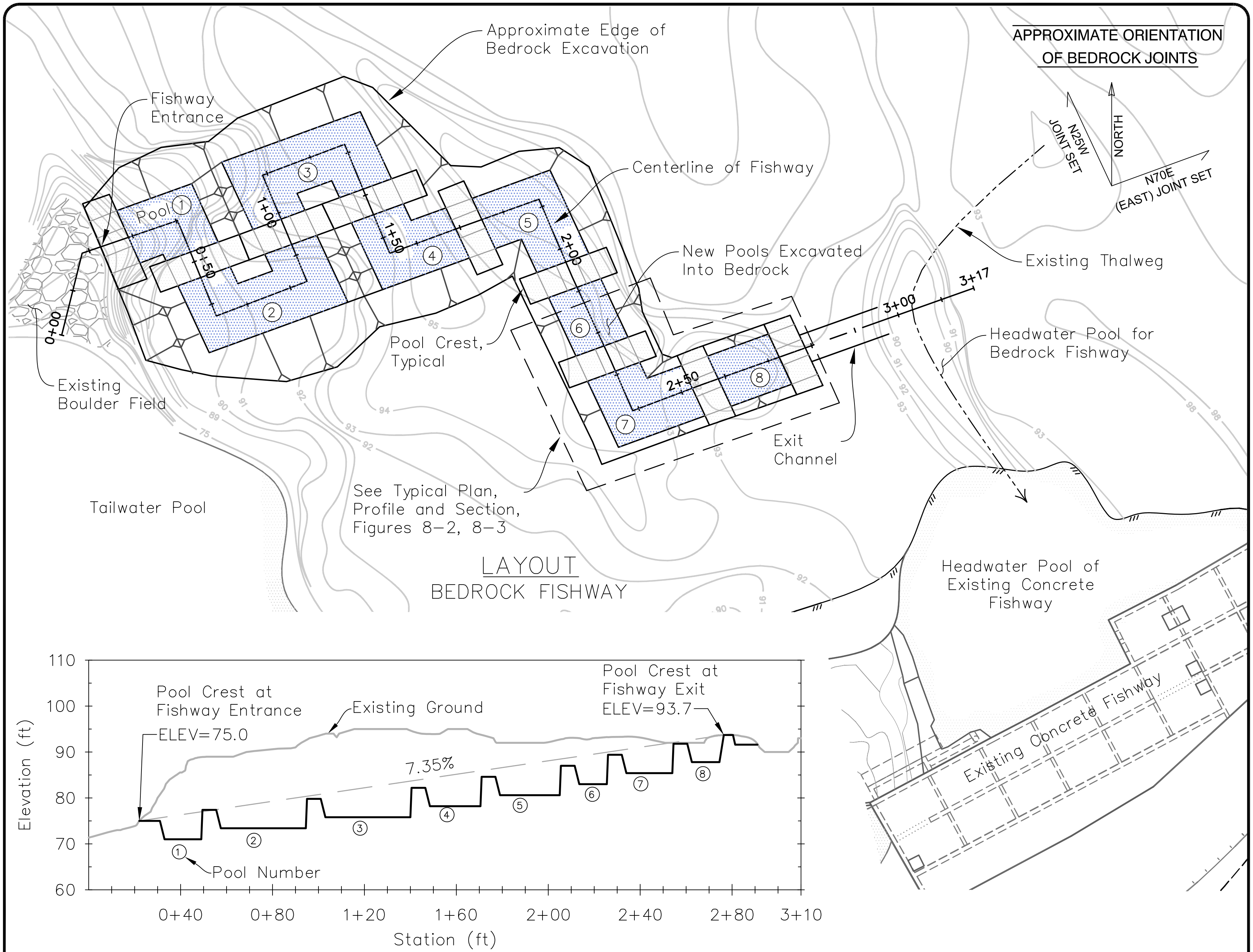
Alternative B improvements include the construction of a bedrock fishway. Based on recommendations summarized in the geologic and geotechnical report (**Appendix E**), excavation of the bedrock fishway could require excavation of depths up to 20 feet. It is expected that the rock can be removed with a standard excavator with hardened teeth. Based on the observed jointing, the rock is anticipated to be removed in blocks up to 4 feet x 4 feet x 4 feet. At the deeper areas of removal and in the turn pool corners, rock removal may require large chippers and or isolated blasting. It is not anticipated that blasting techniques will be required, but could be an option for controlled removal of the rock.

Chipping or minor blasting of the bedrock can be used to achieve the final pool crest shapes and dimensions. If discontinuities in the fracture joints result in uncontrolled fracturing of the bedrock during excavation, the pool crests could be reformed with concrete to achieve the desired crest elevations and hydraulic conditions. The final construction plans will include a tolerance for construction elevations of the pool crest. Because of the complexity associated with bedrock excavation and the importance of maintaining an acceptable tolerance, it is suggested that a geotechnical engineer be present throughout construction.

Equipment access to the bedrock fishway can be from the north side of the falls from Steamboat Creek Road, down a steep embankment to the crest of the falls. The embankment is lined with rock excavated during the construction of the existing fishway. This rock will need to be rearranged to allow construction access down to the falls. If necessary, rock from the bedrock fishway excavation can be used to construction haul roads down the embankment. Construction access to the downstream end of the bedrock fishway can be accomplished through partial excavation of the fishway channel. Final excavation could then proceed from downstream to upstream, beginning with the rearrangement of the existing boulders at the fishway entrance.

Multiple excavators operating in series may be necessary for removing the bedrock blocks out of the channel and loading into equipment for hauling to a disposal site. Equipment access to the project site could prove difficult, and will likely require the use of tracked off-road equipment. A specific disposal site for excavated rock is currently unidentified. It may be feasible to distribute excavated rock through the construction site, possibly eliminating the need for hauling and disposal.

It will be necessary to maintain dewatered conditions within the limits of construction of the bedrock fishway as well as any construction access areas at the head of the falls. To maintain dewatered conditions during construction, a temporary stream diversion will be necessary to divert water to the northern part of the falls and around the work area.



PROFILE ALONG FISHWAY CENTERLINE
BEDROCK FISHWAY

ALTERNATIVE B: BEDROCK FISHWAY
STEAMBOAT FALLS

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STEAMBOAT FALLS FISH PASSAGE PROJECT
The North Umpqua Foundation

ALTERNATIVE B: Bedrock Fishway

DATE	Dec. 2009
SUBMITTAL	Concept
DESIGN	Love / Llanos
DRAWN	Llanos
FIGURE	7-1

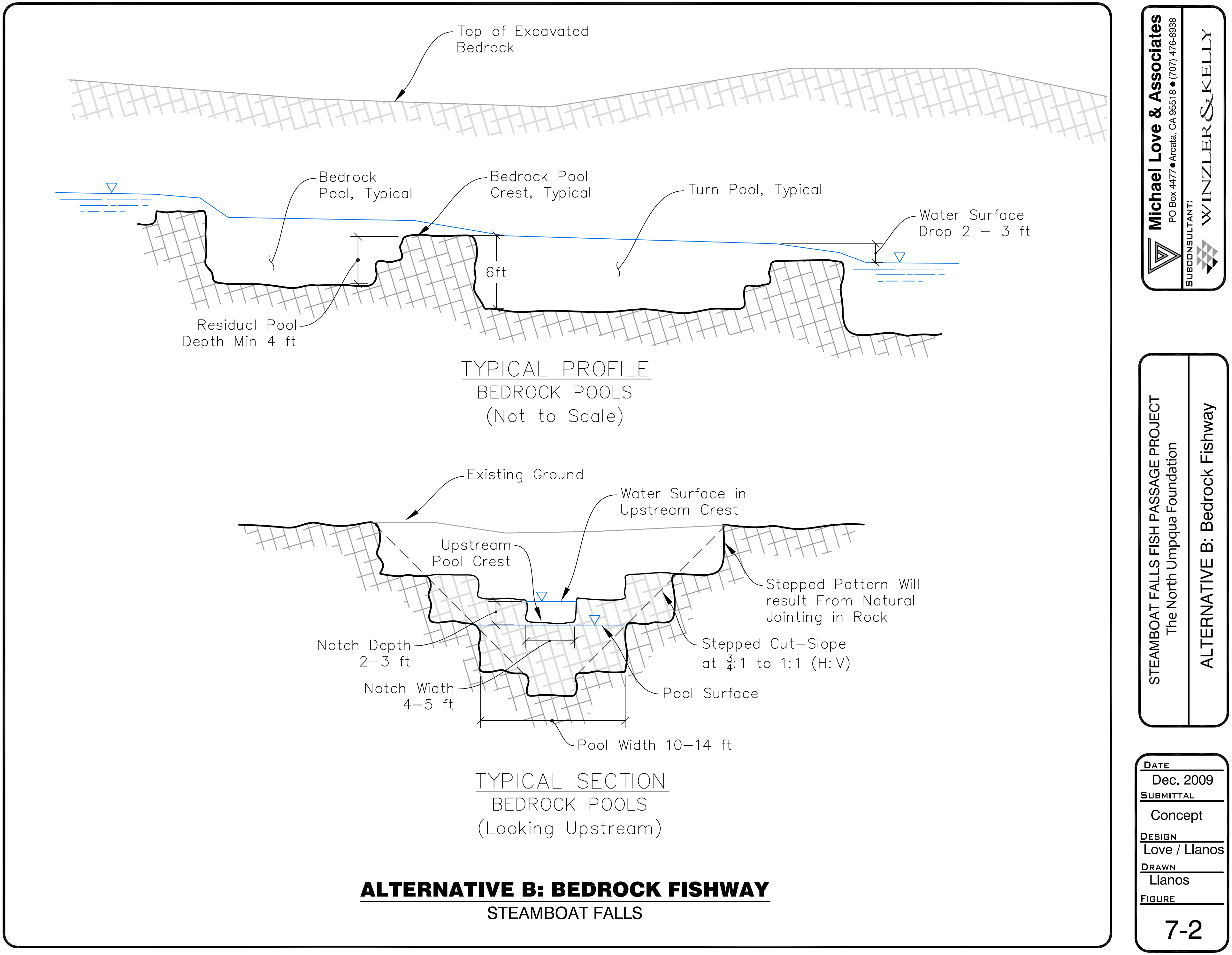


Figure 7-2. Idealized profile and section of Alternative B Bedrock Fishway.

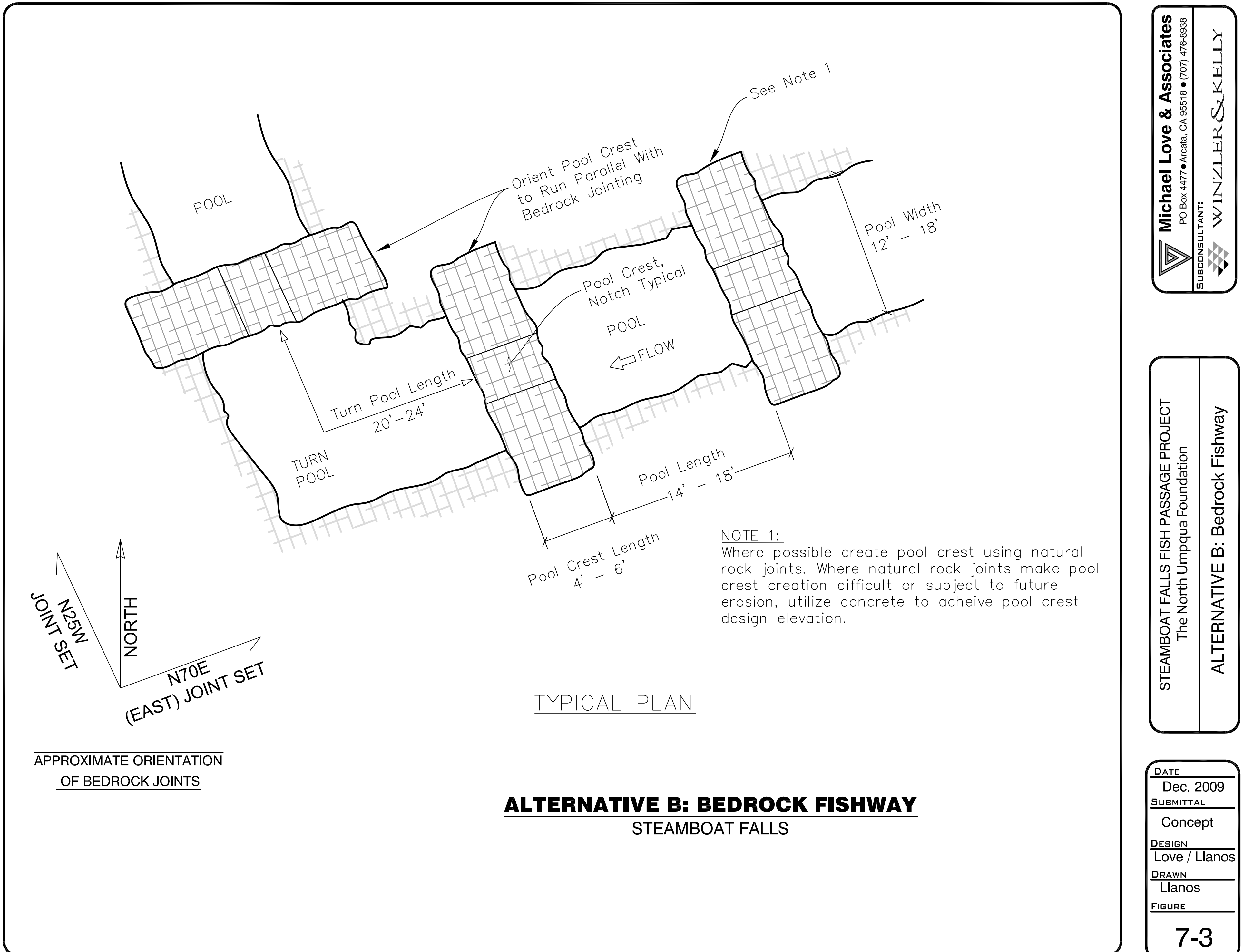


Figure 7-3. Idealized plan view of Alternative B Bedrock Fishway.

8 Alternative C: Bedrock Fishway with Concrete Weirs

Alternative C proposes construction of a new fishway out of bedrock along the northern side of Steamboat Falls, opposite of the existing fishway. It would consist of a series of pools carved into the existing bedrock and controlled with concrete weirs (Figure 8-1). The existing fishway would either be left as-is or modified as recommended in Alternative A (See Chapter 0).

8.1 Bedrock Fishway with Concrete Weirs Concept

Similar to the Alternative B: Bedrock Pools (Chapter 7), the Alternative C concept is to excavate a bedrock passageway through the bedrock falls. The main difference is that the drops would be controlled by concrete fishway weirs keyed into the bedrock walls instead of using bedrock crests, as in Alternative B. This eliminates risks associated with use of bedrock crests and allows the fishway design to satisfy ODFW and NMFS NW fish passage criteria, as well as reduce the project footprint and shorten the overall fishway length. It also provides the ability to select a fishway alignment that does not strictly follow the orientation of the bedrock jointing.

The bedrock-concrete fishway would contain a series of excavated pools divided by constructed concrete crests. Dimensions of the fishway pools would vary to meet geologic site conditions. The bedrock-concrete fishway could be designed to operate effectively during moderate streamflows that occur during late-fall, winter, and spring, when both winter and summer steelhead migrate over Steamboat Falls.

8.2 Geologic Constraints

Like Alternative B, layout of the bedrock pools for Alternative C would utilize the existing bedrock jointing (fracturing), which is summarized in Chapter 2 and below, and detailed in the project geologic and geotechnical report (**Appendix E**). The resulting face of excavated bedrock should also be stepped based on the spacing of the joints and resulting size of the excavated blocks. Geotechnical recommendations for bedrock excavation includes keeping the overall cut-slope between 1:1 (H:V) and ¾:1 (H:V). For concept level development, the cut-face steps above the crests were assumed to be 4 feet wide by 4 feet tall.

8.3 Siting

As described in siting for Alternative B (See Section 7.3), the most suitable site identified for the bedrock-concrete fishway is along the northern side of the falls, opposite of the concrete fishway (Figure 8-1). The headwater pool for Alternative B would serve as the headwater pool for the bedrock-concrete fishway.

8.4 General Fishway Dimensions

Dimensions for the bedrock-concrete fishway were developed based on the observed bedrock jointing patterns and fish passage criteria. Schematic drawings of typical fishway pool shape and dimensions are intended to provide general guidance for design, with the expectation that the final fish passage and geotechnical engineering adjustments must occur onsite during excavation, as subsurface geologic conditions are revealed. Unlike the bedrock pools, the concrete weir shape, dimensions, and drop heights should remain consistent from weir to weir.

8.4.1 Concrete Weirs

Each concrete weir would be 1 foot thick and keyed into the existing bedrock a minimum of 0.5 feet at the sides and floor (Figure 8-2). The length of the entire weir would vary depending on the width of the bedrock pool, but would generally be between 14 and 18 feet. The fishway flows would be confined to an 8-foot wide section of the weir, which would have a level crest and a notch that is roughly 2 feet wide and 1 foot deep to contain the lower fishway flows. Spacing between weirs is a minimum of 10 feet on-center, except where the fishway turns more than 60 degrees the weir spacing is doubled. The drop from crest to crest would be 1 foot, to meet ODFW and NMFS NW fishway criteria. For aesthetics, the concrete could be shaded to match the color of the bedrock.

8.4.2 Pools

The cross sectional shape of the pools was based on the anticipated size of the bedrock blocks and the shape resulting from the excavated step cut-slope (Figure 8-2). The shape was also guided by the pool volume needed to dissipate the flow's energy. The residual depth of the pool downstream of each weir would be a minimum of 3 feet. The top width of the residual pool would range between 14 and 18 feet. The length of each pool would be about 9 feet (Figure 8-3). At turns in the fishway, the centerline length of turn-pools range between 18 and 20 feet.

8.5 Fishway Layout

Layout of the bedrock-concrete fishway was influenced by the orientation of the bedrock jointing and the existing bedrock topography along the northern portion of the falls. Use of concrete weirs allowed for the centerline alignment of the fishway to vary from the alignment of the joints. The pool sides follow the alignment of the jointing while the concrete weirs are oriented orthogonal to the fishway centerline. This results in a staggering of the pool edges, as shown in Figure 8-1.

The preferred route connects the fishway exit channel to an existing pool at the upstream end of the fishway that would serve as the fishway headwater pool. From the exit, the fishway follows the East joint set for about 40 feet, before turning approximately 115 degrees towards the northwest. This is 95 feet long and the centerline is oriented 43 degrees east of north. It then turns towards the southeast and towards the existing tailwater pool. The overall length of the bedrock-concrete fishway measured along its centerline from entrance to exit crest is 220 feet and there are 19 pools. The overall slope of the fishway is 8.6%. Depth of required bedrock excavation, measured from the pool bottom to existing ground, ranges between 4 and 20 feet.

8.5.1 Headwater Pool, Exit Channel and Flow Control

The proposed headwater pool at the exit of the bedrock-concrete fishway is approximately 4 feet deep and 75 feet long. At low and moderate streamflows its water level only varies slightly.

A small exit channel, roughly 4 feet wide, 2 feet deep and 7 feet long, would connect the headwater pool to the pool crest at the fishway exit. The fishway exit pool crest would control flow into the fishway. It would be constructed with different dimensions than the other pool crests within the fishway. Concrete may be used to fine-tune the shape of the exit pool crest to achieve the desired flow control.

8.5.2 Turnbays

Turns in the fishway are necessary to fit within the site constraints. The upstream-most turn, at Pool 16, places the fishway downstream of elevated bedrock, shadowing it from the main flow path of the stream at fish passage flow. The next two turnbays, at Pools 8 and 6, turn the fishway orientation back towards the tailwater pool. The turn bays are designed to dissipate energy from the plunging flow over the upstream weir before the pool turns by maintaining a pool length of 9 feet along the shortest pathway of the flow. Turnbays with turns greater than 60 degrees have a centerline-length that is at least 18 feet.

8.5.3 Entrance

The fishway entrance is connected to the tailwater pool of Steamboat Falls, about 130 feet north of the main portion of the falls. The entrance weir is located at the edge of the tailwater pool. Hydraulic drop across the entrance weir crest and into the tailwater pool would be between approximately 1 and 1.5 feet during late-fall through spring. The entrance weir may need to be slotted to create a jet that penetrates the tailwater pool and improves fishway attraction. The existing boulders currently located on the bedrock shelf where the fishway entrance is sited would need to be removed.

8.6 Fish Passage Performance

8.6.1 Fishway Design Flows

Alternative C was developed assuming it would not be the primary low-flow passageway, but the existing fishway would provide passage during summer months. However, if low flow passage in a new fishway becomes a primary objective, the flow control at the fishway exit could be shaped, or modified after construction, to have either bedrock fishway operate at low flows

The bedrock-concrete fishway should be designed to operate during the winter and early spring, when the existing concrete fishway is most likely to be inoperable due to plugging with sediment and debris (See Section 5.4). The streamflows that the new fishway would be operable depends on the amount of flow entering the fishway. This is controlled by the geometry of the weir crest at the bedrock-concrete fishway exit and the water level in the headwater pool.

Fish passage hydraulics for Alterative C was calculated using the same modeling approach as in Alternative A. The concrete weirs were assumed to function as sharp crested weirs. Flow through the notch was assumed to transition to streaming flow at a depth in the notch greater than 1.5 feet. Streaming flow through the notch was calculated as if it were a vertical slot, with plunging weir flow over the sloping crest beyond the notch. Table 8-1 summarizes fish passage hydraulics for the bedrock-concrete fishway at a range of fishway design flows.

Low Fishway Design Flow
The low fishway design flow was defined as the flow that creates 1 foot of depth over each weir, and occurs at a fishway flow of 6.5 cfs. **Therefore, 6.5 cfs was defined as the low fishway design flow.**

Table 8-1. Predicted bedrock-concrete fishway performance.[1]

Fishway Flow	6.5 cfs	18 cfs	39 cfs	42 cfs
Depth over Weir	1.0 ft	1.5 ft	2.0 ft	2.1 ft
Pool Depth	4.0 ft	4.5 ft	5.0 ft	5.1 ft
EDF in Pool	0.8 ft-lb/s/ft^3	1.9 ft-lb/s/ft^3	3.8 ft-lb/s/ft^3	4.0 ft-lb/s/ft^3

[1] Other fish passage criteria such as flow velocity and depth are well within fish passage criteria at for all fishway design flows.

High Fishway Design Flow
The high fishway design flow was determined by the flow that creates an EDF of 4 ft-lb/s/ft^3 in the pools, which is the maximum recommended EDF by ODFW.

At fishway flows above 6.5 cfs, water will exceed the capacity of the notch and flow over the horizontal weir. This will concentrate flow down the center notch while providing plunging flow along the edges. Assuming the entire receiving pool volume is effective at dissipating the energy of the flow entering the pool, the recommended maximum EDF of 4 ft-lb/s/ft^3 would be reached at a flow of about fishway flow of 42 cfs. **Therefore, 42 cfs was defined as the high fishway design flow.**

Streamflow at Fishway Design Flow
For the purposes of evaluating this alternative, the operable streamflows for the bedrock-concrete fishway were assumed to be between **75 cfs and 420 cfs**.

NMFS NW recommends that a fishway convey at least 10 percent of the total streamflow to provide suitable attraction flow to a fishway. Therefore, at the high fishway design flow of 42 cfs, the bedrock-concrete fishway could provide adequate attraction flow up to a streamflow of 420 cfs (35 annual exceedance flow, See Section 3.3.1) if the exit crest can be designed to prevent excessive flow from entering the fishway. This seems feasible based on interpretation of flow conditions from photos of Steamboat Falls at streamflows around 500 cfs.

During the summer, nearly all of the streamflow below about 75 cfs is conveyed into the headwater pool of the existing concrete fishway. The bedrock-concrete fishway should be designed to avoid capturing too much flow during the summer that would make the concrete fishway inoperable. Therefore, the new fishway should be designed to become operable (fishway flow of 6.5 cfs) at a streamflow of about 65 cfs. At a streamflow of 65 cfs and a low fishway design flow of 6.5 cfs, the new fishway would provide an attraction flow of about 10 percent, which satisfies the recommended NMFS NW criteria.

Final design of the bedrock-concrete fishway exit and determination of its operable streamflows requires collection of additional topographic information, and possibly some direct measurements of water levels in the proposed headwater pool at various flows.

8.6.2 Operations and Maintenance

The bedrock-concrete fishway is not expected to have any operational or maintenance requirements. It is expected to self-maintain similarly to the natural falls within the area. Sediment is expected to be scoured out of the pools during large flow events (See Section 8.7.3). There is a small risk that a piece of large woody debris could occasionally become jammed in the fishway in a manner that would adversely affect fish passage. If this occurs, it may be necessary to cut or remove the wood to restore fish passage.

8.7 Anticipated Design Performance

8.7.1 Structure Shaping

It is expected the bedrock-concrete fishway can be shaped within the face of the existing falls by removing the blocks formed along the bedrock joints. Some uncertainty exists around the subsurface bedrock jointing, which will govern the shape of the fishway pools and length of the concrete weirs. This will likely create natural variability within the fishway that may cause some portions of the fishway to have lower EDF values due to the larger pools.

8.7.2 Fish Passage Streamflows

As previously discussed in Section 8.6.1, there is uncertainty regarding the range of streamflows the bedrock-concrete fishway would be operable. Collection of additional field information during final design would help better define the range.

8.7.3 Sedimentation

The proposed bedrock-concrete fishway pools are not expected to experience any significant sedimentation. The large drops from crest to crest will scour and transport most deposited sediment. Additionally, during large flow events, when the stream is transporting large amounts of bedload, flows are expected to cascade into the new fishway from upstream, providing a tremendous amount of scouring force that will dislodge any deposited sediment.

8.7.4 Adaptive Management to address Uncertainty

If constructed, physical and biological monitoring should be conducted to verify that the fishway performs as desired. Modifications to the bedrock-concrete fishway could be made if post project monitoring identifies issues to be addressed. Modifications could involve removal of additional bedrock or use of concrete to modify the crests.

If in the future, the existing concrete fishway is no longer functional and decommissioned or demolished, the bedrock-concrete fishway could serve as the sole passageway over the falls.

Additionally, if the existing concrete spillway is severely damaged or destroyed, such as during the 1964 flood, the new fishway will continue to function. In either situation, modifications may be required to the bedrock-concrete fishway exit crest to ensure it receives sufficient flow during low summer flows.

8.8 Cost and Constructability

The feasibility level cost estimate for Alternative C modifications is $583,000. The existing fishway can either be left as-is or modified as recommended in Alternative A. A detailed breakdown of the cost estimate is provided in **Appendix I**.

Similar to Alternative B, Alternative C includes excavation of a bedrock channel, but includes installation cast-in-place concrete weirs rather than the bedrock crests in Alternative B. Forming the weirs out of concrete will allow specific weir dimensions and elevations to be achieved, eliminating the uncertainty of weir crest dimensions associated with Alternative B.

The concrete weirs would span the bedrock channel and be keyed into the channel bed and sidewalls to resist the forces from flowing water. Small charges or hammer drills may be necessary to make keys in the channel bed and sidewalls for the concrete. It will also be necessary to dowel the concrete into the bedrock along the length of the keys.

Dewatering and construction access would be similar to Alternative B. Concrete required for the weirs would likely need to be pumped from a mixing truck on the north side of the channel. It is suggested that geotechnical or structural engineer be present during the bedrock excavation and forming of the concrete weirs.

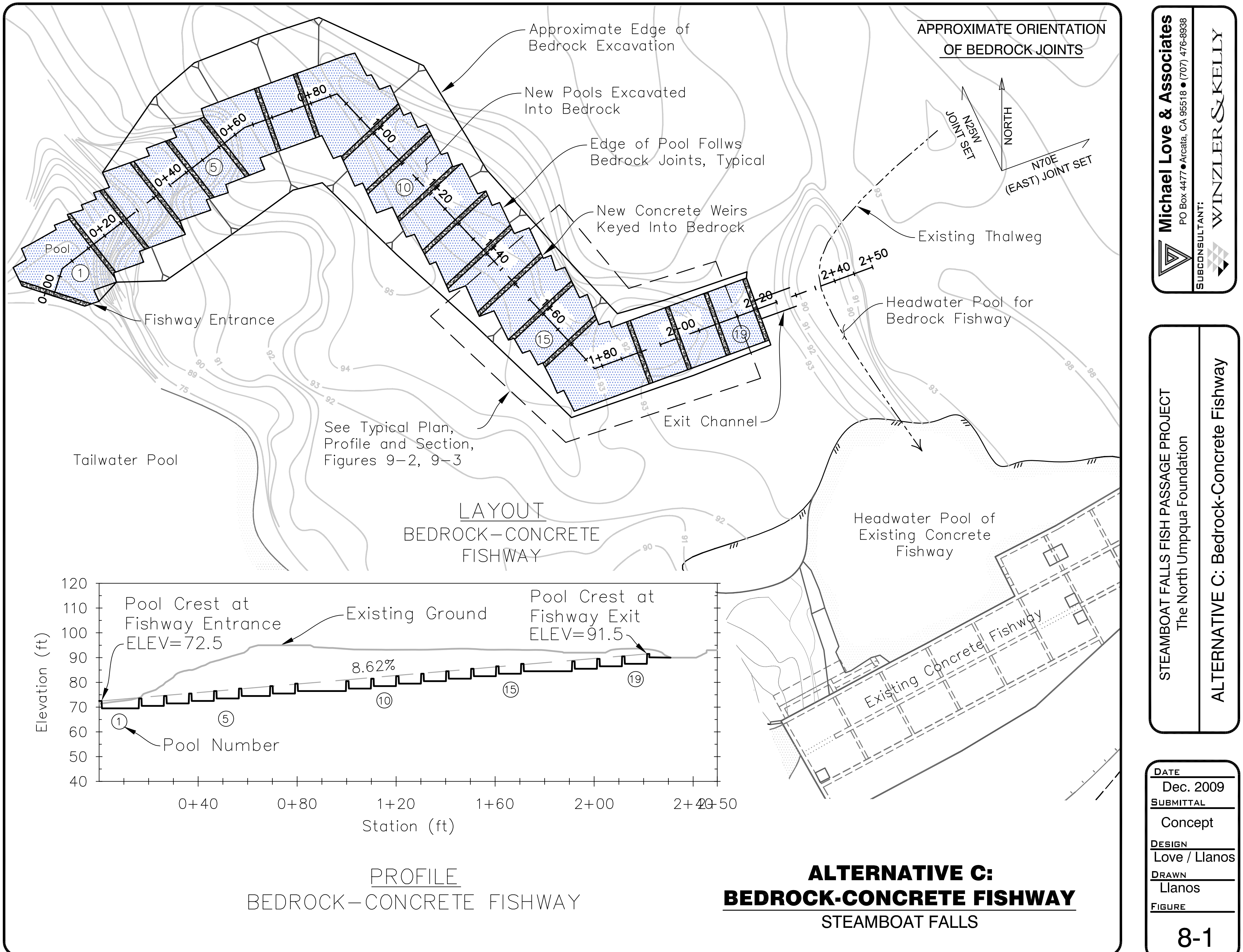
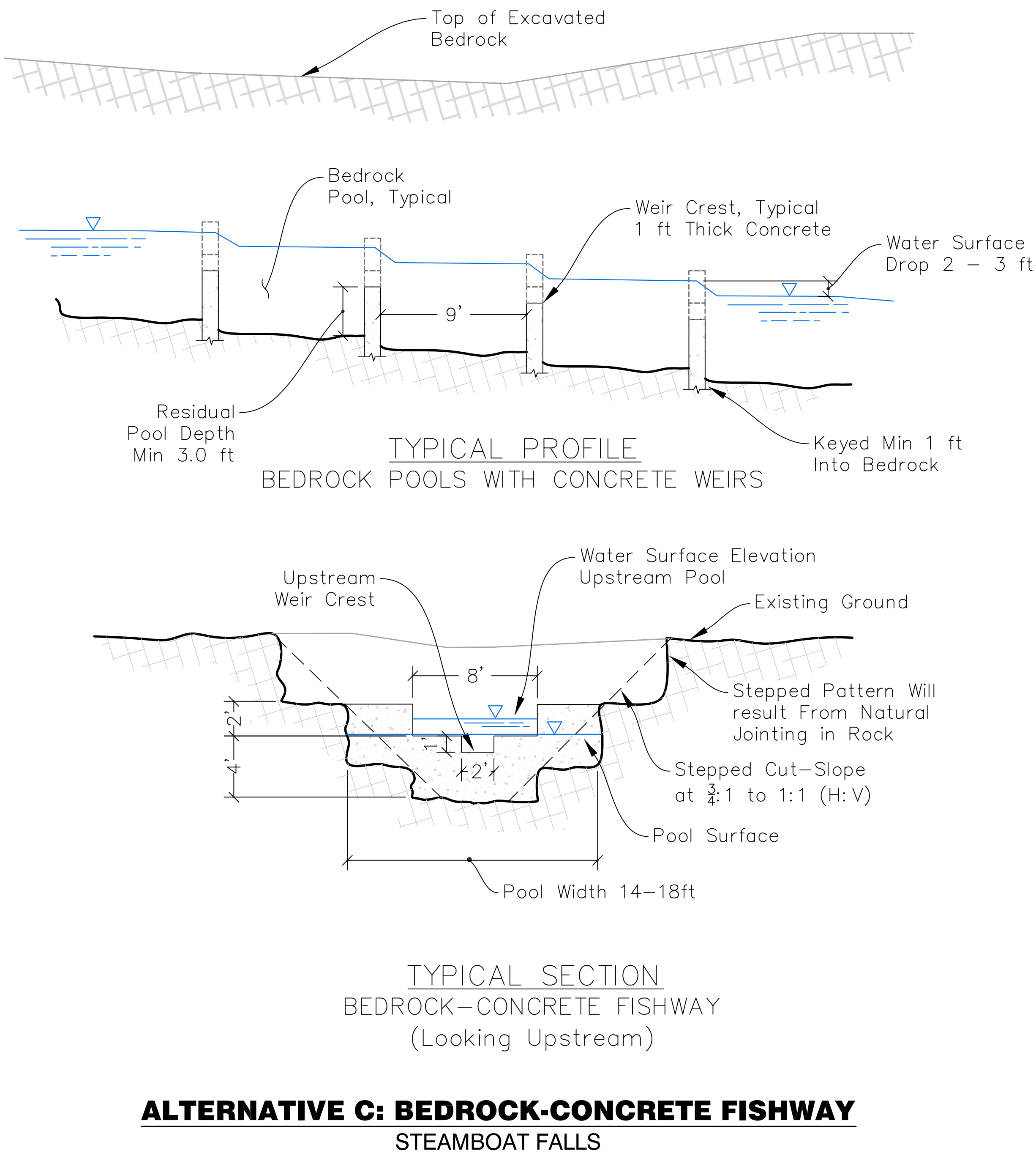


Figure 8-1. Alternative B Bedrock Fishway layout and profile.



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STEAMBOAT FALLS FISH PASSAGE PROJECT
The North Umpqua Foundation
ALTERNATIVE C: Bedrock-Concrete Fishway

DATE	Dec. 2009
SUBMITTAL	Concept
DESIGN	Love / Llanos
DRAWN	Llanos
FIGURE	8-2

Figure 8-2. Idealized plan view of Alternative B Bedrock Fishway.

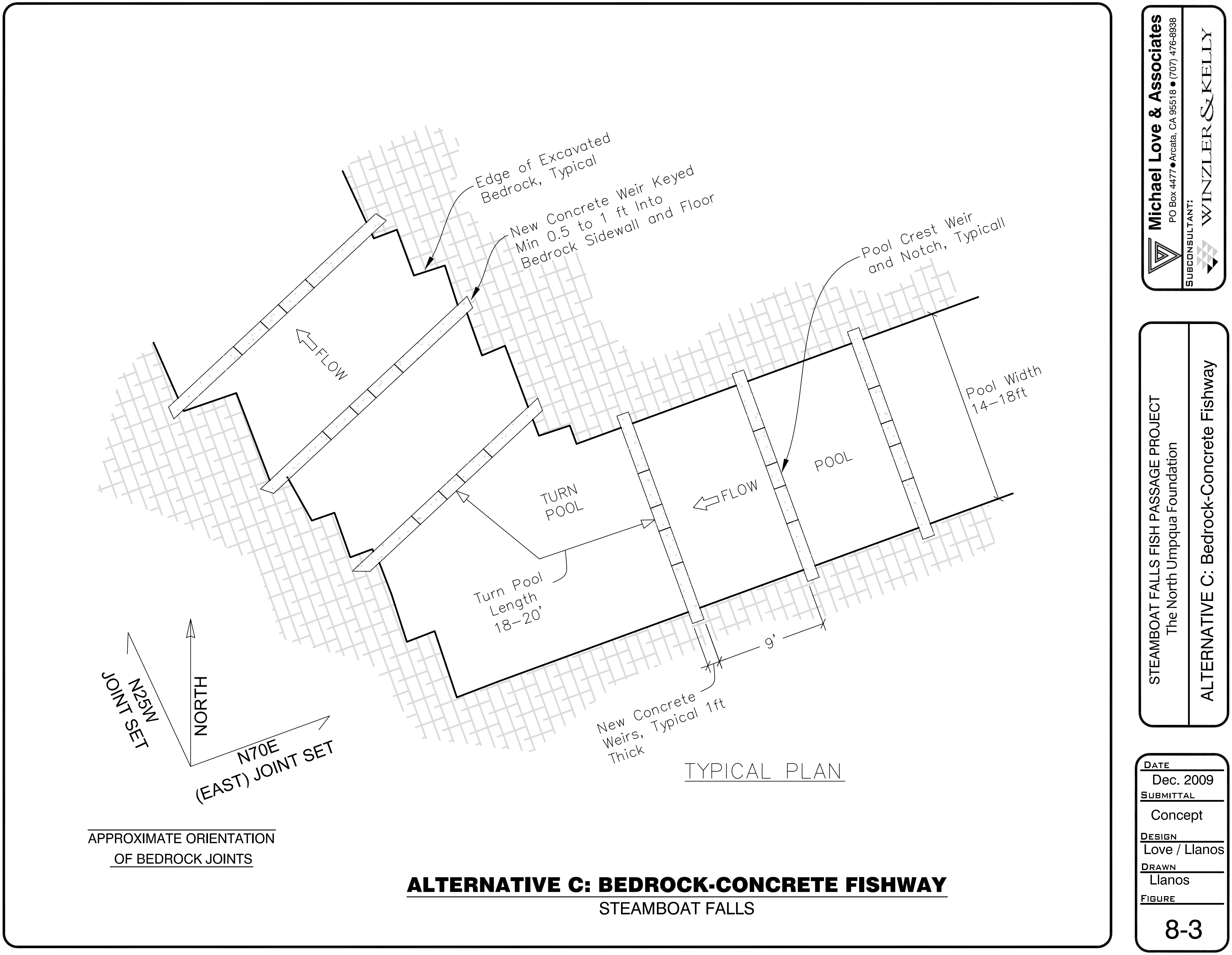


Figure 8-3. Idealized profile and section of Alternative B Bedrock Fishway.

9 Comparison of Alternatives and Recommendations

9.1 Comparison of Alternatives

Alternatives were compared qualitatively to determine if they could meet the following conditions:

- Ability to provide passage through an appropriate flow range and site conditions
- Minimum operation and maintenance requirements, including ability to pass sediment and debris with minimum intervention
- Acceptance of design approach to resource agencies
- Constructability issues and associated costs
- Durability and longevity considering high flow events

A matrix was created to allow direct comparison of alternatives (Table 9-1). The ratings used are "poor/fair/good/excellent" and "low/medium/high/highest". Ratings are qualitative and based on professional judgment. In the end, the best alternative is not dependent solely on its ratings, but on the weight given to each category. The following sections discuss the performance of each alternative relative to each category.

9.1.1 <u>Streamflows Providing Fish Passage</u>

Streamflows common during the peak months of summer steelhead migration, from May through July, range between 30 cfs and 300 cfs. For steelhead attempting to pass over the falls from December through April to spawn, fish passage will likely be limited to winter baseflow conditions, as high flows recede following storm events. During typical dry, average, and wet years the lowest flows that typically occur from December through April are approximately 100 cfs, 300 cfs and 400 cfs, respectively. To meet the objective of fish passage over the falls, the passage facility should operate at flows from 100 cfs to approximately 400 cfs, or higher, during December through April.

Ranges of operational fishway flow and total streamflow were developed for each alternative. For Alternatives B and C the high fish passage design streamflow was defined as the flow that the turbulence, measured as EDF, becomes excessive in the fishway. Both alternatives would operate at streamflows above 400 cfs.

The low fish passage streamflow for Alternatives B and C were set at about 75 cfs and 65 cfs, respectively, to allow the existing concrete fishway to become the primary passageway during low-flow periods. Either alternative could operate at much lower streamflows, but this could reduce the high flow operation or compromise the performance of the existing fishway at the lowest flows, or both. The fish passage streamflow range would be better defined during the final design of Alternative B or C, and could be shifted downward or upward depending on the objectives.

The widest range of fish passage streamflows is associated with Alternative A, Levels 2 and 3. However, unlike Alternative B and C, fishway hydraulics for Alternative A fail to meet ODFW and NMFS NW fish passage criteria at most flows. Because large numbers of steelhead are regularly observed swimming through even poorer passage conditions in the existing fishway, an alternative criterion was applied to establish the high fish passage design flow for Alternative A. This flow was defined for each Level as the streamflow that results in water overtopping the new rooftop curb. At this flow, water begins to sheet across the roof and plunge across the entrance, likely creating a distraction for fish attraction. Though Alternative A Levels 2 and 3, have larger ranges of fish passage streamflows than the other Alternatives, fish attraction may be diminished at the highest flows (See Section 9.1.5).

All levels of Alternative A create hydraulic conditions that meet ODFW and NMFS NW fish passage criteria at streamflows less than 22 cfs. The high passage streamflow for Alternative A Level 1 is about 400 cfs. If this was selected as the preferred alternative and no other modification was made or alternative fishway was built, steelhead migrating from December through April may not have passage over the falls during wet years.

9.1.2 Low Flow Passage Performance in Fishways

Alternative A was developed to have relatively good fish passage conditions during periods of low streamflow. Currently, large numbers of summer steelhead use the existing fishway during the lowest flows. With Alternative A Level 1 improvements, low-flow hydraulics will be dramatically improved, through increased water depths and decreased turbulence.

Alternative B and C were developed assuming they would not be the primary low-flow passageway; the existing fishway would provide passage during summer months. However, if low flow passage in a new fishway becomes a primary objective, the flow control at the fishway exit could be shaped, or modified after construction, to have either bedrock fishway operate at low flows (See Section 9.1.4). If this were the case, Alternative C would operate better than Alternative B at low-flow. The notches in the concrete weirs will concentrate low flows, and the narrow thickness of the weir allows fish to quickly pass over the weir, while Alternative B, requires fish to swim through 4-foot long chutes that have a short distance with water depths less than 1-foot at low flows.

9.1.3 High Flow Passage Performance in Fishways

Alternative C appears to have the best high flow passage performance. The concrete weirs are designed using standard pool-and-weir methods, which have a long record of reliable performance. Additionally, the drops are only 1-foot, reducing turbulence and unsteady hydraulics more than with the 2- to 3-foot drops in Alternative B.

The pools in Alternative B are long and the entire pool volume may not be effective at dissipating the flow's energy. If the energy is unevenly dissipated within the pool, Alternate B may create excessive turbulence close to the pool crest drop at high fishway flows. This could result in lowering the predicted high operational fishway flow.

Despite the high values of EDF for Alternative A at higher flows, the high operational fishway flow may be higher than predicted. At high flows, water both plunges over the weirs and streams through the slot. Because the slots are located along the left side of the pools, a less turbulent passageway would likely be provided along the right edge of the fishway, where fish could swim over the weirs away from the more turbulent flow near the slots. It is difficult to predict the exact flow that the turbulence along the right side of the fishway would become excessive, and block fish passage.

9.1.4 Flow Control

The ability to control the amount of flow entering the fishway during variable streamflow is essential to achieving the desired fish passage streamflow range. Alternative A Level 1 relies on the existing spillway and exit ports, and the new slotted weirs in the exit channel to control fishway flow. Water level in the existing headwater pool does not fluctuate much with changes in streamflow, allowing for relatively good flow control. Stoplogs could be installed across the bottom of the exits ports to reduce fishway flow, if desired.

Alternative A, Level 2 and 3 provide increased flow control with the use of adjustable gates at the exit ports and spillway. The spillway gate could be set at any height between the down and fully-raised positions and the stoplog gate at the exit ports could be easily changed at any time. Rehabilitation of the AWS in Level 3 includes installation of a flow control value, which would allow for additional control of the flowrate discharging from the fishway for attraction.

Alternative B and C rely on the shape of the exit weir crest as a primary means of controlling flow entering the fishway. Because Alternative C would use concrete, the shape of the weir could be more precise, providing improved flow control. Alternative B could also use concrete for the exit crest, if desired, rather than relying on the bedrock excavtion to obtain the weir shape. For both alternatives, upstream most pool in the fishway would be designed such that the south side of the pool would spill water out of the fishway at higher flows, helping to limit the amount of flow going down the fishway.

9.1.5 Fish Attraction

In Alternative A Level 1, the fishway conveys more than 10 percent of the total streamflow, meeting attraction flow criteria. Level 1 improves fish attraction from existing conditions by using a rooftop curb to prevent water from sheeting off the fishway roof and spilling into the tailwater pool at the fishway entrance. Currently it begins sheeting off the roof at around 140 cfs, with the addition of the rooftop curb flow would not overtop the fishway until approximately 400 cfs. Level 1 also includes improvements to the entrance weir to produce a water surface drop across the entrance at most fishway flows. The resulting jet from the drop will penetrate the tailwater pool and help fish find the entrance.

With Level 2 modifications, fish attraction at the highest fish passage streamflows would be fair. Between 400 cfs and 600 cfs the fishway conveys about 8 to 6 percent of the total flow, falling short of the desired 10 percent minimum. Level 3 modifications attempt to rectify this deficiency by providing auxiliary flow to the fishway entrance. This increases the percentage to about 11 to 8 percent for flows between 400 cfs and 600 cfs, respectively. However, at flows above about 400 cfs the tailwater pool around the fishway entrance becomes increasingly turbulent from water plunging over the falls. It is possible that fish may not swim through this turbulence in search of the entrance.

Fish attraction for the bedrock fishways proposed in Alternative B and C is good in terms of percentage of streamflow. However, site conditions may reduce attraction. The fishway entrance for both alternatives is downstream of the main falls. This places it away from the turbulence created by the falls at high flows, but also places it slightly downstream of the barrier. Fish could swim by the new fishway entrance and have to swim back downstream to find it, resulting in a migration delay.

Alternative B has water flow through an existing "boulder field" and into the tailwater pool. Alternative C would create an attractive flow jet using a slotted concrete weir placed at the edge of the tailwater pool, which may provide better attraction conditions than Alternative B.

9.1.6 Certainty of Performance

Alternative A Level 1 hydraulic performance would be affected by sedimentation. Sediment between the slotted weirs could increase water surface drops and turbulence in some locations. The exit channel modifications are intended to improve sediment transport, but it remains susceptible to deposition of coarse sediment. Additionally, slots are prone to clogging with small debris and large cobbles. If slots clog and sedimentation occurs in the exit channel, the fishway should continue to function, but with a decrease in fishway flow and attraction flow.

Alternative A Level 2 modifications involve use of a mechanical gate on the spillway. Even the best-suited gate for this environment is prone to problems associated with fine sediment. Any gate will require occasional maintenance and repair to keep it operational.

Alternative A Level 3 modifications are subject to problems with collection of debris and sediment on the AWS intake grille and sedimentation on the diffusers in the entrance bay. This could reduce the AWS flowrate and increase intake water velocities above criteria, risking impingement of juvenile salmonids and other aquatic organisms onto the intake grille.

Alternatives B and C are expected to perform well, with a high degree of certainty. For Alternative B the entire pool volume was used to evaluate turbulence and define the high operational fishway flow. However, the pools in Alterative B could become too turbulent at flows lower than predicted because the effective pool volume for dissipating energy may be smaller than the entire pool (See Section 9.1.3). This would reduce the operational fishway flow range from the range currently predicted.

9.1.7 Ability to Satisfy Agency Hydraulic Design Criteria

Alternative A Level 1 modifications increase water depth in the pools between the slotted weirs in order to meet ODFW minimum pool depth criteria of 2 feet at all fishway flows. However, EDF exceeds ODFW and NMFS NW criteria at fishway flows above 22 cfs. This was considered acceptable since large numbers of steelhead currently pass through the fishway when the EDF is much higher than predicted with Level 1 modifications. Also, the location of the slot at the side of the fishway concentrates the area of higher EDF, and will allow fish to leap over the weirs from the lower EDF zone away from the slots. Level 2 modifications of adding gates at the exit ports and spillway meet agency criteria. Level 3 modifications meet NMFS NW criteria for auxiliary water systems.

Water surface drops between weirs ranges from 2 to 3 feet for Alternative B, exceeding the 1-foot maximum drop criteria. However, this drop height is well within the leaping ability of adult steelhead and Chinook salmon and is less than some of the naturally occurring drops fish must pass over to reach Steamboat Falls. During low flow, the minimum depth is not achieved for a short distance along each chute; however depth is sufficient for fish locomotion even in these shallow sections. Because the pools in Alternative B are long, the entire pool volume may not be effective at dissipating energy. An EDF value higher than criteria may develop close to the drop at the bedrock pool crest at high fishway flows, possibly reducing the high operational fishway flow.

Alternative C appears to meet agency hydraulic criteria.

9.1.8 Operation and Maintenance Obligations

With Alternative A Level 1 modifications, the fishway will still require annual inspection and some level of sediment cleanout each spring. Modifications to keep flow off the fishway roof will allow maintenance to occur earlier than under current conditions, and will allow inspection during winter baseflows. Because of the weir modifications, it is anticipated that the cleanout will not be as extensive as under current conditions. Level 2 modifications will require one additional site visit by ODFW staff to adjust the new gates into their "winter settings" each fall. Some maintenance of the spillway gate would be required every few years, and some repairs may be needed on a less frequent basis. Level 3 modifications could dramatically increase the amount of maintenance needed. The intake grille should be regularly inspected during winter baseflow conditions, and buildup of small debris and sediment should be cleaned off the grille. During the spring inspection, sediment within the entrance bay may need to be cleaned out to keep the AWS diffusers performing as intended.

Alternatives B and C are expected to require the least amount of maintenance and have no operational requirements. Large wood may occasionally become jammed within the fishway and may reduce fish passage. In such situations, the wood would need to be removed or cut to remove the blockage. As with any concrete placed in a stream, regular inspection is recommended and eventual repair may be required.

9.1.9 Debris and Sediment Passage

Alternative A Level 1 modifications improve sediment transport in the exit channel and the lower 5 weirs, by adding slots to them. However, the 1.5-foot wide slots are susceptible to plugging with small debris. If plugged, sedimentation upstream of the slot is likely to occur. Level 2 modifications should reduce the amount of sediment entering the fishway, which may reduce sedimentation within the fishway. There is some increased risk of catching debris on the exit ports during extreme low flow periods in the winter because the pool surface may drop so low that the top of the ports are exposed and floating debris may get caught in the ports. Level 3 modifications are more vulnerable to sediment and debris because of the dimensions of the opening in the AWS intake grille and diffusers.

Alternatives B and C are expected to pass sediment and debris with little difficulty. The widths of the pools, weirs and bedrock pool crests are sufficient to allow large wood to be transported down the fishway at high flows without jamming. During large flow events, when sediment is in transport, the water will inundate the entire falls. During these flows water will be plunging down the excavated bedrock side-slopes and into the bottom of the fishway, creating large scouring forces. Additionally, both alternatives have relatively high values of EDF at relatively low streamflows, which is expected to scour sediment from the pools on a regular basis.

9.1.10 Footprint

The footprint for Alternative A modifications is limited to the existing concrete fishway and headwater pool. Level 1 modifications are limited to inside and on the roof of the fishway. Level 2 modifications have a slightly increased footprint associated with reconstruction of the spillway. Level 3 modifications are limited to the AWS intake.

Alternative B has the largest footprint, with Alternative C having a slightly smaller footprint than Alternative B.

9.1.11 Construction Complexity

All of the alternatives are expected to have similar challenges associated with working in a remote site. Alternative A and C, and possibly Alternative B to a lesser extent, have the challenge of getting concrete to the site. Alternative A Level 1 involves standard concrete formwork that most contractors have extensive experience with. However, the concrete will need to be pumped to the site and/or mixed onsite, adding some logistical challenges.

Alternative A Level 1 and 2 involves fitting prefabricated mechanical pieces, including the spillway gate and actuator for Level 2, and the intake grille and flow control valve with porosity control for Level 3. This adds some complexity to the construction.

The bulk of the excavation in Alternatives B and C is expected to be straightforward due to the fracture pattern of the bedrock. For Alternative B, the final shaping of the pool crest and the level of construction inspection and onsite engineering increases the complexity. For both Alternative B and C, determination of the disposal area for the excavated rock will also have a large affect on the complexity and cost. If the rock cannot be disposed of onsite, an access ramp suitable for dump trucks will need to be constructed from Steamboat Creek Road down to the top of the falls. Otherwise, the access ramp only needs to be suitable for excavation equipment, which can traverse much steeper slopes.

Table 9-1. Qualitative comparison of alternatives

CATEGORY	Existing Conditions	Alternative A Level 1 Internal Fishway Modifications	Alternative A Level 1&2 Exit Ports & Spillway Modifications	Alternative A Level 1-3 AWS Rehabilitation	Alternative B Bedrock Fishway	Alternative C Bedrock Fishway w/Concrete Weirs
FISH PASSAGE						
Streamflows providing fish passage	**25 to 200 cfs**	**21 to 400 cfs**	**18 to 400 cfs (summer) 52 to 600 cfs (winter)**	**18 to 400 cfs (summer) 52 to 600 cfs (winter)**	**75 to 440 cfs**	**65 to 420 cfs**
Low flow passage performance	**Fair**	**Good**	**Good**	**Good**	**Good**	**Excellent**
High flow passage performance	**Poor**	**Good**	**Good**	**Good**	**Good to Excellent**	**Excellent**
Fishway Flow control	**Fair**	**Fair**	**Good**	**Good**	**Fair to Good**	**Fair to Good**
Fish attraction	**Poor**	**Good**	**Fair**	**Good**	**Fair to Good**	**Good**
Certainty of performance	**Poor**	**Good**	**Good**	**Fair**	**Good**	**Excellent**
Satisfies agency design criteria	**Poor**	**Fair**	**Fair**	**Fair**	**Fair to Good**	**Excellent**
OPERATION AND MAINTENANCE						
O&M obligations	**High**	**Medium**	**Higher**	**Highest**	**Low**	**Low**
Debris and sediment passage	**Poor**	**Fair**	**Good**	**Fair to Good**	**Excellent**	**Excellent**
Durability	**Good**	**Excellent**	**Good**	**Good**	**Excellent**	**Excellent**
OTHER						
Footprint	**N/A**	**Low**	**Medium**	**Medium**	**Highest**	**High**
Construction complexity	**N/A**	**Low**	**Medium**	**Medium**	**Medium**	**Medium**
Probable construction cost	**N/A**	**$255,000**	**$415,000**	**$655,000**	**$410,000**	**$585,000**

9.1.12 Probable Construction Costs

The probable construction cost for each Alternative is presented in Table 9-1. Construction costs and a contingency were developed considering the difficult access to the project area (Alternative B and C) and the uncertainty associated with the conceptual level of the design. Excavation costs for Alternatives B and C were based on the assumption that excavated material can be disposed of on site. Costs do not include maintenance costs. The construction costs also include a cost for engineering design and structural inspection of the existing fishway. Costs do not include preparation of environmental documents, permitting, or consultation with agencies.

Construction of Alternative A Level 2 will possibly slightly reduce the amount of sediment entering the fishway, but will require a small increase in operational effort compared to Level 1. The cost increase between Levels 1 and 2 may not merit the benefit of reducing sediment supply while decreasing attraction conditions.

Construction costs for implementing Alternative A Levels 1-3 is the highest cost of all alternatives, yet provides the least benefit for the cost. Implementation of Alternative A Levels 1-3 does not provide optimal fish passage conditions at higher flows. Expected sedimentation will likely impact performance and will require an increase in maintenance efforts.

Alternative C is slightly more expensive than Alternative B, but meets all fish passage design criteria, unlike Alternative B. The concrete weirs allow specific design criteria to be met without the uncertainty associated with excavation and bedrock jointing in Alternative B.

9.2 Alternatives Considered but Not Developed

Besides the alternatives described in this report, a number of other alternatives and modifications were examined but considered infeasible, unreliable and problematic, or not meeting project objectives. Some of them are discussed in the following sections.

9.2.1 Restoring Headwater Pool Sluicing System

It is evident that the sediment sluicing system in the headwater pools, below the AWS intake, is prone to becoming overwhelmed with sediment. Replacement of the existing sediment sluice gate with a gate that could either be left open or automatically open during high flows in the winter was explored, but found to be costly and problematic. If left open during winter base flow, the headwater pool would be drawn down too low to allow flow into the fishway. A gate that automatically opens would require power to the site, as well as regular operation, inspection, and maintenance.

9.2.2 Sediment Deflection Wall at Fishway Exit

Placement of a sediment deflection wall near the fishway exit ports was explored, but considered to have considerable risk. A deflection wall would change flow patterns in the headwater pool, eliminating the jet of water that keeps it scoured clean in front of the exit ports. Instead, sediment could deposit behind the wall and in front of the exit ports, reducing or blocking flow into the fishway.

9.2.3 Headwater Pool Modifications

Reshaping the headwater pool in conjunction with the deflection wall was also considered; eliminating the sediment sink and ramping the pool bottom up to the spillway crest. Although this may assist transport of sediment over the spillway, it could also create flow patterns in the pool that "eddy" back towards the exit ports, increasing entrainment of sediment into the fishway.

9.2.4 New Fishway in Location of Existing Fishway

Removal of the existing fishway and replacement with a new fishway was examined. This area of the channel is the main flow path of the creek during high flows, making it a problematic location for sitting a new fishway, whether it is bedrock or concrete. The existing fishway does provide passage of large numbers of summer steelhead once it is unplugged. The cost of demolishing the existing fishway and the benefit of constructing a new one in its place is seen as unjustified, and with little benefit.

9.2.5 Smaller Bedrock Fishway

A smaller and steeper bedrock fishway was considered to reduce the project footprint and cost. Initial computations found that increasing the drop heights and/or reducing the pool volumes caused the fishway to either become excessively turbulent at relatively low streamflows or convey insufficient proportion of the streamflow for fish attraction. The narrow range of operational streamflows associated with a smaller and steeper bedrock fishway failed to satisfy a fundamental design objectives, passage of winter steelhead during their period of migration, and was not further developed.

10 Recommendations and Additional Studies

10.1 Recommendations

The objective of this study was to identify and develop to the initial concept design level upstream fish passage alternatives for Steamboat Falls, estimate concept design level probable construction costs, and then compare the advantages and disadvantages of each alternative. All of the developed alternatives are believed to be feasible, with varying levels of uncertainty associated with each. The selection of a single preferred alternative depends on many of the factors listed in the summary and comparison tables (Table 9-1) and the importance placed on each one by the various stakeholders.

Based on findings in this study, we recommend implementing both Alternative A Level 1 modifications and Alternative C. Combined these alternatives provide redundancy and year-round passage for winter and summer steelhead and spring Chinook. Though Alternative B would provide similar fish passage conditions with increased esthetic qualities, it includes an increased level of risk regarding the ability to achieve the desired shaping of the bedrock controls during construction.

10.2 Additional Field Measurements and Site Investigations

This report is intended to guide the selection of a preferred alternative, or alternatives. Once the selection has been made, some additional field measurements and site investigations may be warranted as part of final design. They include measuring water surface level of the tailwater pool below the falls across a range of flows (for all alternatives), measuring the water surface level across a range of flows in the proposed headwater pool for Alternatives B and C, conducting a detailed structural inspection of the existing fishway when it is dewatered to design any needed repairs, and conducting a topographic survey of the falls and potential access route(s) for Alternatives B and C.

11 References

Bates, K. (2001). Fishway Design Guidelines for Pacific Salmon. Olympia, Washington, Washington Department of Fish and Wildlife.

Bates, K. and M. Love (*in press*). *Retrofit of stream crossings for aquatic organism passage.* US Forest Service, San Dimas Technology and Development Center.

Bell, M. 1991. *Fisheries Handbook of Engineering Requirements and Biological Criteria*. U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. *Fluvial Processes in Geomorphology*. Dover Publications Inc., New York, New York.

Love, M. and K. Bates (2009). Fish Passage Design and Implementation: Part XII of California Salmonid Stream Habitat Restoration Manual, California Department of Fish and Game.

NMFS NW. 2008. *Anadramous Salmonid Passage Facility Design*. NOAA National Marine Fisheries Service, Northwest Region. Portland, Oregon.

ODFW. 2006. Division 412 Fish Passage. Oregon Administrative Rules, Oregon Department of Fish and Wildlife.

Rajaratnam, N., G. Van der Vinne, et al. (1986). "Hydraulics of Vertical Slot Fishways." Journal of Hydraulic Engineering 112(10): 909-927.

Spencer, Lee. 2007. *Steelhead Notes for 2006 CE Wild Summer Steelhead in Their Warm and Low Water Refuge May 7th through December 7th*. Prepared for The North Umpqua Foundation.

Stuart, T. A. 1962. *The Leaping Behaviour of Salmon and Trout at Falls and Obstructions*. Freshwater and Salmon Fisheries Research 28. Department of Agriculture and Fisheries for Scotland, Edinburg, Scotland.

USGS. 1982. *Guidelines for determining flood flow frequency. Bulletin #17B of the Hydrology Subcommittee*. Interagency Advisory Committee on Water Data. U.S. Geological Survey, Reston, Virginia.

Villemonte, J. R. 1947. Submerged-weir discharge studies. *Engineering News Record* 2:866-869.

APPENDIX A

Photographs of the Project Site

Photo 1. Looking upstream at the Steamboat Falls, the concrete spillway and headwater pool, and the fishway exit.

Photo 2. Looking downstream from the fishway at the long tailwater pool below the falls.

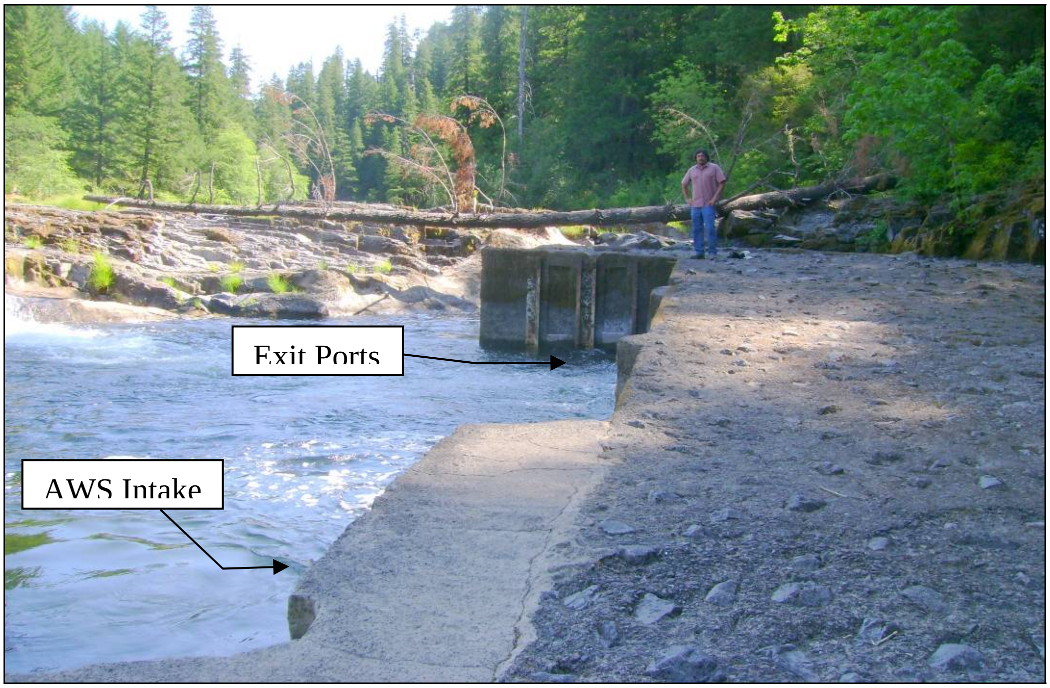


Photo 3. Looking upstream at the fishway roof, exit ports (under water) and location of the AWS intake, which is currently sealed shut.


Photo 4. Looking down from the adjacent campground to the fishway entrance. At low flows the water going over the spillway is directed towards the entrance, which is likely beneficial for attraction.

Photo 5. Looking downstream at headwater pool and spillway.

Photo 6. Fishway entrance and spillway. Note the outfall of the sediment sluice pipe for the headwater pool.

Photo 7. Looking up the sediment sluice pipe at partially opened slide gate plugged with sediment.

Photo 8. Damaged actuator for the sediment sluice gate on the spillway crest.

Photo 9. Exit ports (underwater) and stoplog guides in headwater pool.

Photo 10. Flow entering the headwater pool scours the face of the exit ports, preventing sediment buildup.

Photo 11. Slotted concrete weir with nearly 3-foot drop in the water surface due to large cobbles clogging the bottom of the slot.

Photo 12. Sedimentation in the exit channel between the exit ports and Slot 20. Taken during annual cleanout on July 3, 2009. (photo courtesy of ODFW)

Photo 13. Small woody debris clogging Slotted Weir 18, taken during annual cleanout on July 3, 2009. (photo courtesy of ODFW).

Photo 14. Spalled concrete on cross-member inside fishway (photo courtesy of ODFW).

Photo 15. Concrete spillway and fishway exit at low flows, with all streamflow conveyed in fishway. Note spalled concrete and rebar exposed in numerous locations on the face of spillway.

Photo 16. Rebar exposed on face of concrete spillway.


Photo 17. Estimated Flow of 32 cfs.


Photo 18. Estimated Flow of 68 cfs.

Photo 19. Estimated Flow of 123 cfs. Substantial proportion of streamflow bypassing spillway. No flow spilling off fishway roof.

Photo 20. Estimated Flow of 151 cfs. Note flow beginning to overtop at both the upstream end and downstream end of the fishway roof. Nearly half the flow is bypassing the headwater pool as it goes over the falls.

Photo 21. Estimated Flow of 400 cfs. Approximately the high fish passage streamflow for Alternative A, Level 1 Modifications.

Photo 22. Estimated Flow of 451 cfs. Looking across the channel at the northern portion of the falls and the tailwater pool.

Photo 23. Estimated Flow of 451 cfs. Note that flow over the northern section of falls is minimal (top of photo).

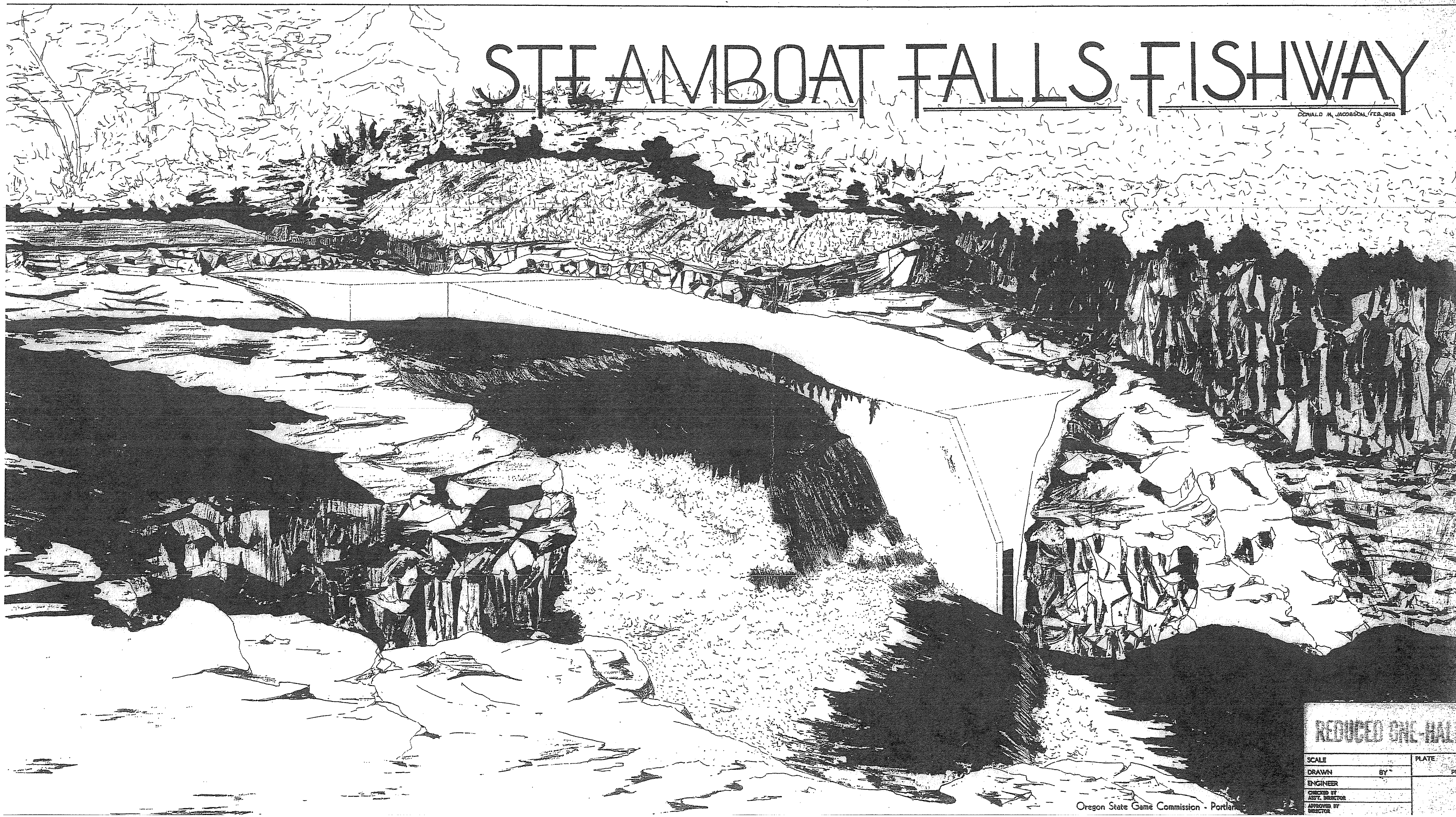
Photo 24. Estimated Flow of 519 cfs. Note the turbulence at the fishway entrance.


Photo 25. Estimated Flow of 519 cfs. Note the water flowing onto the fishway roof from upstream.

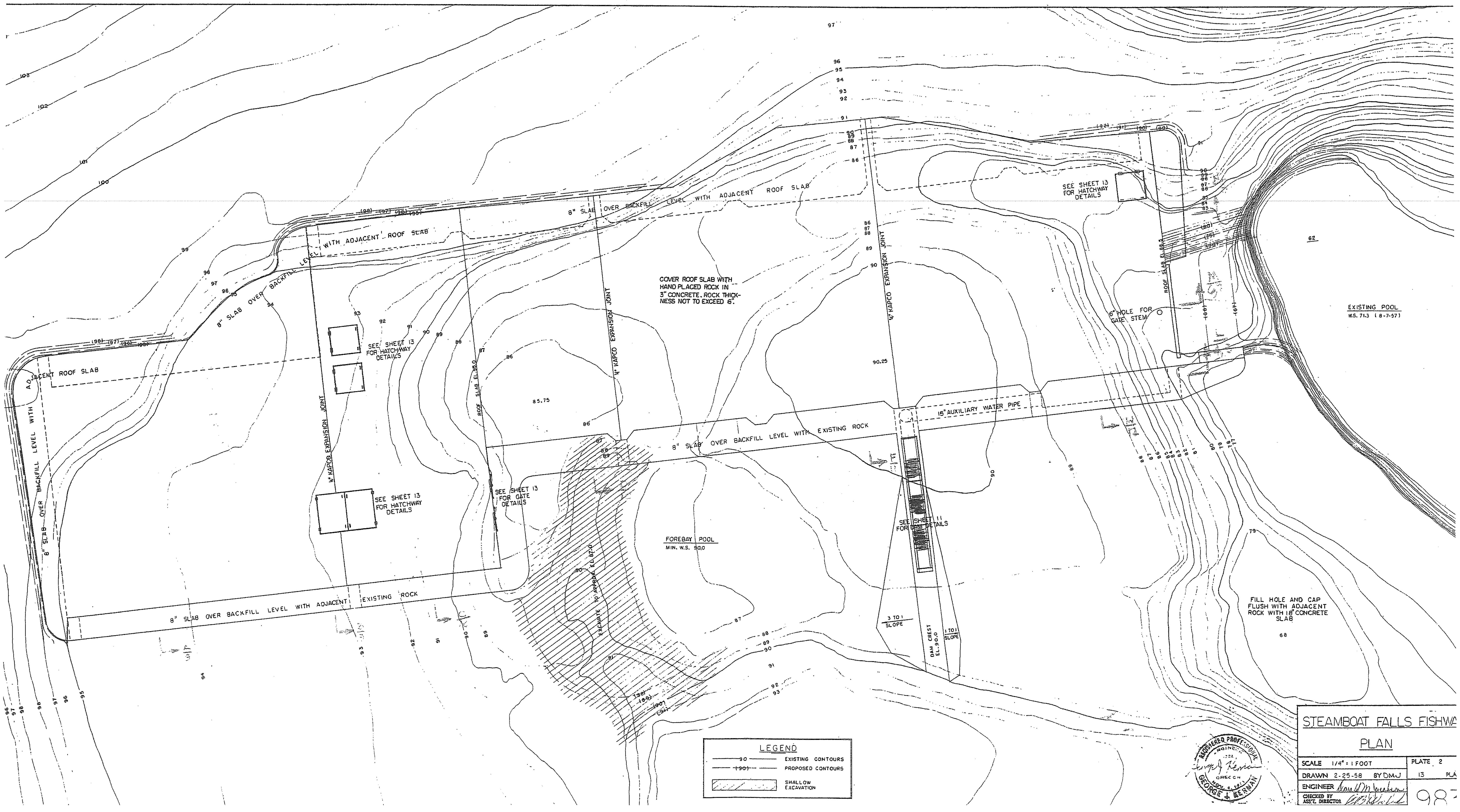

Photo 26. Estimated Flow of 744 cfs. Note the extreme turbulence near the fishway entrance.

APPENDIX B

1958 Steamboat Falls Fishway Plan Set


STEAMBOAT FALLS FISHWAY
DONALD M. JACOBSON FEB 1958
REDUCED ONE-HAL
SCALE
PLATE
DRAWN
BY
PLAT
ENGINEER
CHECKED BY ASST. DIRECTOR
APPROVED BY DIRECTOR
Oregon State Game Commission - Portlan

TO EUGENE
US 99
STEAMBOAT CR.
STEAMBOAT CR. ROAD
CANTON CR.
STEAMBOAT FALLS PROJECT SITE
IDLEYLD PARK
NORTH UMPQUA RIVER
GLIDE
NORTH UMPQUA RD.
DIXONVILLE
ROSEBURG
VICINITY MAP
MILES
TO MEDFORD
STEAMBOAT CREEK
SITE
PROPOSED FISHWAY
FISHWAY
STEAMBOAT FALLS
POOL W.S. 71.3 (8-7-57)
BM EL 100
TOE OF ROAD FILL
DISPOSAL AREA ALONG TOE OF FILL
STEAMBOAT CREEK
STEAMBOAT CREEK ROAD
ROSEBURG 46 MILES
STEAMBOAT FALLS FISHWAY
SITE - CONTOURS
SCALE 1 INCH = 25'-0"
DRAWN 11-13-57 BY DMJ
ENGINEER
CHECKED BY ASST. DIRECTOR
APPROVED BY
PLATE 1
13
983
REGISTERED PROFESSIONAL ENGINEER
OREGON
GEORGE
Oregon State Game Commission - Portland, Oregon



8" SLAB OVER BACKFILL LEVEL WITH ADJACENT ROOF SLAB
ADJACENT ROOF SLAB
8" SLAB OVER BACKFILL LEVEL WITH ADJACENT ROOF SLAB
4" KAPCO EXPANSION JOINT
SEE SHEET 13 FOR HATCHWAY DETAILS
SEE SHEET 13 FOR HATCHWAY DETAILS
ROOF SLAB EL 95.0
SEE SHEET 13 FOR GATE DETAILS
4" KAPCO EXPANSION JOINT
COVER ROOF SLAB WITH HAND PLACED ROCK IN 3" CONCRETE. ROCK THICKNESS NOT TO EXCEED 6".
4" KAPCO EXPANSION JOINT
SEE SHEET 13 FOR HATCHWAY DETAILS
6" HOLE FOR GATE STEM
ROOF SLAB EL 88.5
EXISTING POOL
W.S. 71.3 (8-7-57)
8" SLAB OVER BACKFILL LEVEL WITH EXISTING ROCK
15" AUXILIARY WATER PIPE
8" SLAB OVER BACKFILL LEVEL WITH ADJACENT EXISTING ROCK
FOREBAY POOL
MIN. W.S. 90.0
SEE SHEET 11 FOR DAM DETAILS
3 TO 1 SLOPE
DAM CREST EL. 90.0
1 TO 1 SLOPE
FILL HOLE AND CAP FLUSH WITH ADJACENT ROCK WITH 18" CONCRETE SLAB
LEGEND
EXISTING CONTOURS
PROPOSED CONTOURS
SHALLOW EXCAVATION
STEAMBOAT FALLS FISHWA
PLAN
SCALE 1/4" = 1 FOOT
PLATE 2
DRAWN 2-25-58 BY DMJ
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ENGINEER
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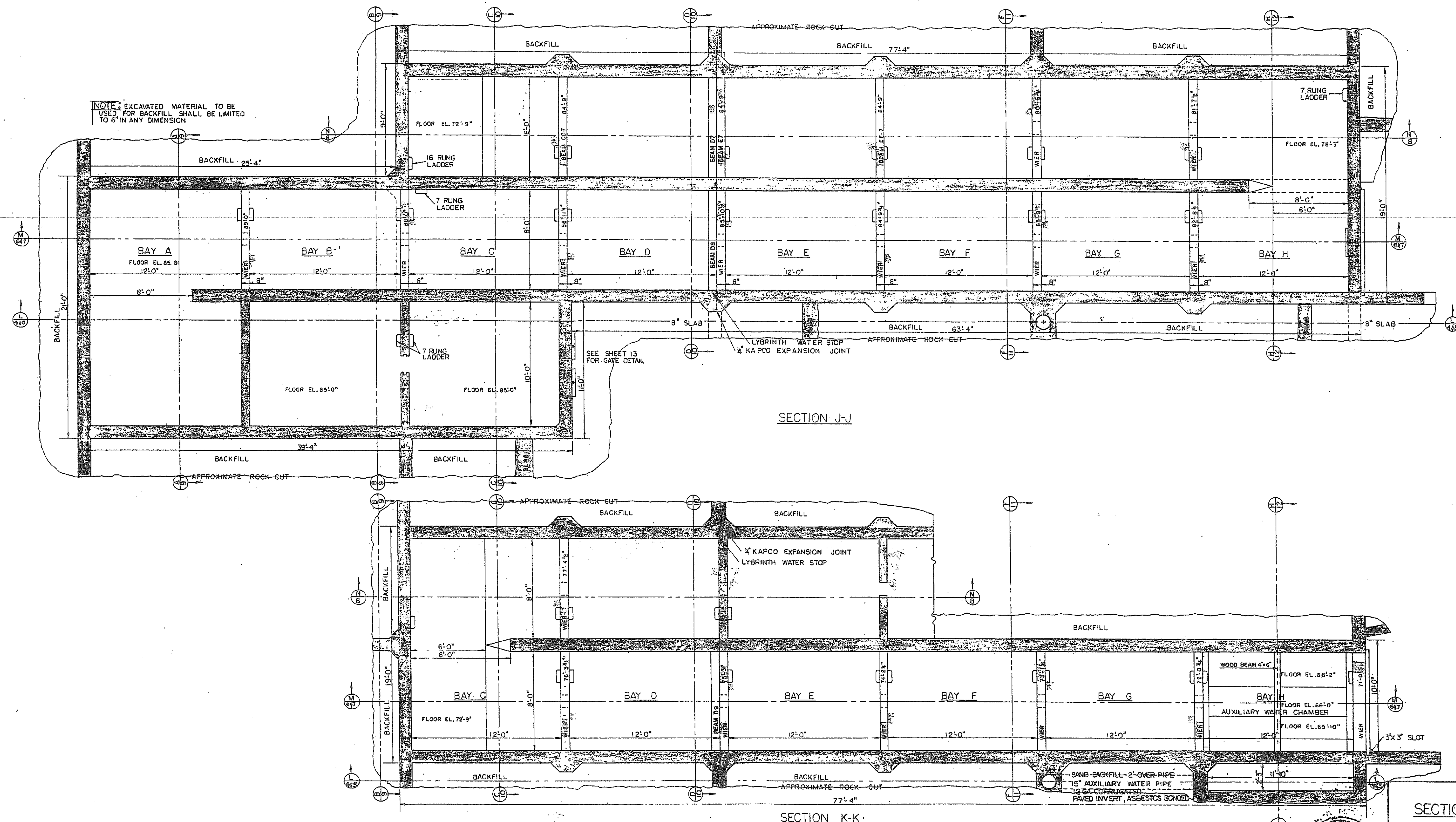
REGISTERED PROFESSIONAL ENGINEER
OREGON
GEORGE J. KERNAN



SECTIONS J-J & K-K

SCALE 1/4" = 1 FOOT	PLATE 3
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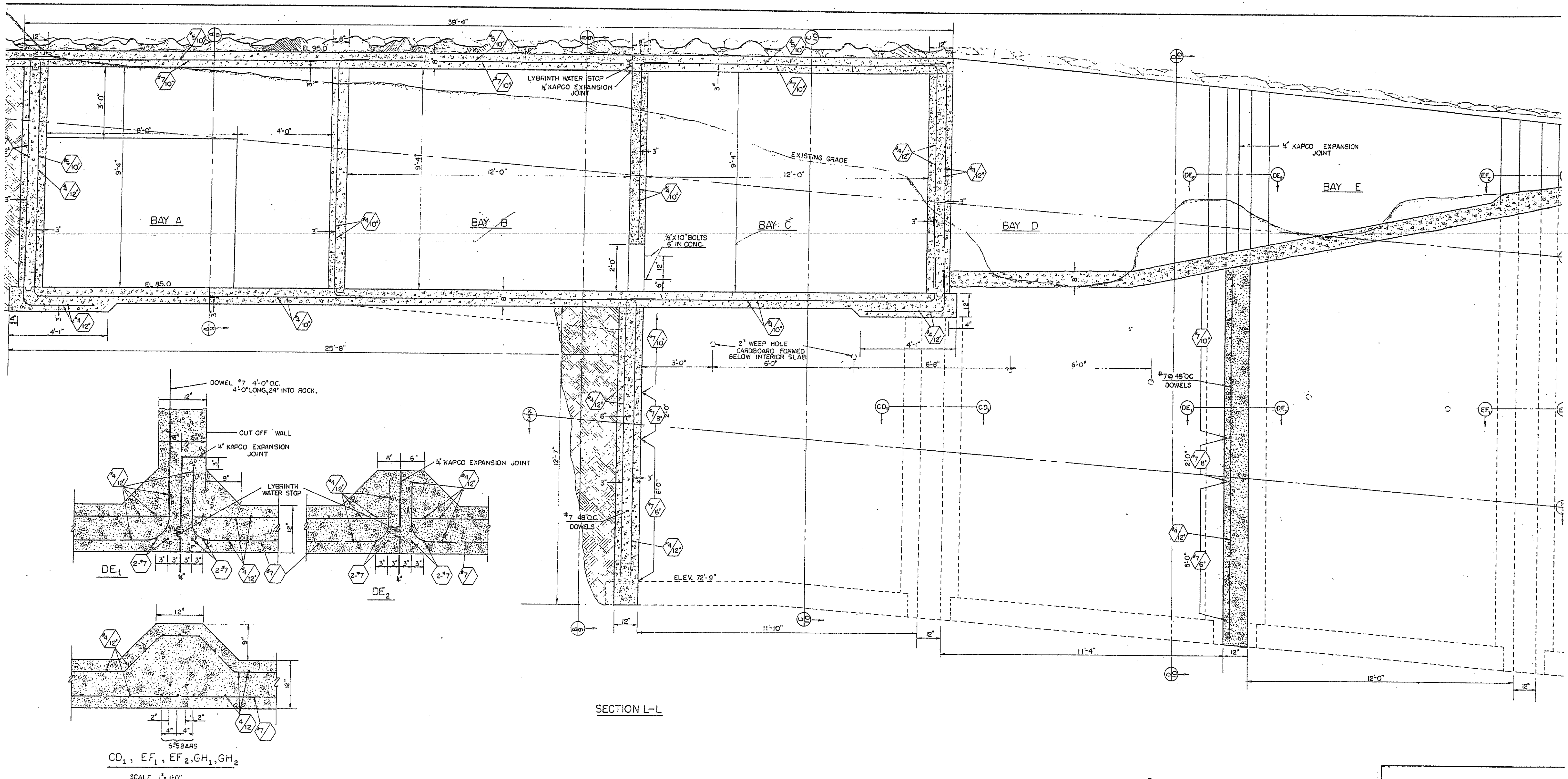
APPROVED BY DIRECTOR	98

REGISTERED PROFESSIONAL ENGINEER — GEORGE J. KEHRAN — OREGON



SECTION L-L
(UPPER PART)

SCALE 1/2" = 1 FOOT
DRAWN 3-5-58 BY KSL
PLATE 4 OF 13 PLATES
ENGINEER
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APPROVED BY DIRECTOR

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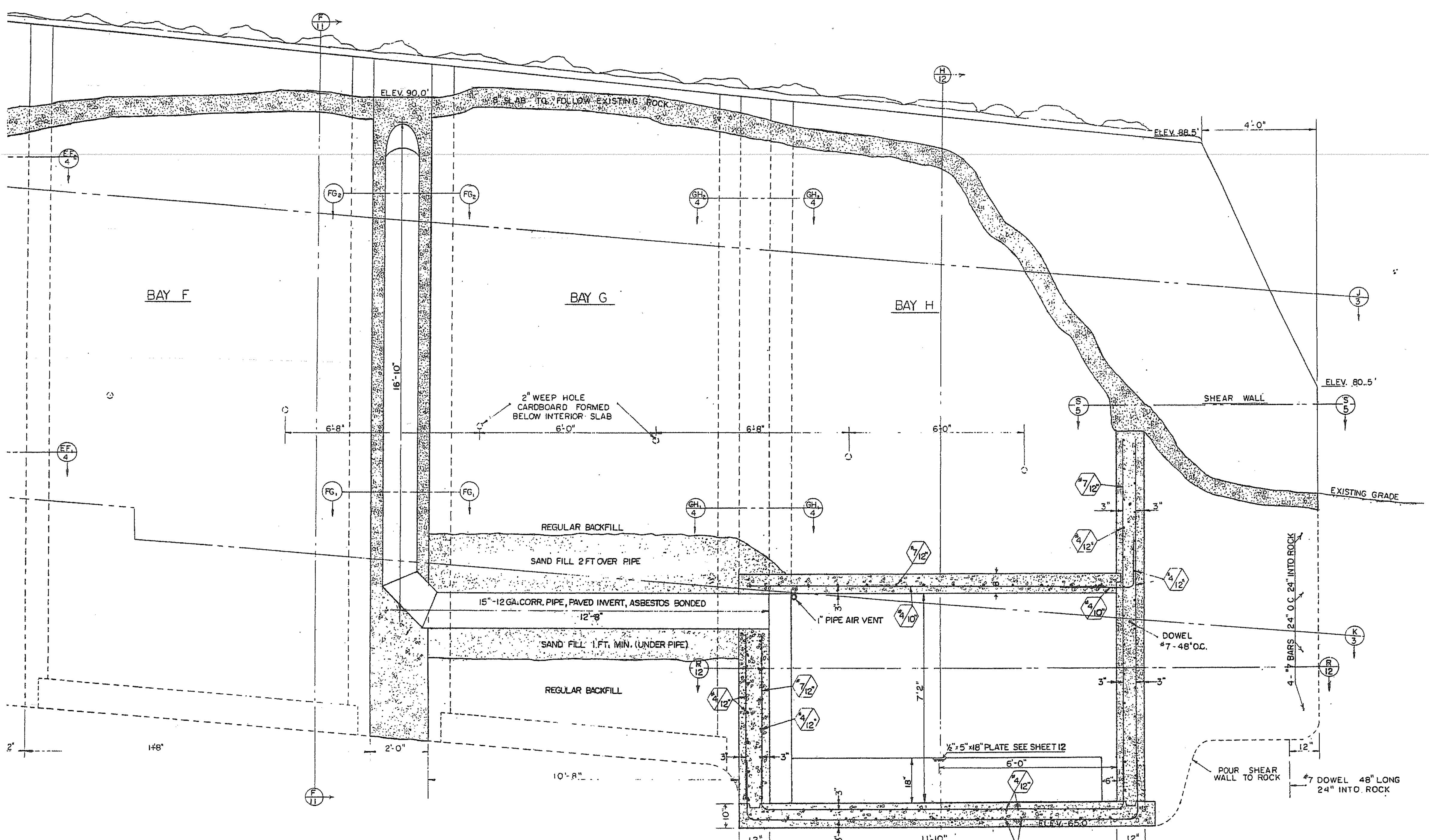

SECTION L-L
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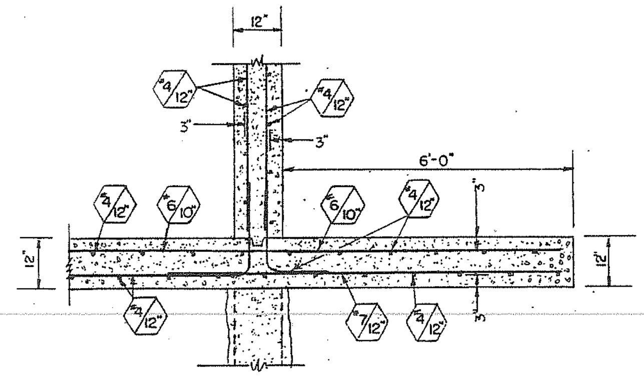
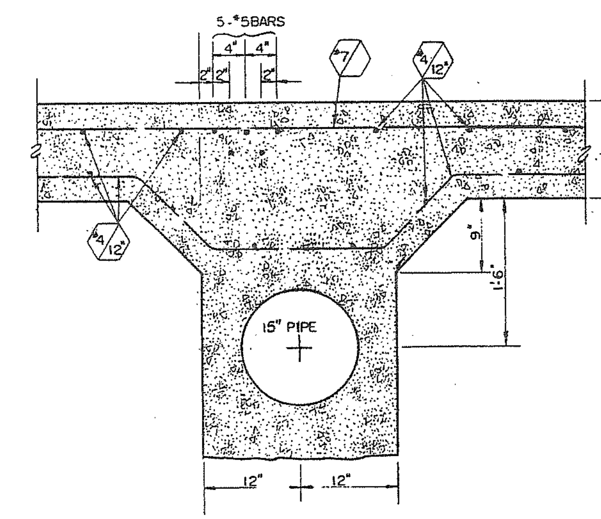


SECTION S-S
SCALE 1/2"=1'-0"



FG1, FG2
SCALE 1"=1'-0"

SECTION L-L
(LOWER PART)

SCALE AS SHOWN	PLATE 5
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ENGINEER	
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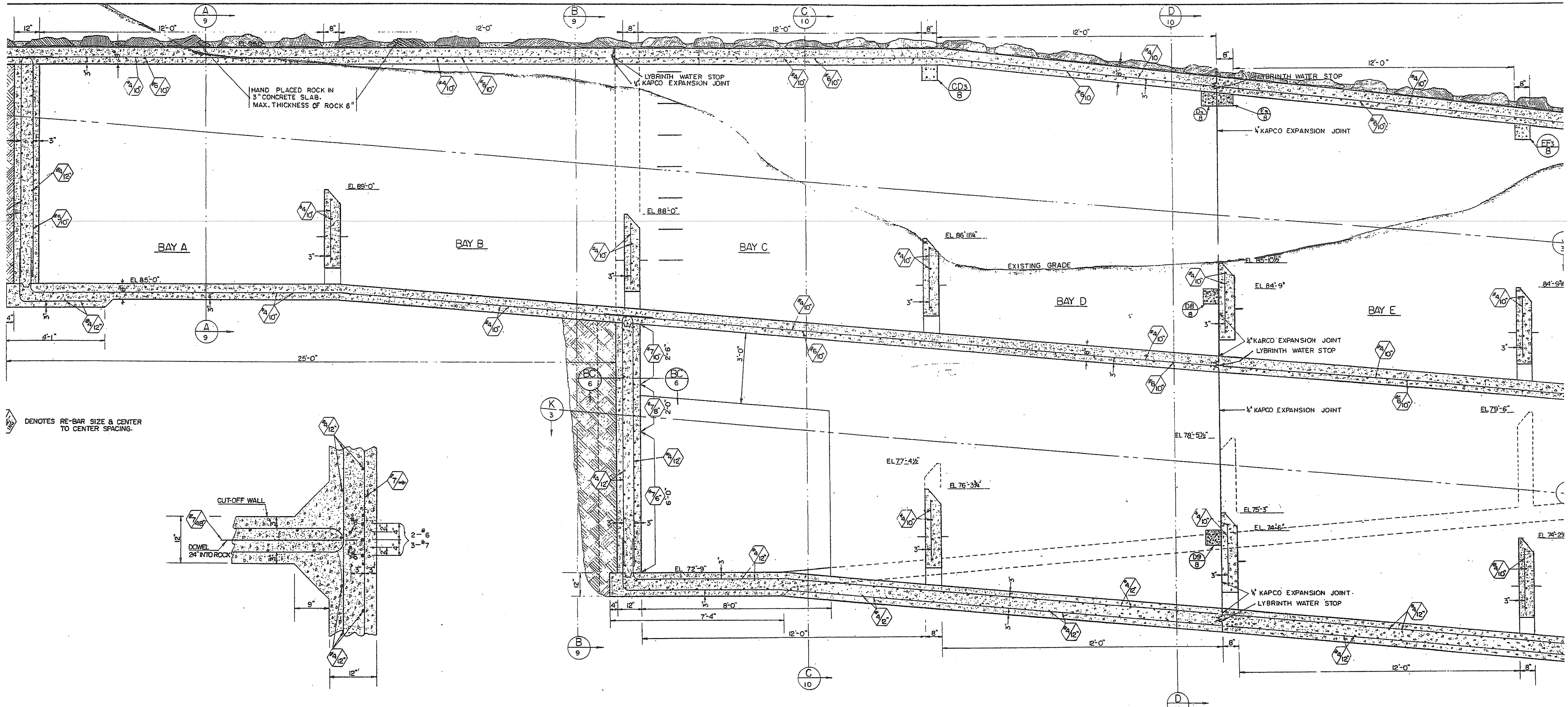

BEAM BC
SCALE 1"=1'-0"

SECTION M-M
SCALE 1/2"=1'-0"

SECTION M-M
(UPPER END)

SCALE AS SHOWN	PLATE 6
DRAWN 3-24-58 BY GHC	13
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APPROVED BY DIRECTOR	

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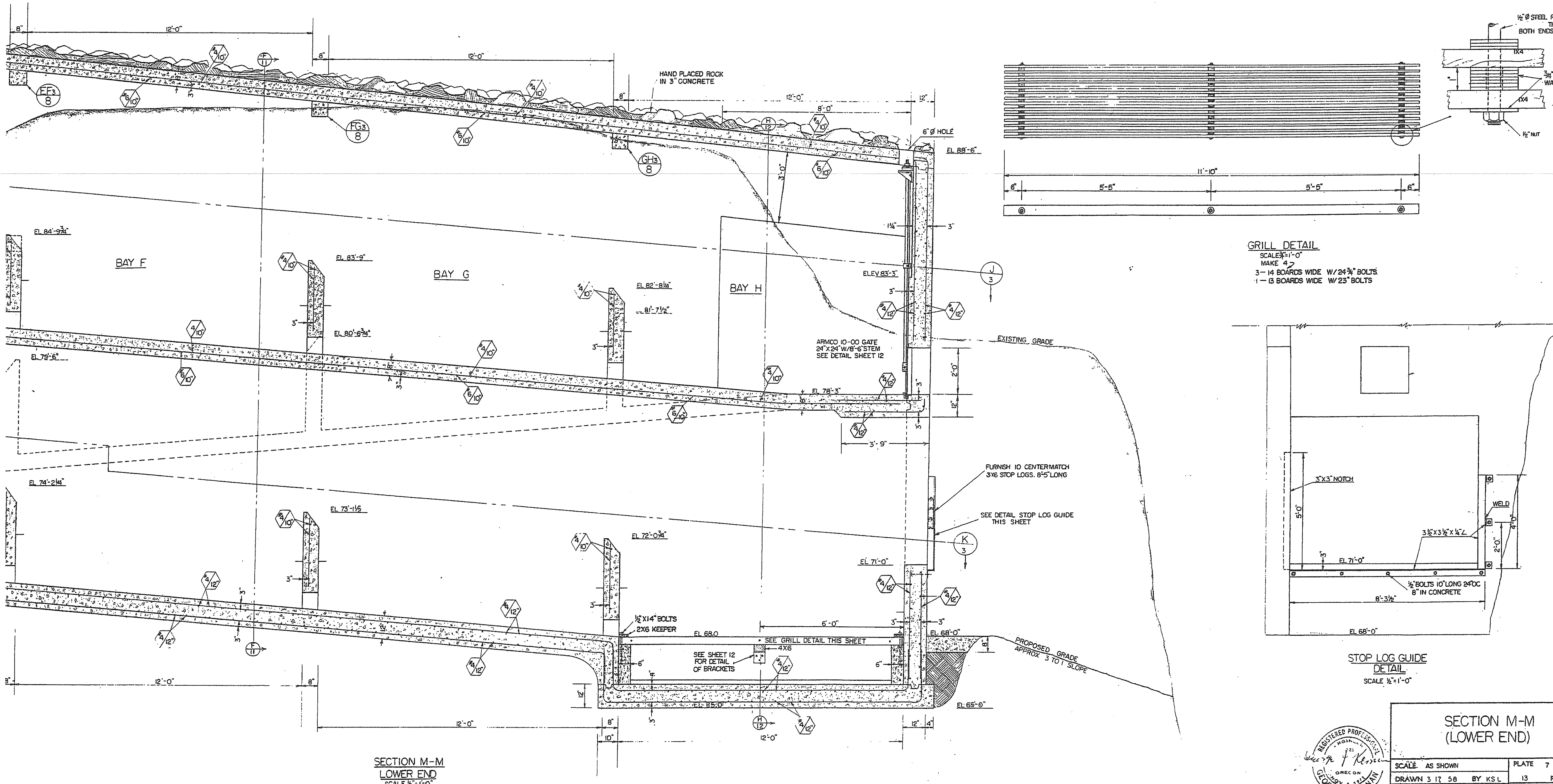

SECTION M-M
(LOWER END)

SCALE AS SHOWN	PLATE 7
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ENGINEER	983
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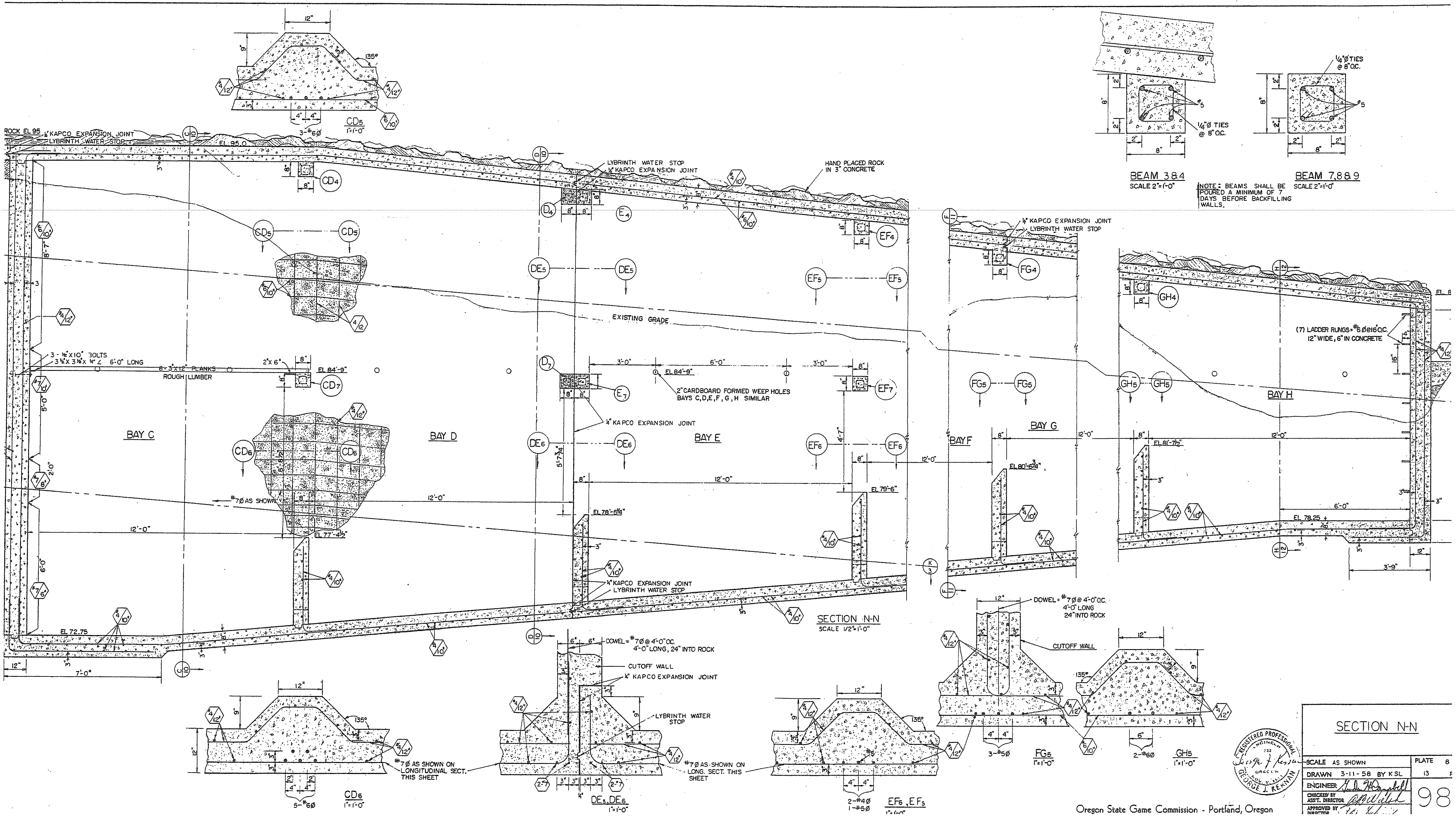
Oregon State Game Commission - Portland, Oregon



SECTION N-N
SCALE 1/2"=1'-0"
BAY C
BAY D
BAY E
BAY F
BAY G
BAY H
ROCK EL 95
1/2" KAPCO EXPANSION JOINT
LYBRINTH WATER STOP
EL 95.0
HAND PLACED ROCK IN 3" CONCRETE
EXISTING GRADE
3 - 1/2"X10" BOLTS
3 1/2"X 3 1/2"X 1/4" ∠ 6'-0" LONG
6-3"X12" PLANKS ROUGH LUMBER
EL 84'-9"
2" CARDBOARD FORMED WEEP HOLES BAYS C,D,E,F,G,H SIMILAR
(7) LADDER RUNGS = #6Ø@16"O.C. 12" WIDE, 6" IN CONCRETE
EL 81'-7 1/2"
EL 80'-6 3/4"
EL 79'-6"
EL 78'-5 1/4"
EL 77'-4 1/2"
EL 78.25
EL 72.75
#7Ø AS SHOWN
BEAM 3&4
SCALE 2"=1'-0"
BEAM 7,8&9
SCALE 2"=1'-0"
1/4"Ø TIES @ 8" O.C.
NOTE: BEAMS SHALL BE POURED A MINIMUM OF 7 DAYS BEFORE BACKFILLING WALLS.
CD5
1"=1'-0"
3-#6Ø
CD6
1"=1'-0"
5-#6Ø
#7Ø AS SHOWN ON LONGITUDINAL SECT. THIS SHEET
DOWEL = #7Ø @ 4'-0" O.C. 4'-0" LONG, 24" INTO ROCK
CUTOFF WALL
1/4" KAPCO EXPANSION JOINT
LYBRINTH WATER STOP
#7Ø AS SHOWN ON LONG. SECT. THIS SHEET
DE5, DE6
1"=1'-0"
2-#4Ø
1-#5Ø
EF6, EF5
1"=1'-0"
DOWEL = #7Ø @ 4'-0" O.C. 4'-0" LONG 24" INTO ROCK
FG5
1"=1'-0"
3-#5Ø
GH5
1"=1'-0"
2-#6Ø
REGISTERED PROFESSIONAL ENGINEER OREGON
GEORGE J. KEENAN
SECTION N-N
SCALE AS SHOWN
DRAWN 3-11-58 BY KSL
ENGINEER
CHECKED BY ASS'T. DIRECTOR
APPROVED BY DIRECTOR
PLATE 8
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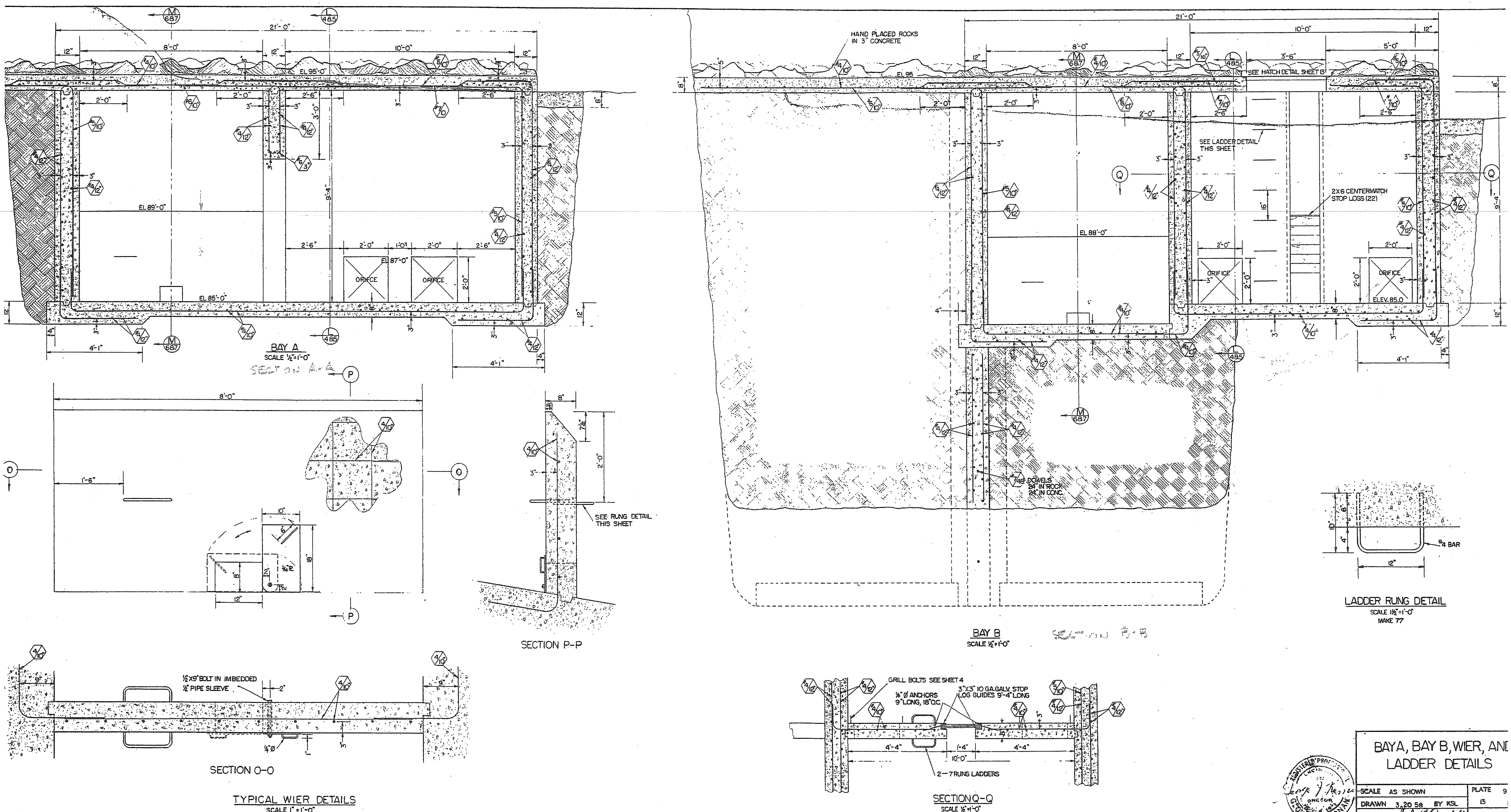
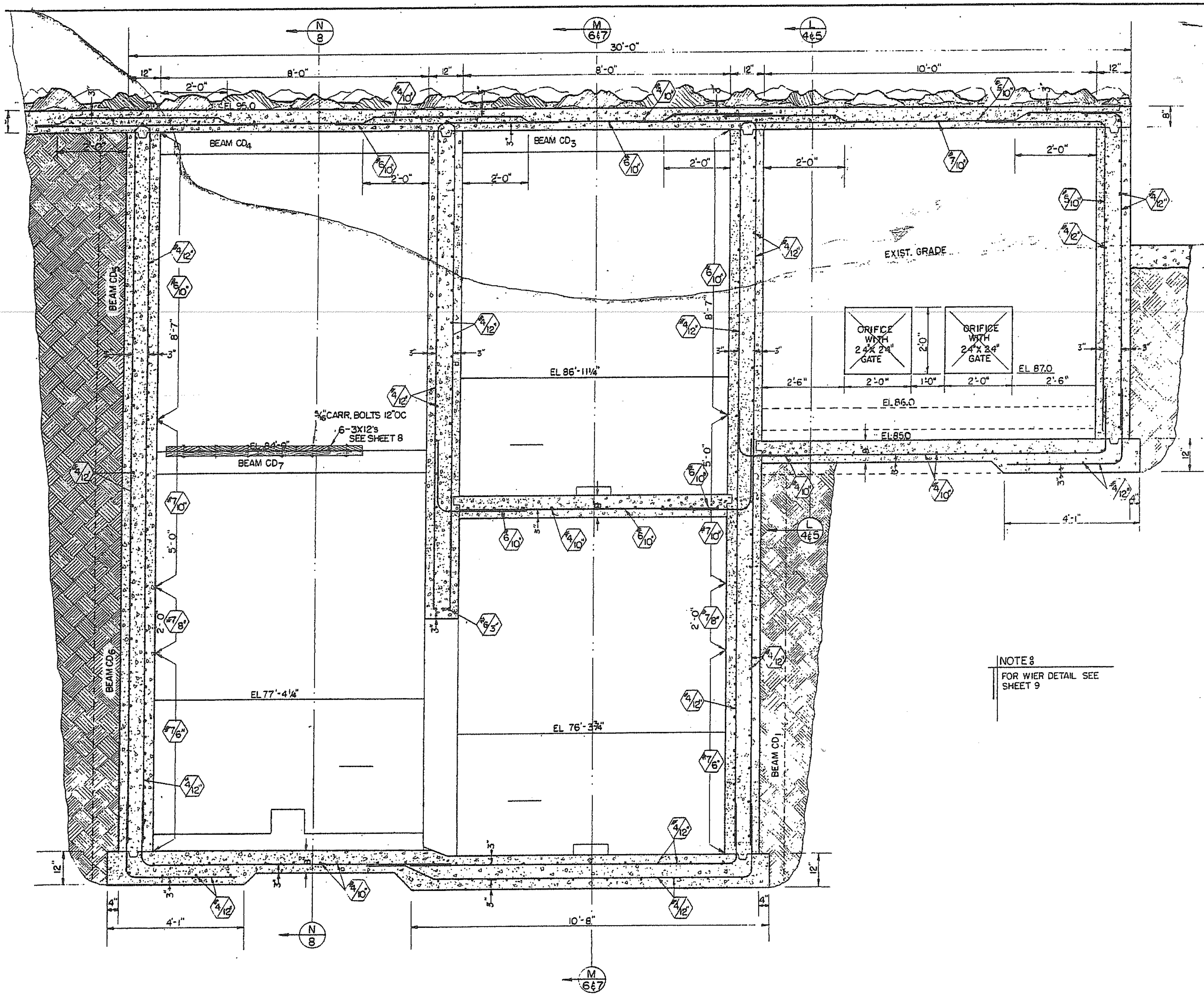
Oregon State Game Commission - Portland, Oregon



BAY A, BAY B, WIER, AND LADDER DETAILS

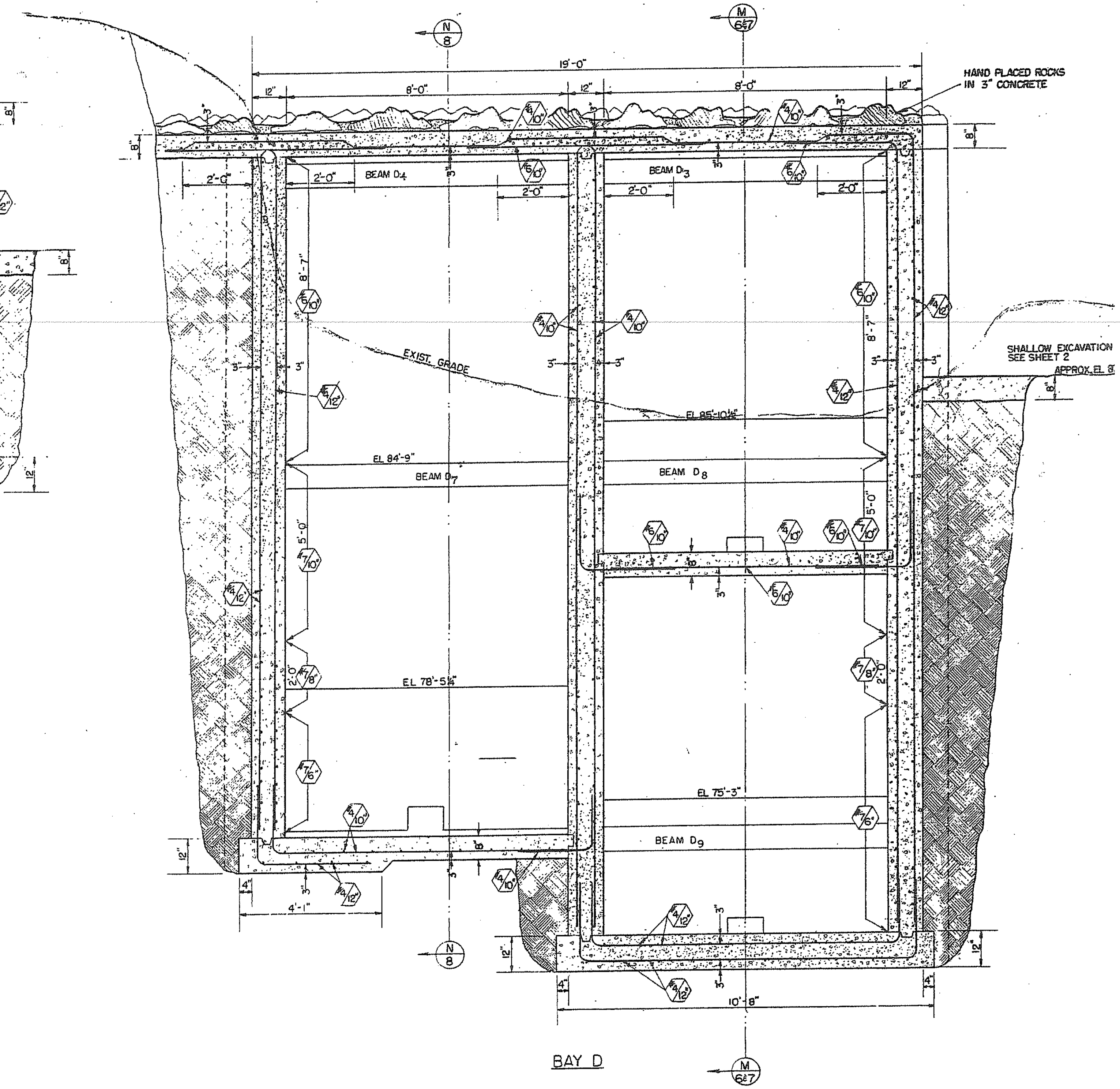
SCALE AS SHOWN	PLATE 9
DRAWN 3-20-58 BY KSL	13
ENGINEER	
CHECKED BY ASS'T. DIRECTOR	98



BAY C

SECTION C-C

NOTES
FOR WIER DETAIL SEE SHEET 9



BAY D

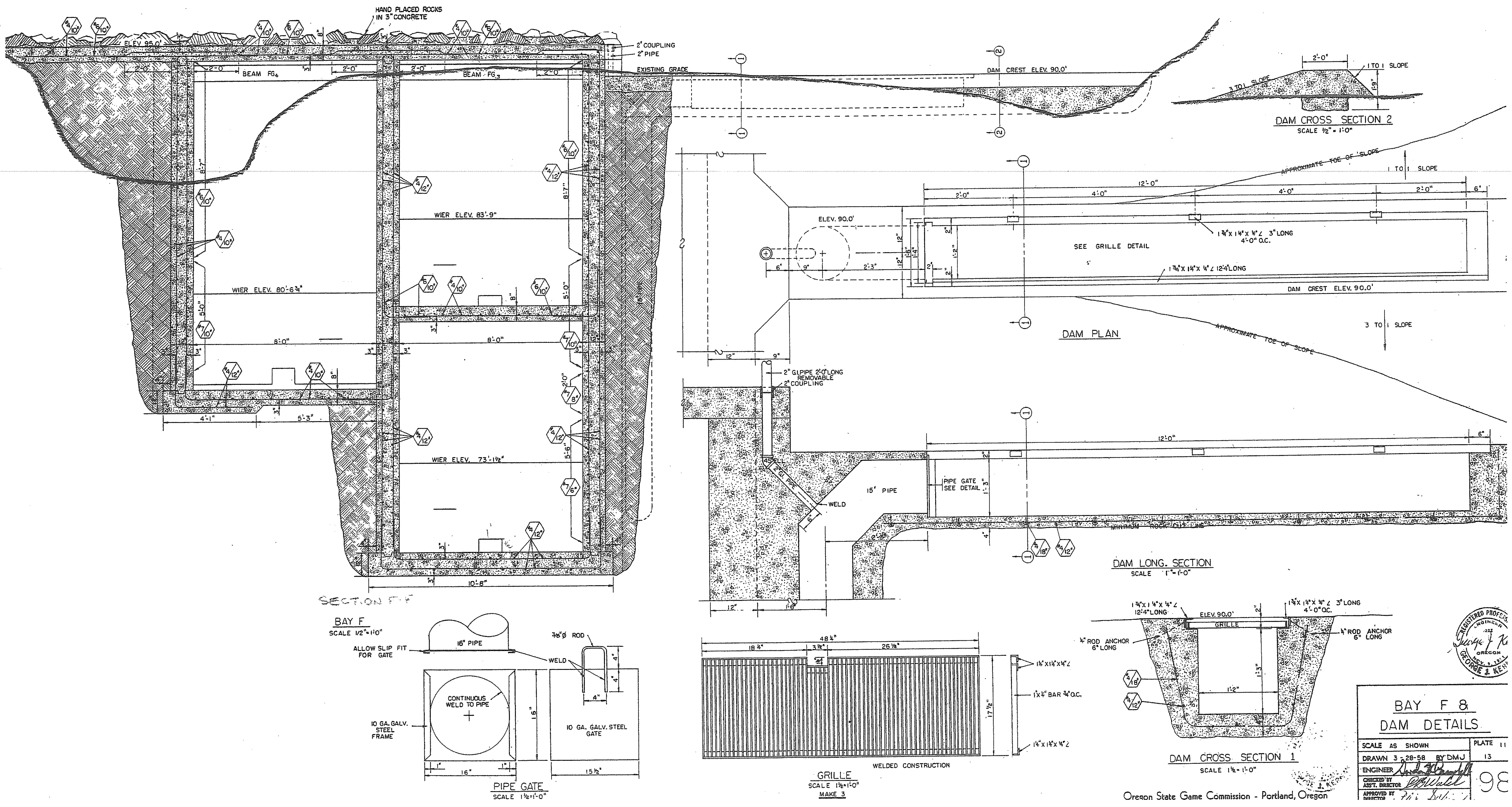
SECTION D-D

SECTION BAY C
SECTION BAY D

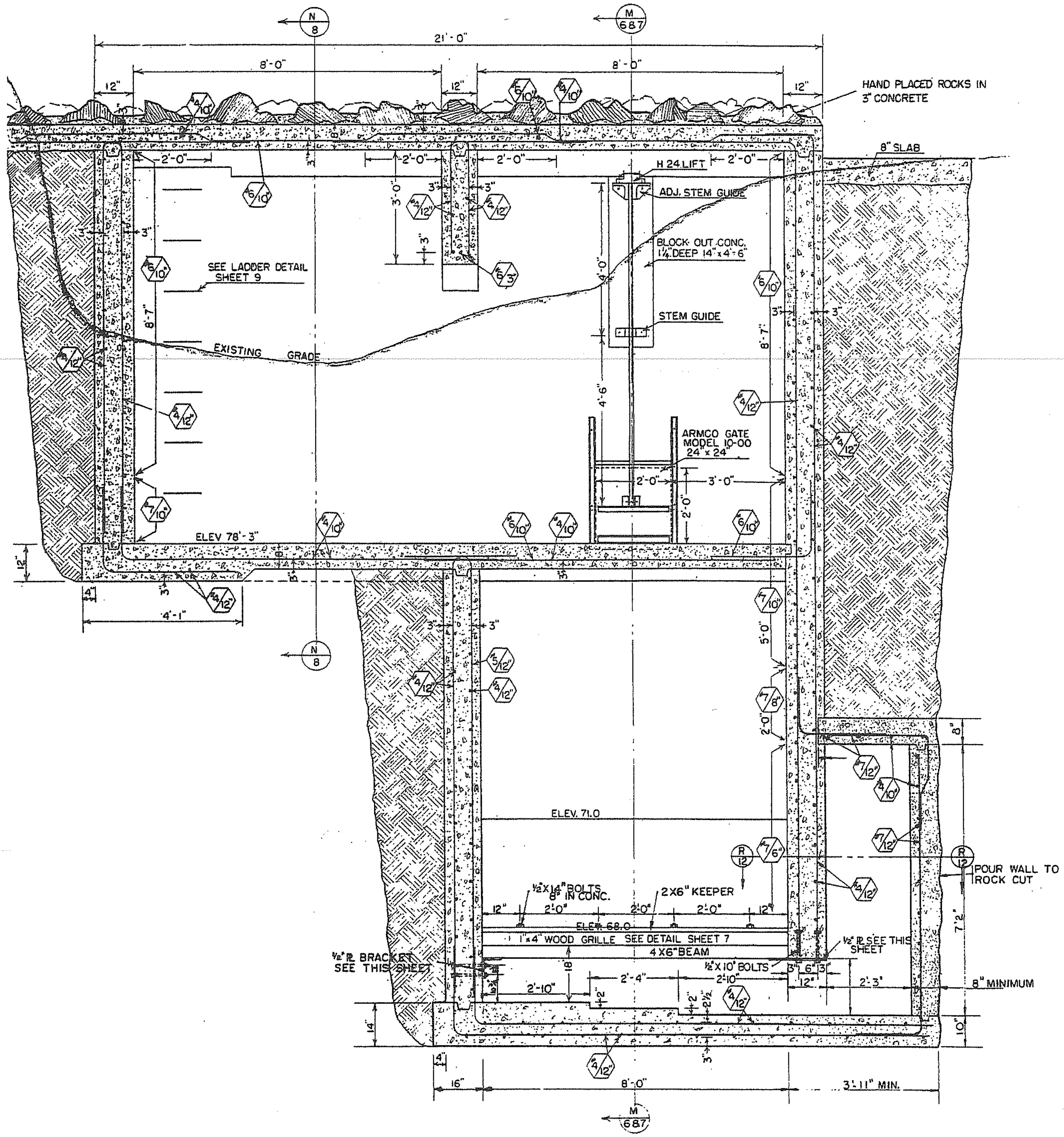
SCALE 1/2"=1'-0"	PLATE 13
DRAWN 3-27-58 BY KSL	
ENGINEER	98
CHECKED BY ASS'T. DIRECTOR	
APPROVED BY DIRECTOR	

REGISTERED PROFESSIONAL ENGINEER — OREGON — GEORGE J. KERNAN

Oregon State Game Commission - Portland, Oregon



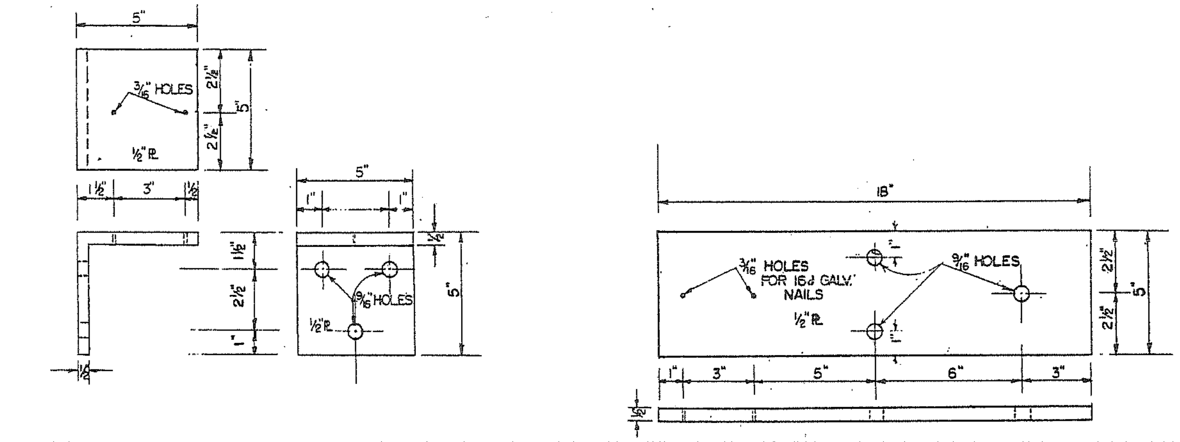
HAND PLACED ROCKS IN 3" CONCRETE
ELEV. 95.0'
2" COUPLING
2" PIPE
EXISTING GRADE
BEAM FG4
BEAM FG3
WIER ELEV. 83'-9"
WIER ELEV. 80'-6 3/4"
WIER ELEV. 73'-1 1/2"
8'-0"
4'-1"
5'-3"
10'-8"
SECTION F-F
BAY F
SCALE 1/2"=1'-0"
DAM CREST ELEV. 90.0'
DAM CROSS SECTION 2
SCALE 1/2" = 1'-0"
3 TO 1 SLOPE
1 TO 1 SLOPE
APPROXIMATE TOE OF SLOPE
ELEV. 90.0'
SEE GRILLE DETAIL
1 3/4" x 1 3/4" x 1/4" ∠ 3" LONG 4'-0" O.C.
1 3/4" x 1 3/4" x 1/4" ∠ 12'-4" LONG
DAM PLAN
2" G.I. PIPE 2'-0" LONG REMOVABLE
2" COUPLING
2" G.I. PIPE
15" PIPE
WELD
PIPE GATE SEE DETAIL
MINIMUM ROCK CUT LINE
DAM LONG. SECTION
SCALE 1"=1'-0"
GRILLE
1/2" ROD ANCHOR 6" LONG
DAM CROSS SECTION 1
SCALE 1 1/2"= 1'-0"
ALLOW SLIP FIT FOR GATE
16" PIPE
3/8" Ø ROD
CONTINUOUS WELD TO PIPE
10 GA. GALV. STEEL FRAME
10 GA. GALV. STEEL GATE
PIPE GATE
SCALE 1 1/2=1'-0"
1 1/2" x 1 1/2" x 1/4" ∠
1" x 1/4" BAR 3/4" O.C.
WELDED CONSTRUCTION
GRILLE
SCALE 1 1/2=1'-0"
MAKE 3
BAY F & DAM DETAILS
SCALE AS SHOWN
PLATE 11
DRAWN 3-28-58 BY DMJ
13
ENGINEER
CHECKED BY ASS'T. DIRECTOR
APPROVED BY DIRECTOR
Oregon State Game Commission - Portland, Oregon



BAY H

SCALE ½"=1'-0"

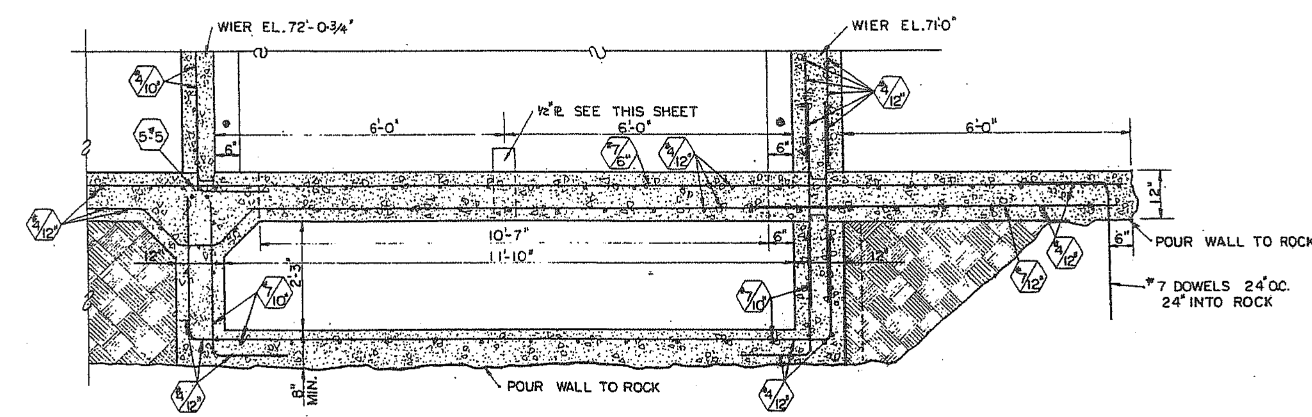
SECTION H-H



4X6 BEAM SUPPORT BRACKETS

SCALE 3"=1'-0"

MAKE 1 OF EACH

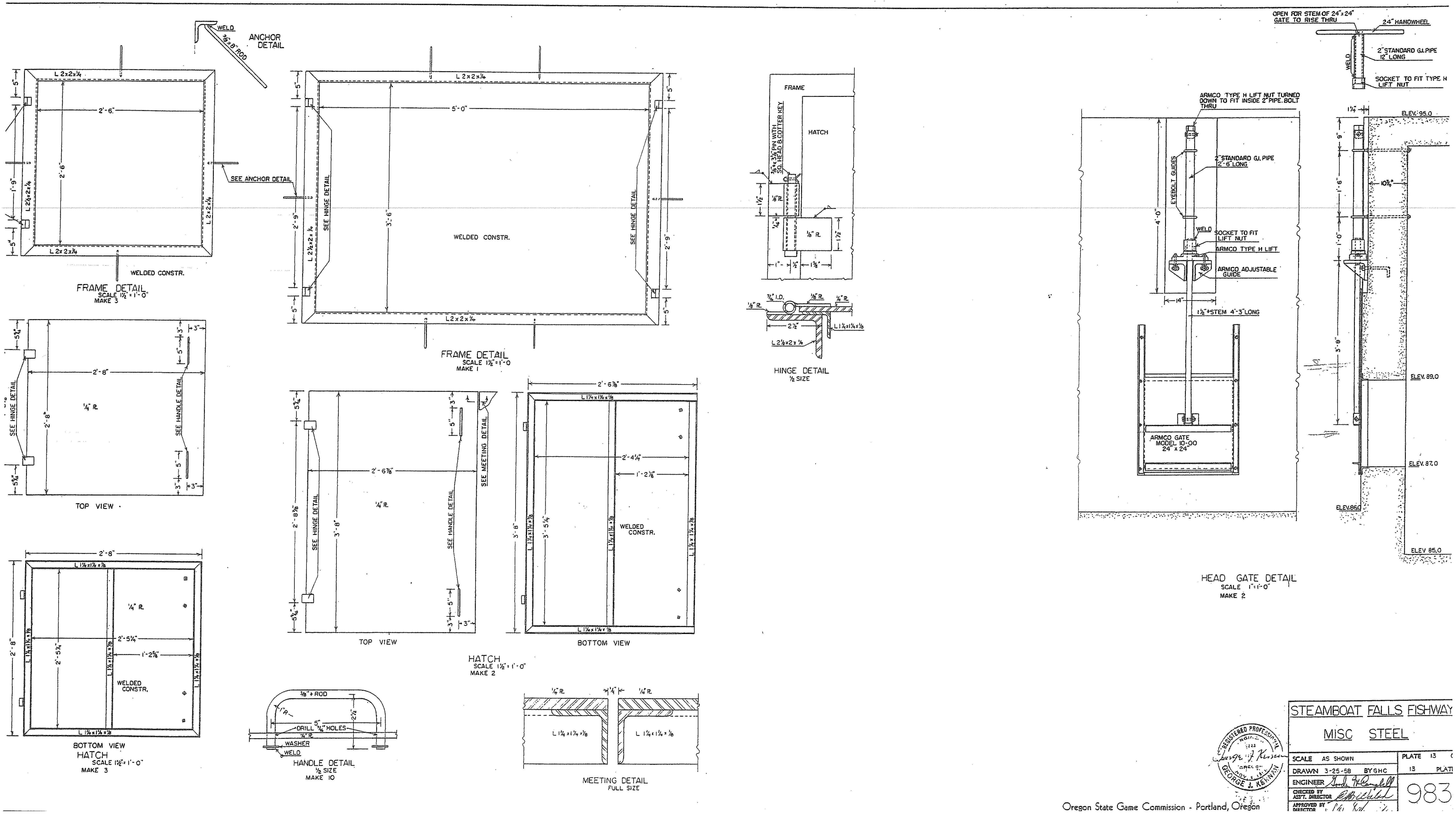


SECTION R-R

SCALE 1/2"=1'-0"

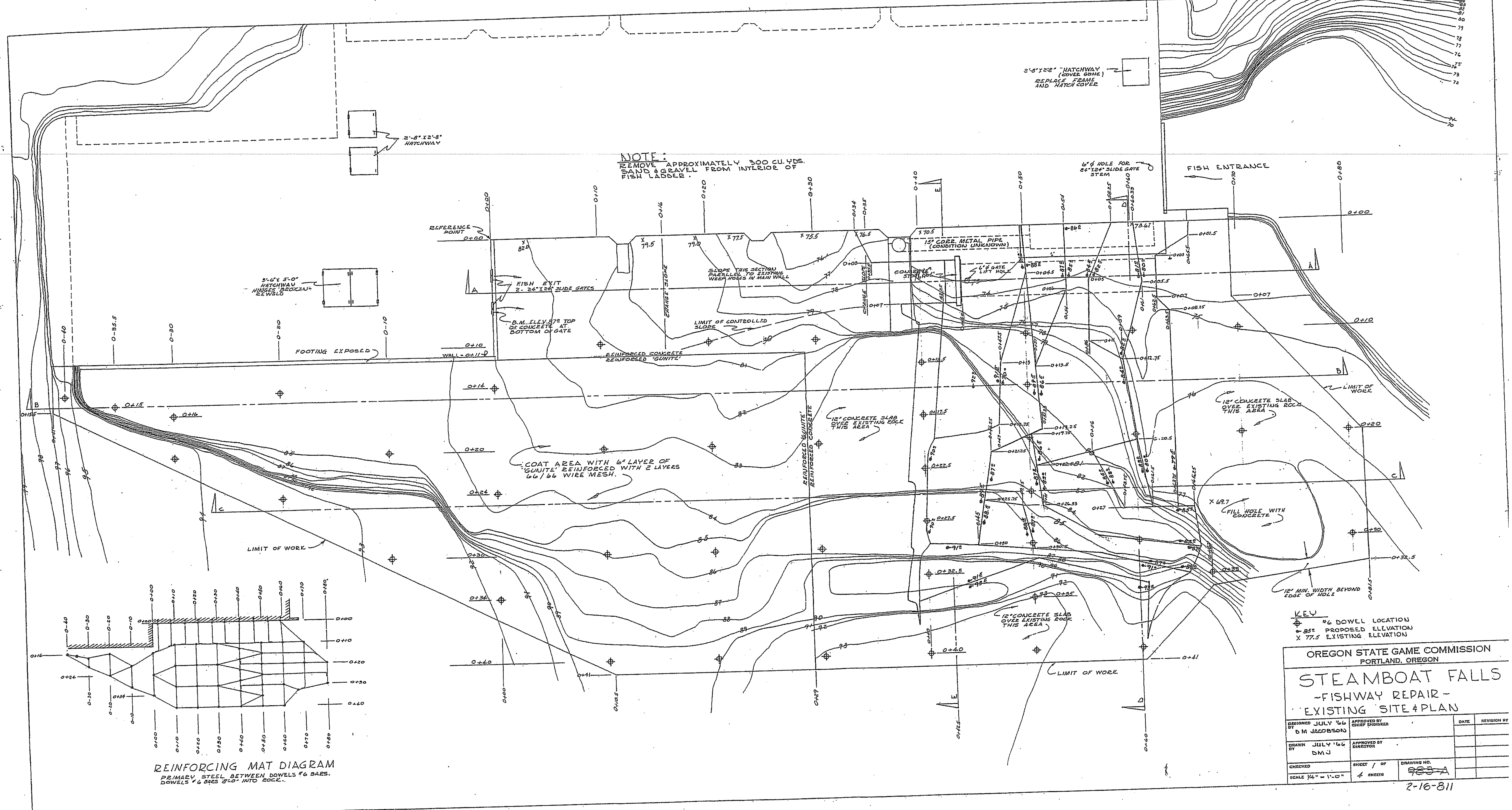
STEAMBOAT FALLS FISHWA[Y] BAY H	
SCALE AS SHOWN	PLATE 12
DRAWN 3 26 57 BY GHC	13
ENGINEER	98[…]
CHECKED BY ASST. DIRECTOR	
APPROVED BY DIRECTOR	

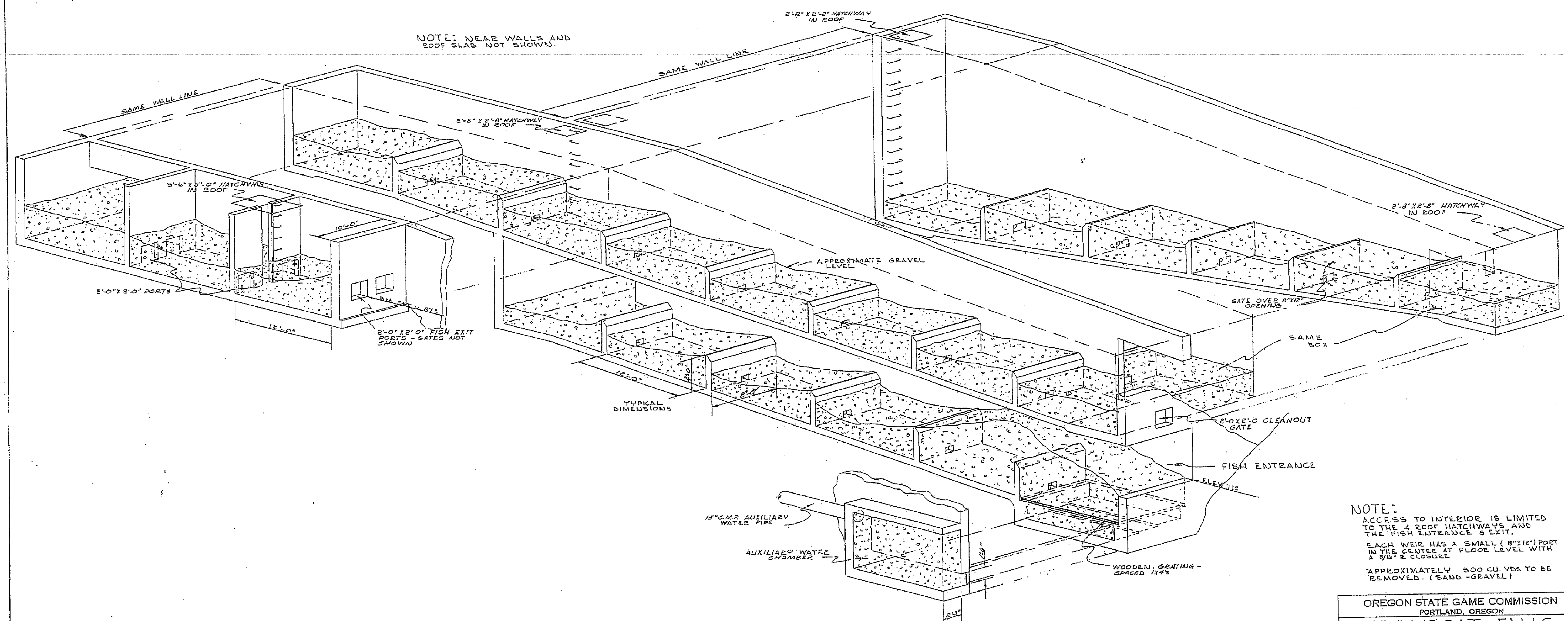
Oregon State Game Commission - Portland, Oregon


ANCHOR DETAIL
WELD
3/8" x 8" ROD
SEE ANCHOR DETAIL
FRAME DETAIL
SCALE 1½" = 1'-0"
MAKE 3
WELDED CONSTR.
L 2x2x¼
L 2½x2x¼
FRAME DETAIL
SCALE 1½" = 1'-0
MAKE 1
SEE HINGE DETAIL
WELDED CONSTR.
FRAME
HATCH
5/8"x3½" PIN WITH SQ. HEAD & COTTER KEY
HINGE DETAIL
½ SIZE
L 2½x2x¼
L 1¾x1¾x⅛
TOP VIEW
¼" R.
SEE HANDLE DETAIL
SEE MEETING DETAIL
BOTTOM VIEW
HATCH
SCALE 1½" = 1'-0"
MAKE 3
HATCH
SCALE 1½" = 1'-0"
MAKE 2
L 1¾x1¾x⅛
HANDLE DETAIL
½ SIZE
MAKE 10
3/8" ROD
DRILL 7/16" HOLES
WASHER
WELD
MEETING DETAIL
FULL SIZE
OPEN FOR STEM OF 24"x24" GATE TO RISE THRU
24" HANDWHEEL
2" STANDARD G.I. PIPE 12" LONG
SOCKET TO FIT TYPE H LIFT NUT
ARMCO TYPE H LIFT NUT TURNED DOWN TO FIT INSIDE 2" PIPE. BOLT THRU
2" STANDARD G.I. PIPE 2'-6" LONG
EYEBOLT GUIDES
SOCKET TO FIT LIFT NUT
ARMCO TYPE H LIFT
ARMCO ADJUSTABLE GUIDE
1½" ϕ STEM 4'-3" LONG
ARMCO GATE MODEL 10-00 24" x 24"
ELEV. 95.0
ELEV. 89.0
ELEV. 87.0
ELEV. 86.0
ELEV. 85.0
HEAD GATE DETAIL
SCALE 1" = 1'-0"
MAKE 2
STEAMBOAT FALLS FISHWAY
MISC STEEL
SCALE AS SHOWN
DRAWN 3-25-58 BY GHC
ENGINEER
CHECKED BY ASST. DIRECTOR
APPROVED BY DIRECTOR
PLATE 13
983
REGISTERED PROFESSIONAL ENGINEER
GEORGE J. KEHNAN
Oregon State Game Commission - Portland, Oregon

APPENDIX C

1966 Repair Plan Set for Steamboat Falls Fishway


NOTE:
REMOVE APPROXIMATELY 300 CU. YDS. SAND & GRAVEL FROM INTERIOR OF FISH LADDER.
2'-8" X 2'-8" HATCHWAY
2'-8"X2'-2" HATCHWAY (COVER GONE) REPLACE FRAME AND HATCH COVER
3'-6" X 5'-0" HATCHWAY HINGES BROKEN - REWELD
REFERENCE POINT
FISH EXIT 2 - 24"X24" SLIDE GATES
B.M. ELEV. 87.2 TOP OF CONCRETE AT BOTTOM OF GATE
FOOTING EXPOSED
15" CORR. METAL PIPE (CONDITION UNKNOWN)
6" Ø HOLE FOR 24"X24" SLIDE GATE STEM
FISH ENTRANCE
SLOPE THIS SECTION PARALLEL TO EXISTING WEEP HOLES IN MAIN WALL
LIMIT OF CONTROLLED SLOPE
REINFORCED CONCRETE
REINFORCED 'GUNITE'
COAT AREA WITH 6" LAYER OF 'GUNITE' REINFORCED WITH 2 LAYERS 66/66 WIRE MESH.
12" CONCRETE SLAB OVER EXISTING ROCK THIS AREA
FILL HOLE WITH CONCRETE
12" MIN. WIDTH BEYOND EDGE OF HOLE
LIMIT OF WORK
REINFORCING MAT DIAGRAM
PRIMARY STEEL BETWEEN DOWELS #6 BARS. DOWELS #6 BARS 8'-0" INTO ROCK.
KEY
#6 DOWEL LOCATION
85.0 PROPOSED ELEVATION
X 77.5 EXISTING ELEVATION
OREGON STATE GAME COMMISSION
PORTLAND, OREGON
STEAMBOAT FALLS
-FISHWAY REPAIR-
EXISTING SITE & PLAN
DESIGNED BY JULY '66 D M JACOBSON
APPROVED BY CHIEF ENGINEER
DATE
REVISION BY
DRAWN BY JULY '66 DMJ
APPROVED BY DIRECTOR
CHECKED
SCALE 1/4" = 1'-0"
SHEET 1 OF 4 SHEETS
DRAWING NO. 983-A
2-16-811



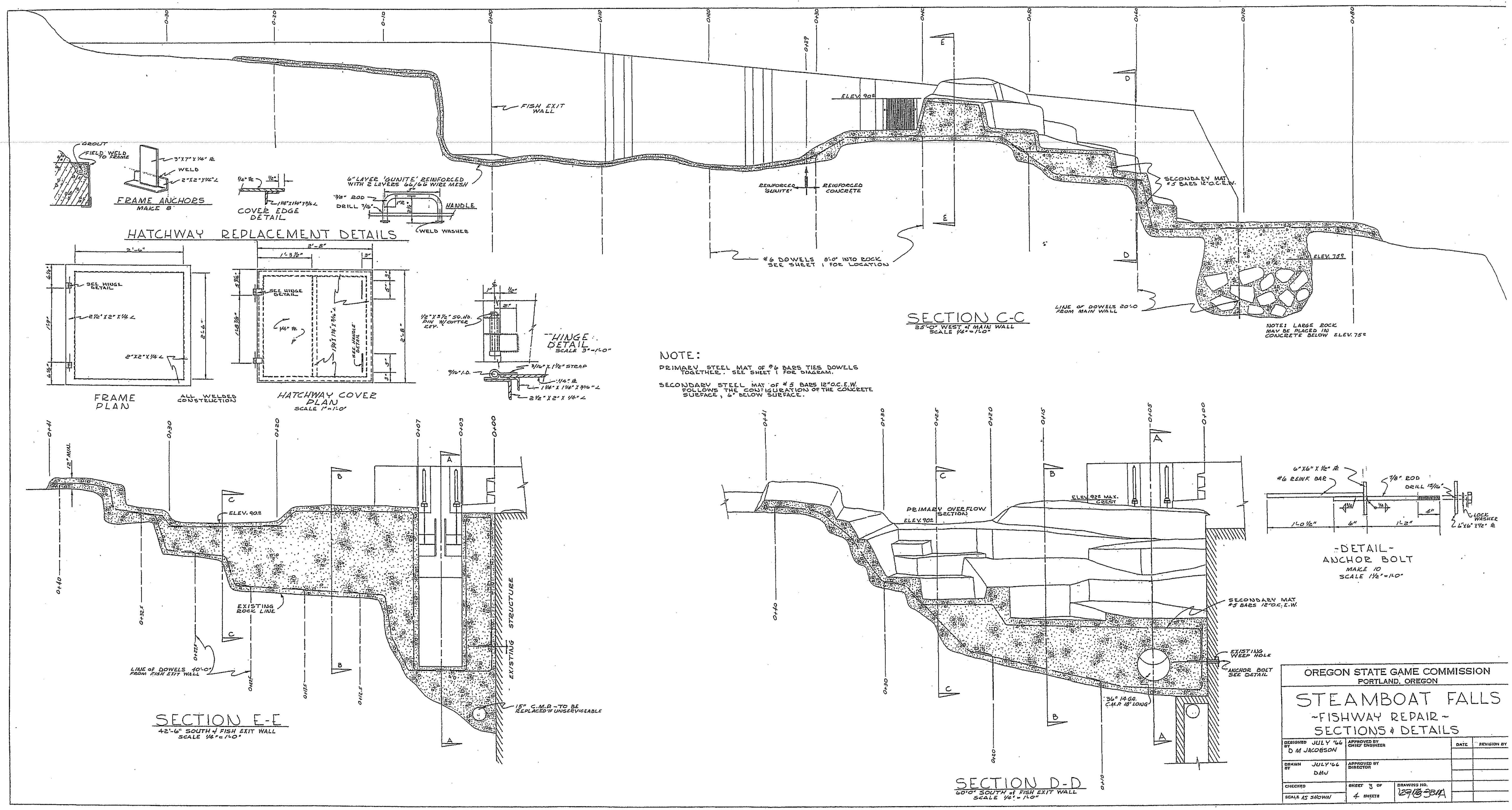
NOTE:

ACCESS TO INTERIOR IS LIMITED TO THE 4 ROOF HATCHWAYS AND THE FISH ENTRANCE & EXIT.

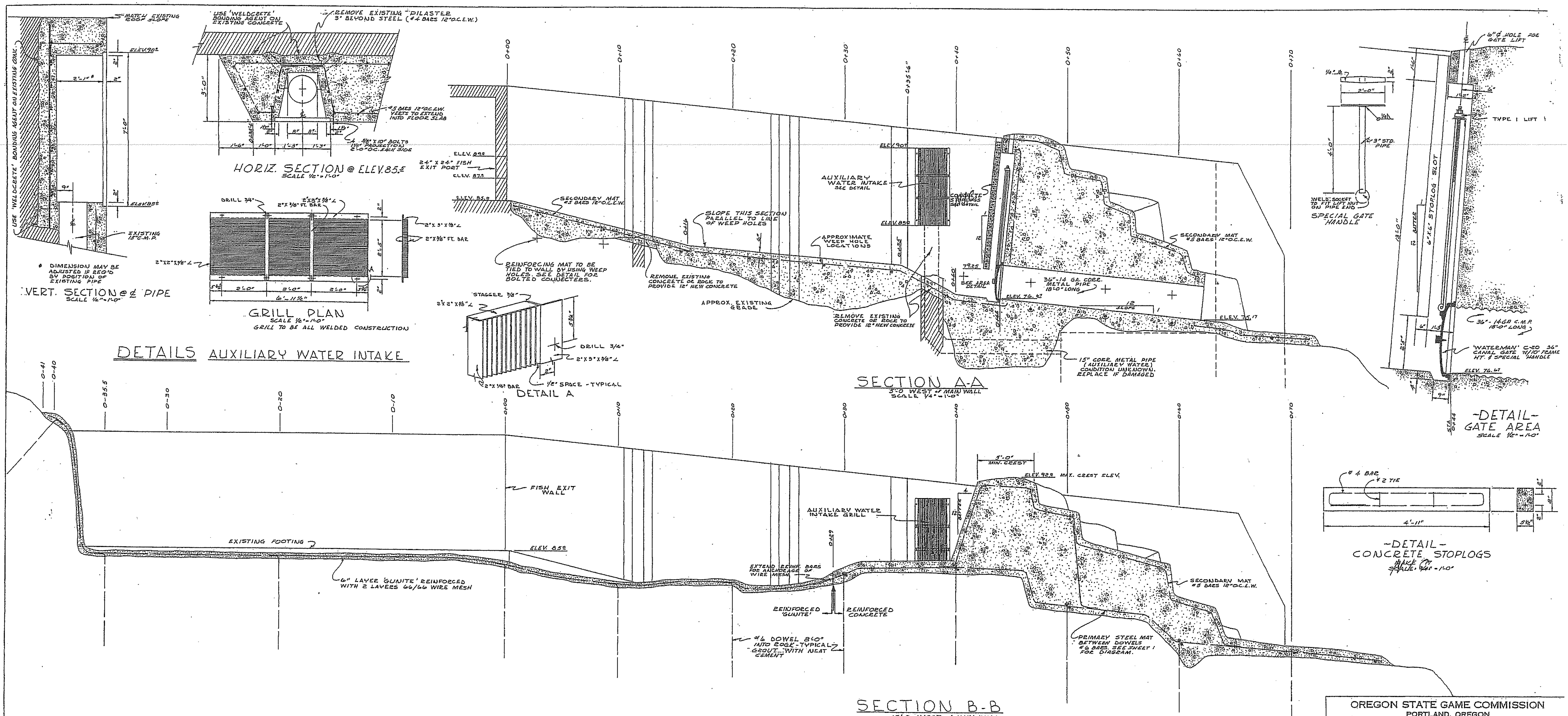
EACH WEIR HAS A SMALL (8"X12") PORT IN THE CENTER AT FLOOR LEVEL WITH A 3/16" ℞ CLOSURE

APPROXIMATELY 300 CU. YDS TO BE REMOVED. (SAND-GRAVEL)

OREGON STATE GAME COMMISSION PORTLAND, OREGON			
STEAMBOAT FALLS -FISHWAY REPAIR- DIAGRAM of EXISTING FISHWAY INTERIOR			
DESIGNED BY JULY '66 D M JACOBSON	APPROVED BY CHIEF ENGINEER		DATE / REVISION
DRAWN BY AUG '66 DMJ	APPROVED BY DIRECTOR		
CHECKED	SHEET 4 OF	DRAWING NO.	
SCALE 3/16" = 1'-0"	4 SHEETS	27B-B11A	



FISH EXIT WALL
ELEV. 90±
REINFORCED 'GUNITE'
REINFORCED CONCRETE
SECONDARY MAT #5 BARS 12" O.C.E.W.
#6 DOWELS 8'-0" INTO ROCK SEE SHEET 1 FOR LOCATION
ELEV. 75±
LINE OF DOWELS 20'-0 FROM MAIN WALL
NOTE: LARGE ROCK MAY BE PLACED IN CONCRETE BELOW ELEV. 75±
SECTION C-C
35'-0" WEST of MAIN WALL
SCALE 1/4" = 1'-0"
GROUT
FIELD WELD TO FRAME
3"X7"X1/4" PL
WELD
2"X2"X1/4" L
FRAME ANCHORS
MAKE 8
COVER EDGE DETAIL
6" LAYER 'GUNITE' REINFORCED WITH 2 LAYERS 66/66 WIRE MESH
HANDLE
WELD WASHER
HATCHWAY REPLACEMENT DETAILS
SEE HINGE DETAIL
2 1/2" X 2" X 1/4 L
2"X2"X1/4 L
FRAME PLAN
ALL WELDED CONSTRUCTION
HATCHWAY COVER PLAN
SCALE 1" = 1'-0"
HINGE DETAIL
SCALE 3" = 1'-0"
NOTE:
PRIMARY STEEL MAT OF #6 BARS TIES DOWELS TOGETHER. SEE SHEET 1 FOR DIAGRAM.
SECONDARY STEEL MAT OF #5 BARS 12" O.C.E.W. FOLLOWS THE CONFIGURATION OF THE CONCRETE SURFACE, 6" BELOW SURFACE.
12" MIN.
ELEV. 90±
EXISTING ROCK LINE
LINE OF DOWELS 40'-0" FROM FISH EXIT WALL
EXISTING STRUCTURE
15" C.M.P. - TO BE REPLACED IF UNSERVICEABLE
SECTION E-E
42'-6" SOUTH of FISH EXIT WALL
SCALE 1/4" = 1'-0"
ELEV. 92± MAX. CREST
PRIMARY OVERFLOW SECTION
ELEV. 90±
SECONDARY MAT #5 BARS 12" O.C. E.W.
EXISTING WEEP HOLE
ANCHOR BOLT SEE DETAIL
36" 14 GA. C.M.P. 18' LONG
SECTION D-D
60'-0" SOUTH of FISH EXIT WALL
SCALE 1/4" = 1'-0"
6"X6"X1/2" PL
#6 REINF. BAR
7/8" ROD
LOCK WASHER
-DETAIL-
ANCHOR BOLT
MAKE 10
SCALE 1 1/2" = 1'-0"
OREGON STATE GAME COMMISSION
PORTLAND, OREGON
STEAMBOAT FALLS
-FISHWAY REPAIR-
SECTIONS & DETAILS
DESIGNED BY JULY '66 D M JACOBSON
APPROVED BY CHIEF ENGINEER
DRAWN BY JULY '66 DMJ
APPROVED BY DIRECTOR
CHECKED
SHEET 3 OF 4 SHEETS
SCALE AS SHOWN
DATE
REVISION BY



NOTE:

PRIMARY STEEL MAT OF #6 BARS TIES DOWELS TOGETHER. SEE SHEET 1 FOR DIAGRAM.

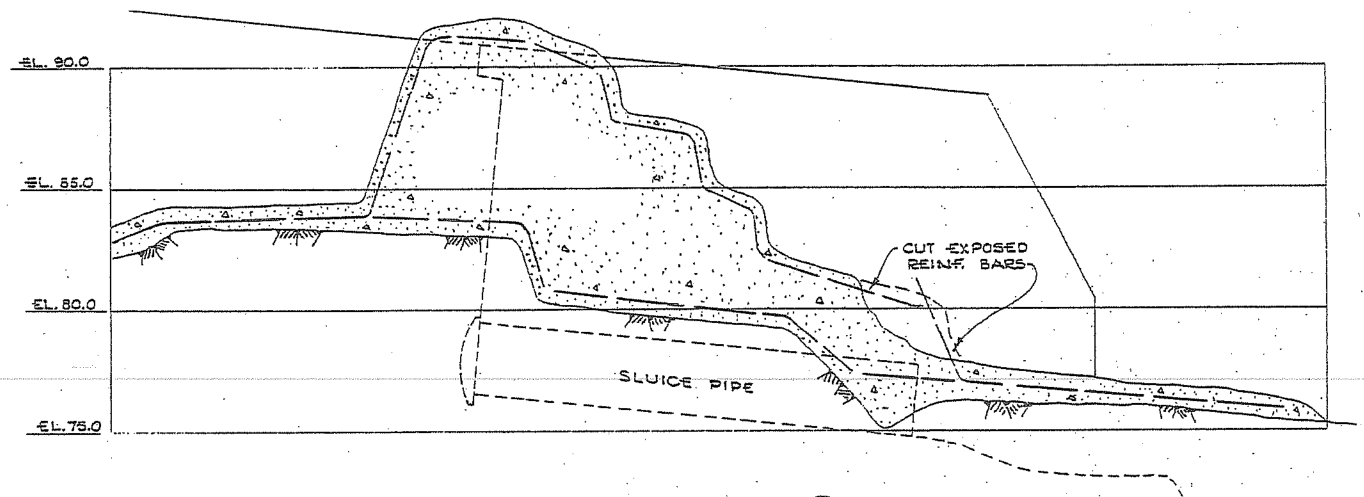
SECONDARY STEEL MAT OF #5 BARS 12"O.C.E.W. FOLLOWS THE CONFIGURATION OF THE CONCRETE SURFACE, 6" BELOW SURFACE.

GROUT DOWELS WITH NEAT CEMENT

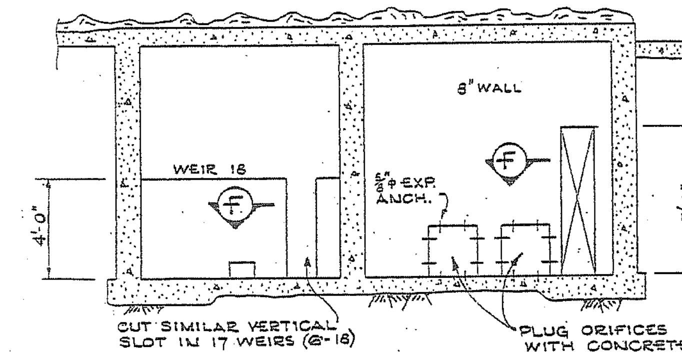
OREGON STATE GAME COMMISSION PORTLAND, OREGON			
STEAMBOAT FALLS -FISHWAY REPAIR- SECTIONS & DETAILS			
DESIGNED BY JULY '66 D M JACOBSON	APPROVED BY CHIEF ENGINEER	DATE	REVISION BY
DRAWN BY JULY '66 DMJ	APPROVED BY DIRECTOR		
CHECKED	SHEET 2 OF 4 SHEETS	DRAWING NO. 2316-BHA	
SCALE AS SHOWN			

APPENDIX D

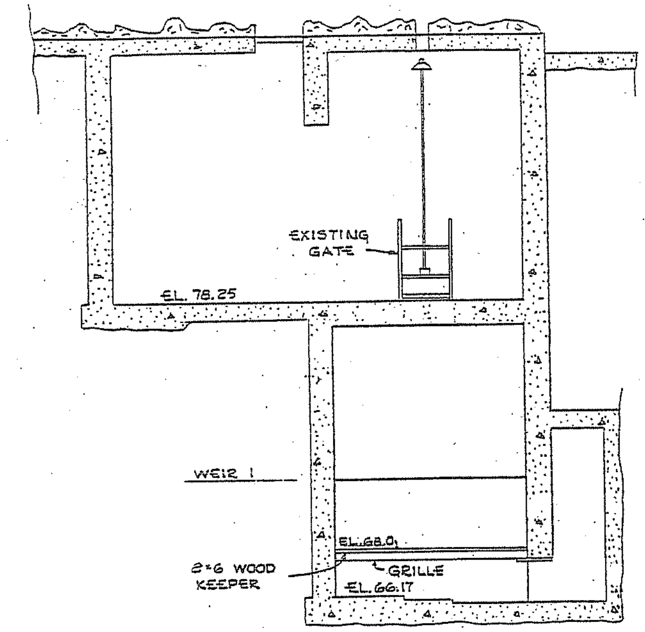
1985 As-Built Drawings for Steamboat Falls Fishway Modifications



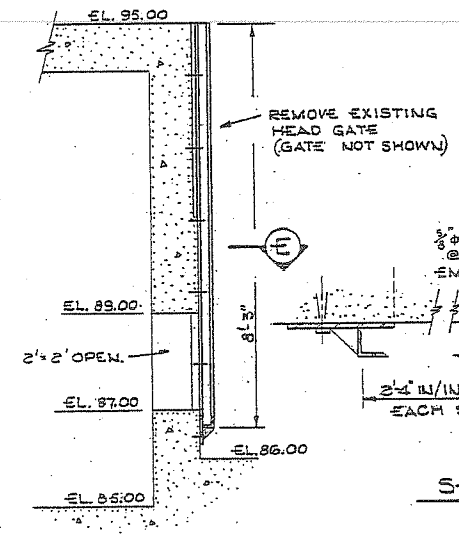
SECTION (A)
1/4" = 1'-0"



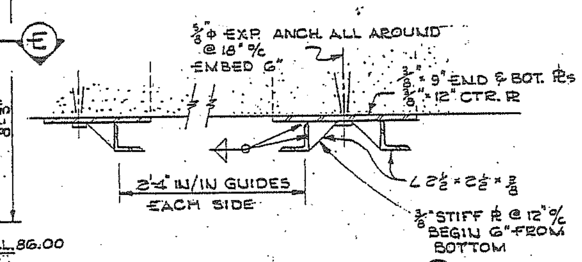
BAY A
SECTION (B)
1/4" = 1'-0"



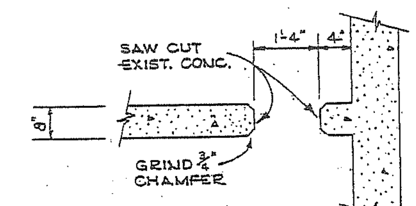
BAY H ⚠1
SECTION (C)
1/4" = 1'-0"



SECTION (D)
1/2" = 1'-0"

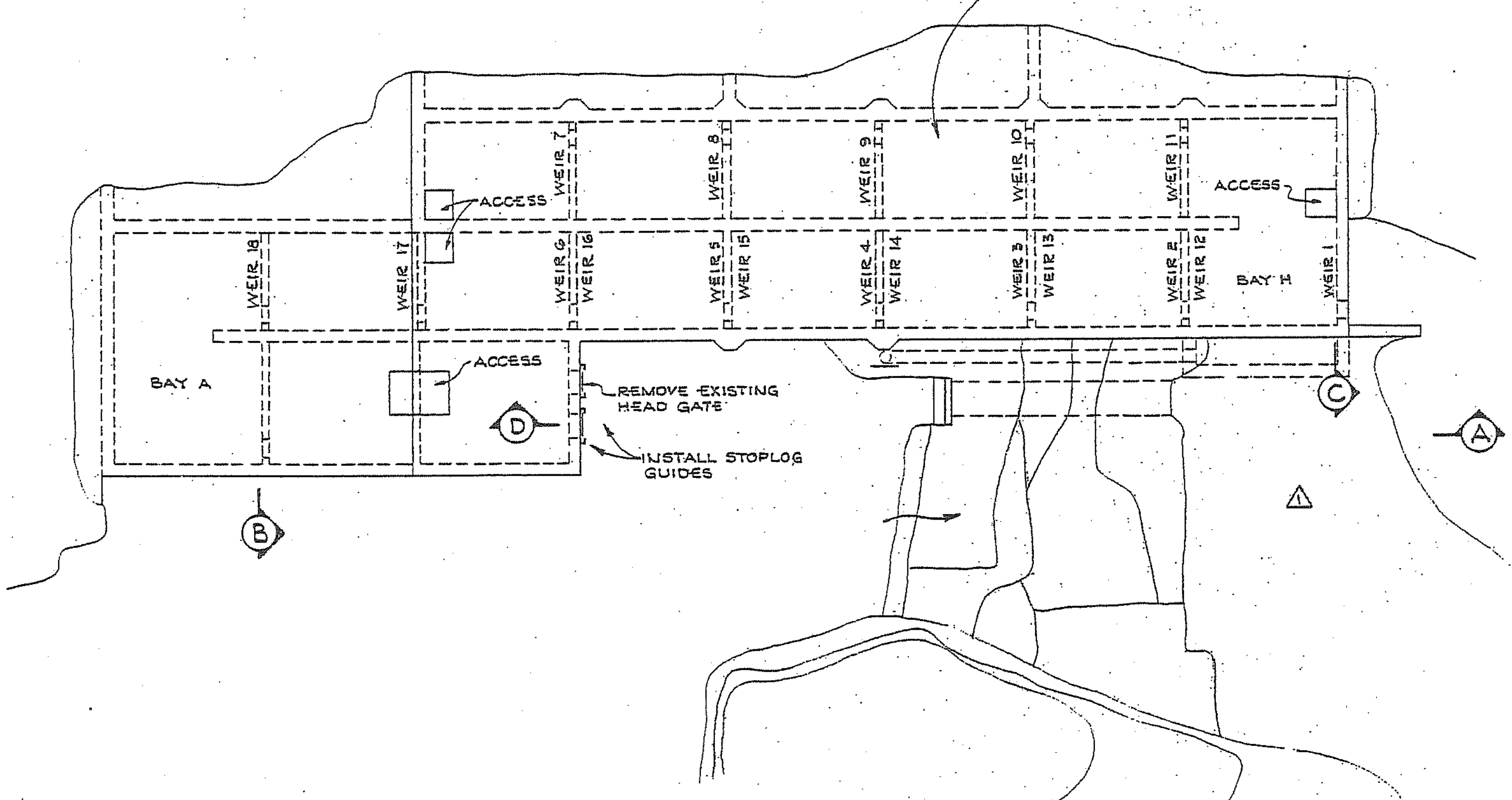


SECTION (E)
1 1/2" = 1'-0"



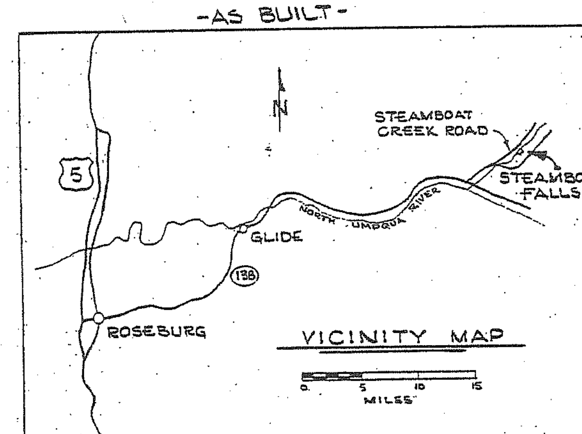
SECTION (F)
1/2" = 1'-0"

⚠1 REMOVE ROCKS, GRAVEL & DEBRIS IN THE FISHWAY BETWEEN WEIR 5 AND THE HEADWALL



FISHWAY PLAN
1/8" = 1'-0"

-AS BUILT-



VICINITY MAP

⚠1 AS BUILT — REVISIONS	11/8/85

REGISTERED PROFESSIONAL ENGINEER 4004 OREGON JULY 9, 1973 EDW. K. NEUBAUER

CHIEF ENGINEER

DATE	6/14/85
DESIGN BY	ROD
DRAWN BY	ROD
CHECKED BY	

DEPARTMENT OF FISH & WILDLIFE
STATE OF OREGON

STEAMBOAT FALLS FISHWAY

FISHWAY MODIFICATIONS

APP'D JACK DONALDSON — DIRECTOR

FILE NO. 8435 — SHT. 1 OF 1

BRUNING 40-107

APPENDIX E

Geologic and Geotechnical Project Report

By

The Galli Group

APPENDIX F

Steamboat Creek Hydrology

Flow Duration Table for Flows on the Steamboat Creek at Steamboat Falls

Water Years 1957-2008

STEAMBOAT CREEK NEAR GLIDE, OR:	227	sqare miles
Steamboat Falls:	133	sqare miles

Scale Factor: 0.59

Percent Time Flow is Equalled or Exceeded	Annual (cfs)	Winter Steelhead Dec-Apr (cfs)	Summer Steelhead May-July (cfs)	October (cfs)	November (cfs)	December (cfs)	January (cfs)	February (cfs)	March (cfs)	April (cfs)	May (cfs)	June (cfs)	July (cfs)	August (cfs)	September (cfs)
1%	3,703	4,721	1,167	907	3,806	5,858	5,635	4,818	2,939	2,033	1,500	864	160	153	452
2%	2,683	3,588	926	661	3,170	4,460	4,587	3,743	2,534	1,692	1,231	609	131	113	249
3%	2,191	2,894	797	516	2,548	3,955	3,449	3,012	2,180	1,517	1,135	508	119	102	207
4%	1,881	2,528	709	426	2,146	3,644	3,081	2,628	2,034	1,386	1,011	467	109	92	155
5%	1,684	2,292	639	364	1,899	3,233	2,812	2,282	1,795	1,284	942	425	103	86	131
6%	1,523	2,104	586	309	1,734	2,805	2,643	2,104	1,719	1,186	867	389	99	84	120
7%	1,389	1,922	538	271	1,528	2,532	2,415	1,896	1,648	1,136	814	360	94	80	105
8%	1,283	1,775	505	240	1,415	2,344	2,298	1,769	1,564	1,090	785	333	91	77	95
9%	1,195	1,676	484	221	1,258	2,215	2,144	1,676	1,471	1,043	756	316	88	76	90
10%	1,113	1,570	460	201	1,184	2,057	2,021	1,582	1,394	1,008	715	301	86	74	85
12%	1,002	1,430	416	170	1,037	1,797	1,803	1,470	1,289	949	666	276	81	71	74
14%	908	1,295	375	148	930	1,620	1,649	1,350	1,216	914	624	252	78	68	68
16%	826	1,195	348	127	832	1,472	1,495	1,254	1,137	867	581	237	75	66	62
18%	762	1,101	321	107	738	1,348	1,371	1,119	1,084	820	539	224	72	64	59
20%	703	1,037	297	95	662	1,248	1,266	1,055	1,043	786	514	212	69	63	56
22%	656	978	275	85	615	1,143	1,181	1,008	994	750	495	202	67	61	54
23%	633	949	264	82	582	1,090	1,143	984	964	735	487	195	66	61	53
24%	609	932	253	77	562	1,060	1,096	943	943	721	475	189	65	60	52
25%	592	902	245	74	535	1,021	1,050	926	920	709	465	186	64	59	52
26%	570	879	236	70	521	991	1,025	891	902	701	460	180	63	59	51
27%	552	855	229	67	493	961	990	877	879	680	449	176	63	58	50
28%	536	832	221	64	476	937	966	855	861	671	439	172	62	57	49
29%	520	809	214	62	458	889	937	832	831	662	431	169	61	57	49
30%	504	791	204	60	439	860	918	812	803	650	418	164	60	56	48
31%	490	768	199	57	418	838	882	797	789	639	412	160	60	56	48
32%	474	756	192	55	408	814	867	779	773	627	407	156	59	55	48
33%	460	738	186	53	390	791	834	762	762	621	396	152	58	55	47
34%	444	721	180	51	377	768	803	749	750	609	387	149	57	54	47
35%	432	703	176	50	360	744	780	727	732	603	378	146	57	54	46
36%	418	686	170	48	342	727	762	709	721	592	369	143	56	53	46
37%	405	674	166	47	331	703	744	697	703	586	363	141	56	52	46
38%	390	662	161	46	316	686	721	681	684	576	356	138	55	52	45
39%	378	650	156	45	308	666	703	668	668	570	352	137	54	52	45
40%	367	633	150	44	298	656	686	656	656	561	349	134	54	51	44
41%	354	621	146	43	286	639	668	650	650	551	344	133	53	51	44
42%	345	609	141	42	274	621	650	644	639	542	339	131	53	50	43
43%	334	598	138	41	266	605	639	627	621	535	333	129	52	50	43
44%	322	585	134	41	255	586	615	609	609	529	325	127	52	49	43
45%	311	572	130	40	243	575	609	603	592	519	319	125	52	49	42
46%	302	561	126	39	235	561	592	586	580	513	311	124	51	48	42
47%	292	551	123	39	228	549	582	571	566	508	309	122	50	48	41
48%	282	540	120	37	221	539	565	559	559	502	303	120	50	48	41
49%	271	531	116	37	212	528	553	548	550	497	298	118	49	47	41
50%	262	521	112	36	204	511	539	539	541	491	293	117	49	47	41
51%	252	511	108	35	194	496	527	533	528	484	287	115	48	46	40
52%	242	500	105	35	187	482	517	525	518	476	282	113	48	46	40
53%	233	490	103	34	181	473	501	517	510	466	277	111	47	45	40
54%	225	481	99	33	175	452	489	500	497	460	271	110	47	45	39
55%	215	472	96	32	169	440	475	493	486	451	268	108	47	45	39
56%	205	462	93	32	166	422	469	485	476	444	262	106	46	44	39
57%	197	451	90	32	161	412	457	479	468	440	258	105	46	43	38
58%	189	442	88	31	154	400	445	469	458	434	252	103	46	43	38

Michael Love and Associates
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Flow Duration Table for Flows on the Steamboat Creek at Steamboat Falls

Water Years 1957-2008

STEAMBOAT CREEK NEAR GLIDE, OR:	**227**	**sqare miles**
Steamboat Falls:	**133**	**sqare miles**

Scale Factor: 0.59

Percent Time Flow is Equalled or Exceeded	Annual (cfs)	Winter Steelhead Dec-Apr (cfs)	Summer Steelhead May-July (cfs)	October (cfs)	November (cfs)	December (cfs)	January (cfs)	February (cfs)	March (cfs)	April (cfs)	May (cfs)	June (cfs)	July (cfs)	August (cfs)	September (cfs)
59%	182	433	86	30	147	387	434	458	449	424	247	101	45	43	38
60%	175	423	83	30	142	372	422	450	440	419	242	100	45	42	37
61%	168	414	81	30	137	363	414	443	430	410	239	98	45	42	37
62%	161	407	79	29	131	353	401	434	425	407	233	96	44	42	37
63%	152	396	77	29	126	346	390	426	417	398	229	95	43	41	37
64%	144	387	75	28	123	336	380	413	410	388	226	93	43	41	36
65%	137	379	73	28	118	328	370	406	402	385	221	92	43	41	36
66%	130	370	71	28	113	319	362	396	393	377	216	90	42	40	36
67%	124	363	69	28	108	310	351	389	387	371	213	88	42	40	35
68%	117	354	67	27	104	296	343	381	381	366	205	87	42	40	35
69%	110	348	66	27	98	291	334	374	372	359	201	86	41	39	34
70%	103	340	64	26	93	282	324	367	366	353	199	85	41	39	34
71%	96	332	62	26	90	272	314	354	359	350	195	84	40	39	34
72%	91	324	61	26	86	260	308	346	353	341	190	82	40	38	34
73%	86	316	59	25	84	254	295	336	346	335	187	81	40	37	33
74%	81	308	58	25	80	246	285	330	339	324	185	80	39	37	33
75%	77	300	57	25	76	236	277	322	332	318	180	78	39	36	33
76%	73	293	56	25	73	231	266	312	327	312	178	77	39	36	32
77%	70	286	54	25	71	225	258	306	320	306	176	76	38	36	32
78%	66	278	53	24	68	216	255	297	313	300	172	74	38	35	31
79%	63	268	52	24	64	206	245	290	303	293	170	73	37	35	31
80%	60	261	51	23	61	200	233	281	297	289	167	73	37	34	30
81%	58	253	50	23	58	193	227	268	292	284	164	71	37	34	30
82%	55	244	49	23	56	185	213	260	286	275	161	70	36	34	30
83%	53	234	47	22	53	180	205	248	280	269	158	69	36	33	29
84%	50	228	46	22	50	175	199	241	272	264	154	67	36	33	29
85%	49	220	45	22	49	170	188	233	265	257	152	66	35	33	28
86%	47	211	45	21	47	161	179	226	258	247	148	64	35	32	28
87%	45	202	43	21	44	155	171	215	246	239	144	62	34	32	28
88%	43	195	42	21	43	146	167	207	240	230	141	60	34	32	27
89%	41	187	42	21	40	135	158	200	229	224	138	59	33	31	27
90%	39	179	40	21	39	120	148	194	220	219	134	59	33	30	26
91%	37	170	39	21	37	108	142	185	213	210	129	57	33	30	25
92%	36	159	38	20	37	94	132	174	203	199	125	56	32	29	25
93%	34	148	37	20	35	81	128	155	194	190	118	54	32	28	25
94%	32	135	36	20	34	70	122	138	186	186	112	53	31	28	23
95%	30	122	35	19	32	63	115	128	178	180	104	52	30	27	23
96%	28	106	34	19	32	55	106	115	159	170	98	49	29	26	22
97%	25	88	32	19	27	49	97	104	141	159	92	47	29	25	21
98%	23	69	31	18	25	40	80	94	99	148	83	45	28	24	21
99%	21	49	29	18	22	32	56	36	73	130	71	41	27	21	19
99.5%	19	35	28	18	20	30	45	35	62	94	65	38	26	19	19

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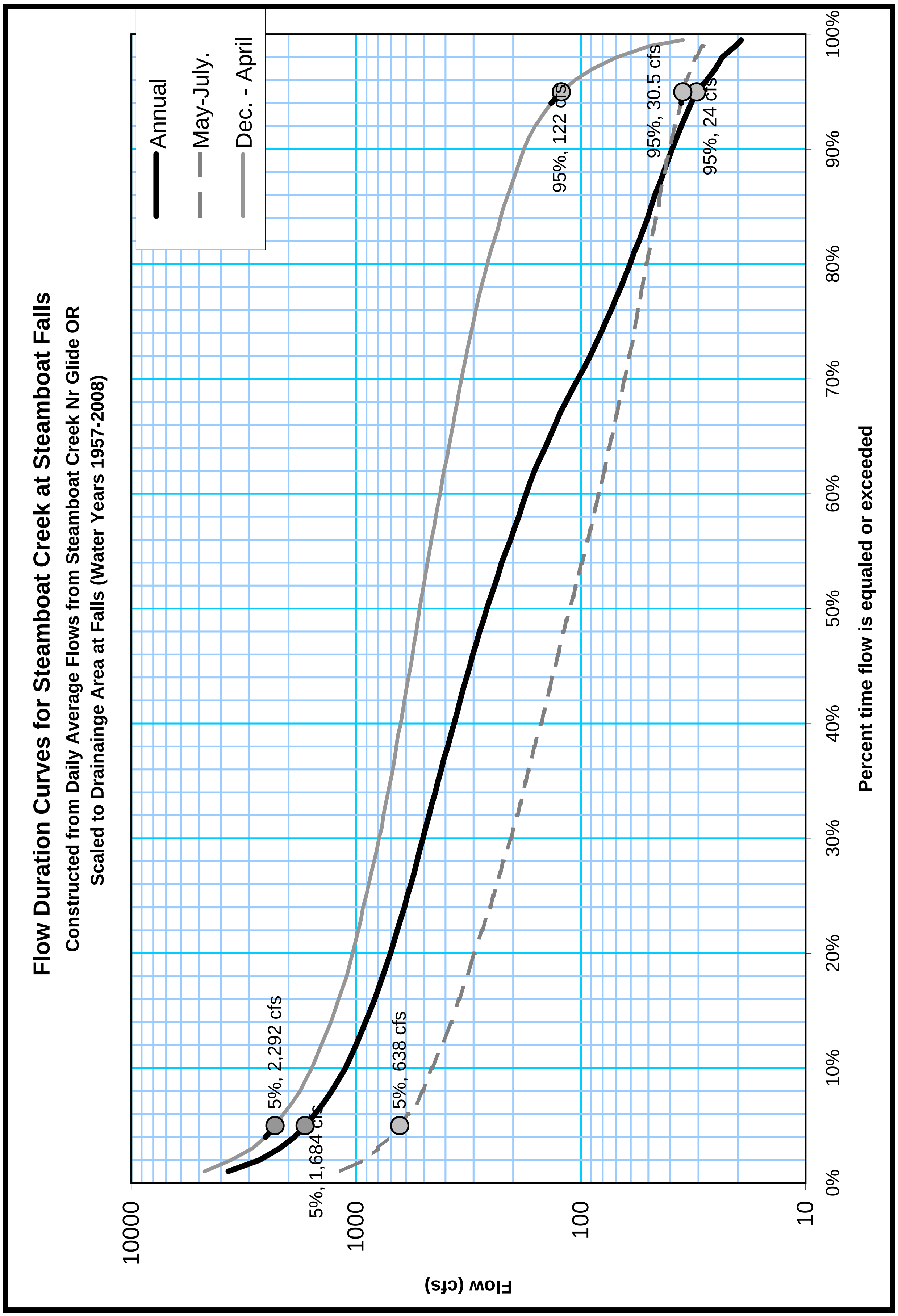

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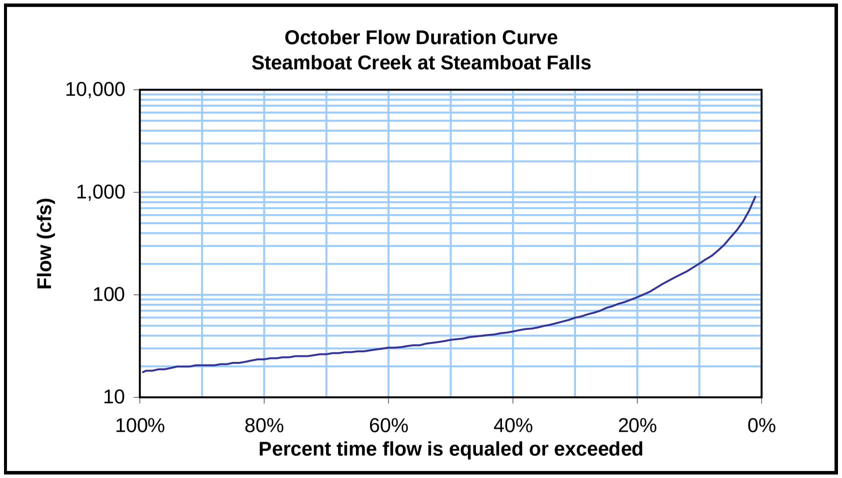
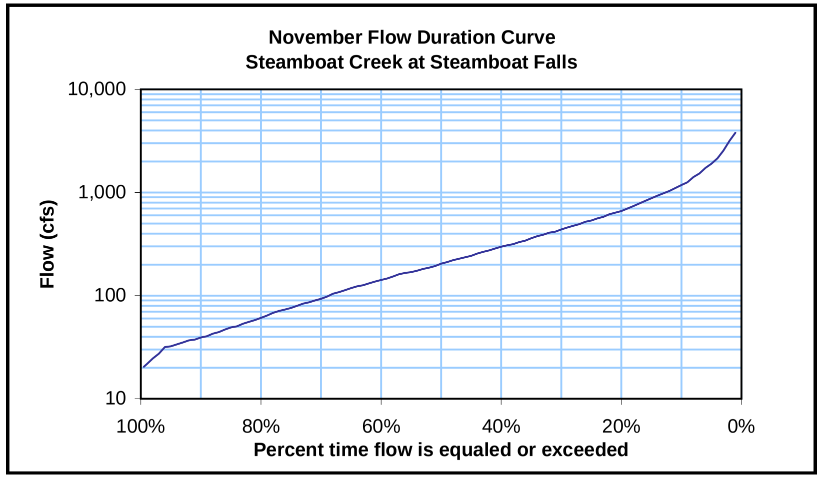
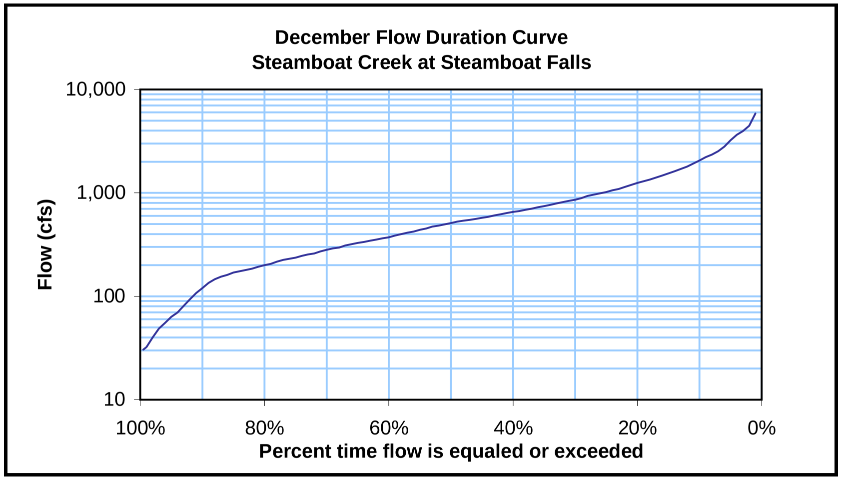
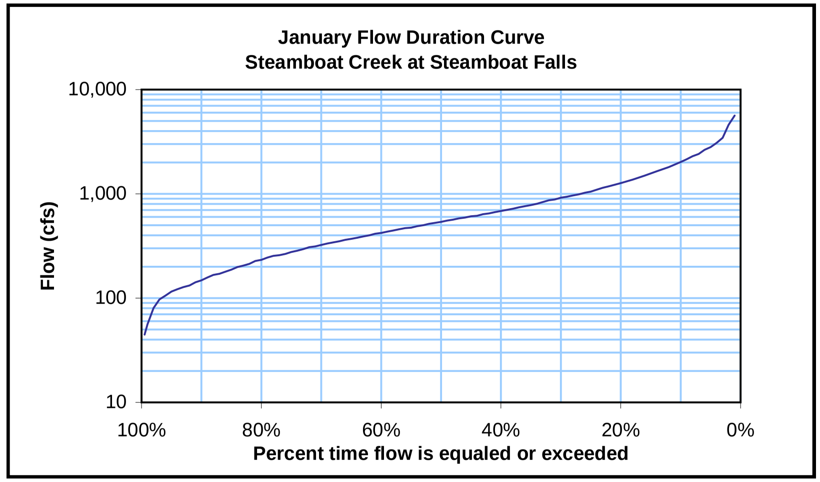
Monthly Flow Duration Curves









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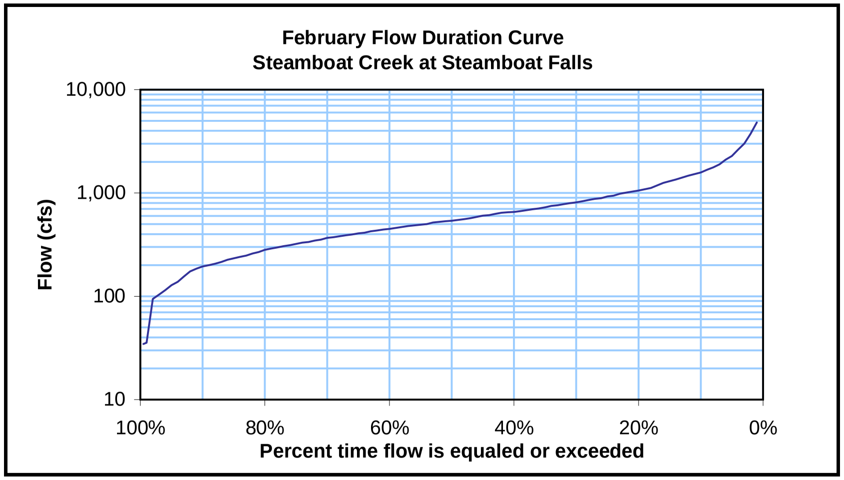
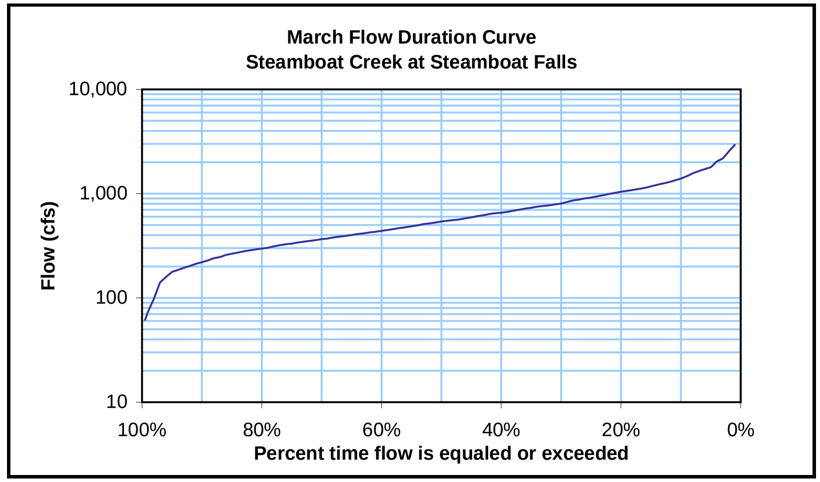
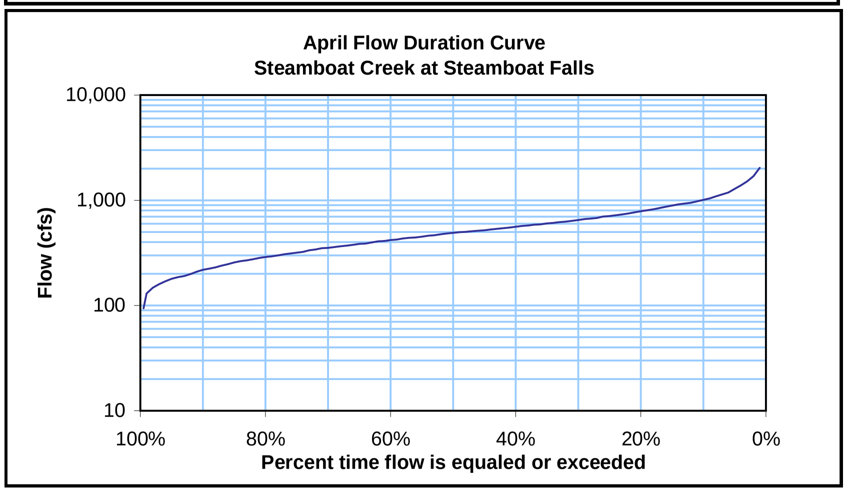
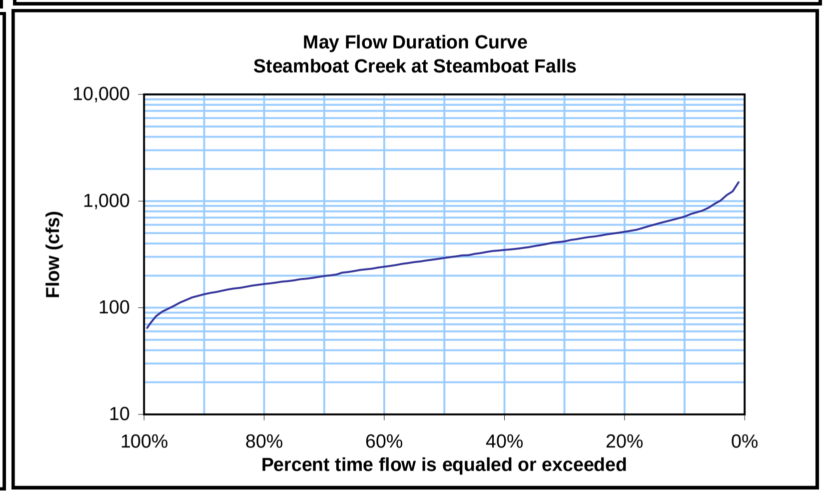
Monthly Flow Duration Curves

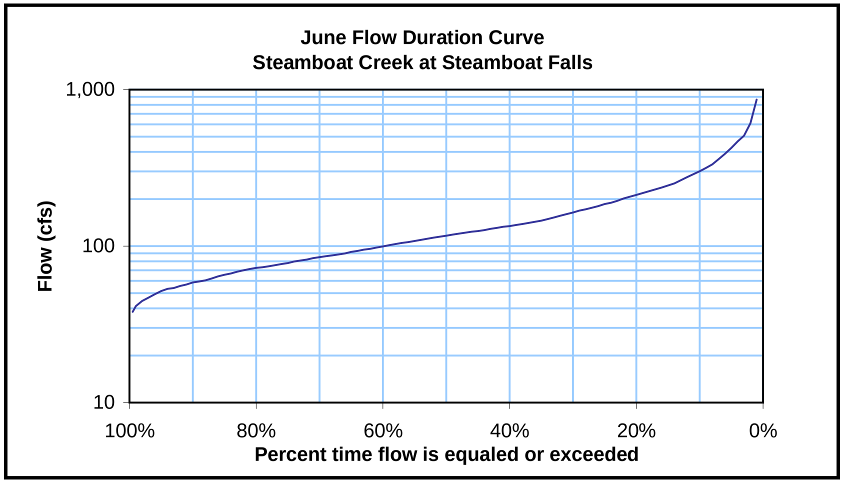


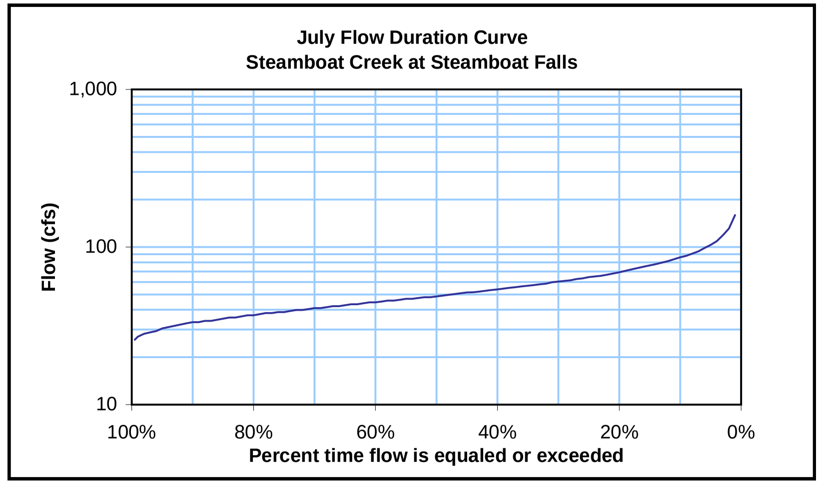


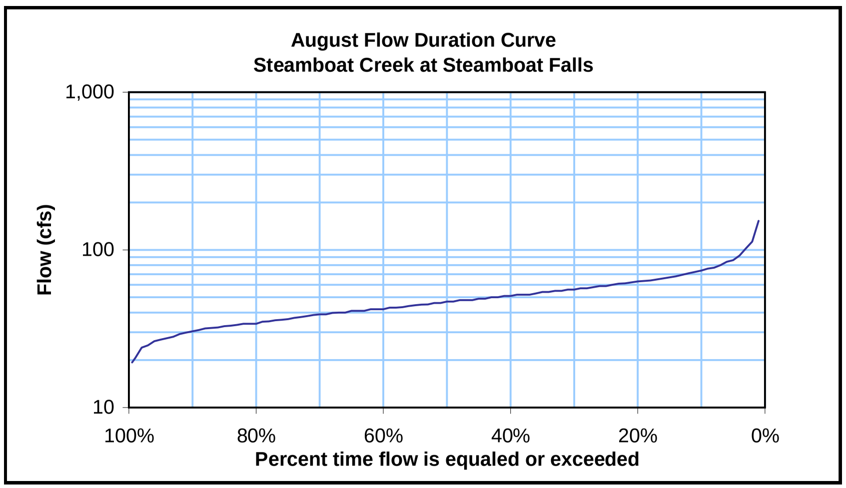


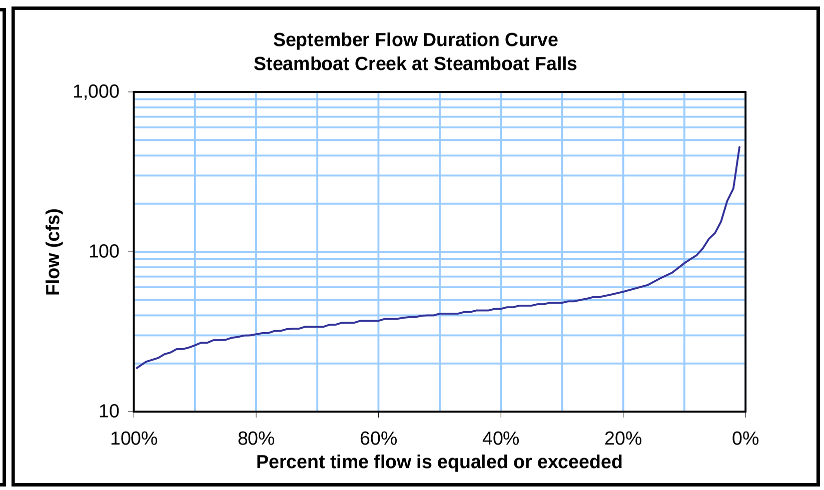


Monthly Flow Duration Curves

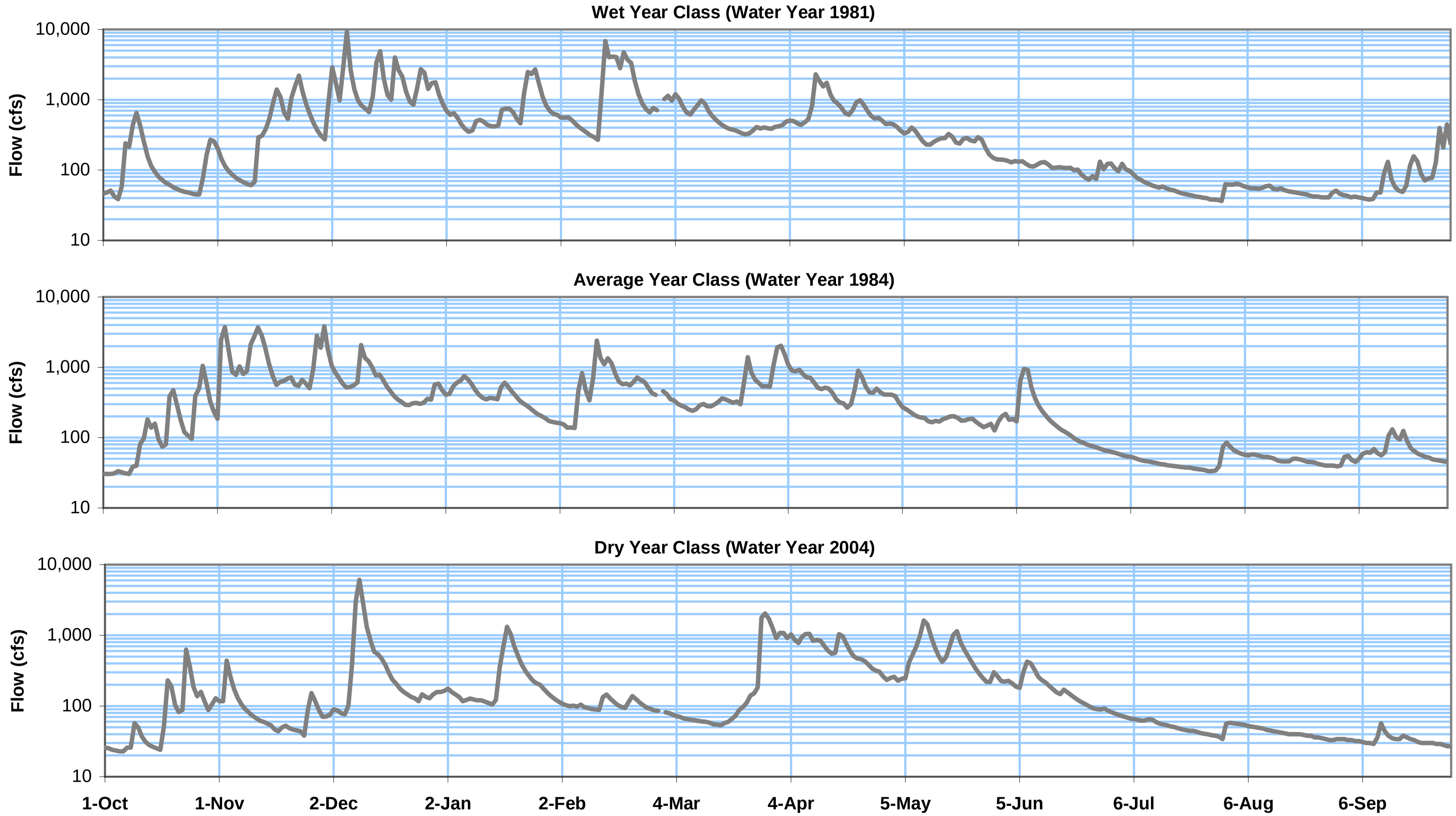








Annual Hydrographs for Steamboat Creek at Steamboat Falls
Year Class Based on Annual Water Yeild



** Hydrographs constructed using daily average flows recorded at Steamboat Creek Nr Glide, OR (USGS Gaging Station No. 14316700), scaled to the drainage area at Steamboat Falls. (Drainage Area at Gage = 227 mi^2 / Drainage Area at Falls = 133 mi^2)*

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APPENDIX G

Calculations of Existing Fishway Hydraulics

Existing Fishway (Assumes no Sediment in Fishway)

Date: 12/1/2009

Project: STEAMBOAT FALLS FISHWAY FEASIBILITY STUDY

Summary of Fishway Type and Dimensions

EXISTING FISHWAY

Spillway: Crest at Elev 89.8'

Weir 1: Slotted weir with orifice, 1 ft drop, uniform flow

Weir 2: Vertical Slot 1.5' wide

Weir 3: Vertical Slot 1.5' wide

Exit Port: 2 - 2'x2' orifices set 2' above fishway floor.

DESIGN INPUTS

Coefficients

Horiz. Weir Coeficient	**Cs**	**= 0.602+0.075(ho/P)**	
V-Notch Weir coeficient	**Cv**	**=0.607165-0.0008744669*Ø+6.103933x10^ $^{-6}$*Ø^^{2}**	
Broad Crested Weir Coeficient	**Cb**	**0.64**	
Orrfice Coeficient	**Corifice**	**0.62**	
Slot Coeficient	**Cslot**	**0.60**	from Rajaratnam 1986
Gravity	g	32.2	ft/s2

Fishway Flows of Intrest

Lowest Operating Flow	**Q_lp**	25.0	cfs (Min Depth = 2.5 ft)
Stage	**H_lp**	3.0	ft
Optimal Operating Flow	**Q_opt**	32.2	cfs (Min EDF)
Stage	**H_opt**	4.0	ft
Highest Operating Flow	**Q_hp**	33.6	cfs (overtopping of fishway roof)
Stage	**H_hp**	4.1	ft

Bypass Spillway (broad crested weir)

Crest1 Width	Width1	9.6	ft
Crest1 Elev	El_1	89.8	ft
Crest2 Width	Width2	24.0	ft
Crest2 Elev	El_2	91.1	ft
Crest3 Width	Width3	10.0	ft
Crest3 Elev	El_3	91.4	ft

WEIR 1 (Assume Uniform Flow at this Weir)

Floor Elevation	Elev1	84.00	ft
Total Weir Width	W	8.00	ft
Drop height between weirs	dH	1.0	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	**Wslot**	**1.50**	**ft**
Slot Height above Floor	Hslot	4.00	ft
Sill Height above Floor	Hsill	0.00	ft

Orifice Dimensions

Orifice Width	W1orifice	1.00	ft
Sill Height above Floor	H1orifice	0.67	ft

Horiz Weir Dimensions

Width	Length1	6.50	ft
Height above Floor	Height1	4.00	ft

WEIR 2 (upstream of weir 1)			
Floor Elevation	Elev2	85.00	ft
Total Weir Width	W	8.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft
Slot Dimensions			
Slot Width	Wslot2	1.50	ft
Slot Height above Floor	Hslot2	4.00	ft
Sill Height above Floor	Hsill2	0.00	ft
Orifice Dimensions			
Orifice Width	W2orifice	1.00	ft
Sill Height above Floor	H2orifice	0.67	ft
Triangular Weir Dimensions			
Side Slope	SS2	0.00	ft/ft
Height of crest above Floor	Hvee	4.00	ft
Coefficient of Discharge	Cd_vee2	0.62	
Horiz Weir Dimensions			
Width	Length2	6.50	ft
Height above Floor	Height2	4.00	ft

WEIR 3 (upstream of weir 2)			
Floor Elevation	Elev3	85.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft
Slot Dimensions			
Slot Width	Wslot3	1.50	ft
Slot Height above Floor	Hslot3	9.00	ft
Sill Height above Floor	Hsill3	0.00	ft
Triangular Weir Dimensions			
Side Slope	SS3	0.00	ft/ft
Height of crest above Floor	Hvee3	4.00	ft
Coefficient of Discharge	Cd_vee3	0.61	
Horiz Weir Dimensions			
Width	Length3	0.00	ft
Height above Floor	Height3	4.00	ft

WEIR 4 (upstream of weir 3)			
Floor Elevation	Elev4	85.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft
Slot Dimensions			
Slot Width	Wslot4	1.50	ft
Slot Height above Floor	Hslot4	9.00	ft
Sill Height above Floor	Hsill4	0.00	ft
Triangular Weir Dimensions			
Side Slope	SS4	0.00	ft/ft
Height of crest above Floor	Hvee4	9.00	ft
Coefficient of Discharge	Cd_vee4	0.61	
Horiz Weir Dimensions			
Width	Length4	0.00	ft
Height above Floor	Height4	9.00	ft

Exit Port			
Headgate Orifice Elev	Elev_Exit	87.0	ft
Orifice Width	Worifice	4.0	ft
Orifice Height	Horifice	2.0	ft

Directions in Comments

	Initial Guess of Ho	OK	OK	OK	OK	OK	OK
	Total Residual (solve = 0)	0.00	0.00	0.00	0.00	0.00	0.00

Summary of Hydraulic Results

	Flow Designation						
Bypass	**Streamflow over Spillway?**	No	Bypass	Bypass	Bypass	Bypass	Bypass
WSE_Forebay	**WSE in Forebay**	**89.17**	**89.82**	**90.49**	**91.16**	**91.36**	**92.00**
Qstream	**Streamflow in Headwater Pool**	**21.4**	**25.1**	**47.2**	**85.4**	**109.0**	**231.9**
QLadder	**Total Flow in Fish Ladder**	**21.4**	**25.0**	**28.6**	**32.2**	**33.6**	**38.3**
dH1	Drop over weir 17	1.00	1.00	1.00	1.00	1.00	1.00
dH2	Drop over weir 18	1.00	1.00	1.00	1.00	1.00	1.00
dH3	Drop across slot 19	0.80	0.82	0.83	0.85	0.87	1.00
dH4	Drop across slot 20	0.58	0.61	0.63	0.66	0.68	0.76
dH exit	Drop across Exit Port	0.29	0.39	0.52	0.65	0.71	0.93
%Attraction	**Attraction Flow**	**100%**	**100%**	**61%**	**38%**	**31%**	**17%**

Bypass Spillway							
Q_spillway	**Bypass Flow over Spillway**	**0.00**	**0.12**	**18.65**	**53.15**	**75.43**	**193.57**
	Crest 1 (broad)						
H_crest1	**Upstream Head above Spillway**	0.00	0.02	0.69	1.36	1.56	2.20
Q_crest1	**Total Flow in Slot**	**0.00**	**0.12**	**18.65**	**52.01**	**64.29**	**107.33**
	Crest 2 (broad)						
H_crest2	**Upstream Head above Spillway**	0.00	0.00	0.00	0.06	0.26	0.90
Q_crest2	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**1.14**	**11.14**	**70.28**
	Crest 3 (broad)						
H_crest3	**Upstream Head above Spillway**	0.00	0.00	0.00	0.00	0.00	0.60
Q_crest3	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**15.95**

WEIR 17 (assume Uniform Flow)							
WSE at Weir		**86.50**	**87.00**	**87.50**	**88.00**	**88.10**	**88.32**
Ho(floor)	**Upstream Head above FLOOR**	**2.50**	**3.00**	**3.50**	**4.00**	**4.10**	**4.32**
Uslot	Velocity in Slot	4.8	4.8	4.8	4.8	4.8	4.8
Dpool	Min Pool Depth	**1.5**	**2.0**	**2.5**	3.0	3.1	3.3
EDF	**TOTAL Energy Disipation Factor**	**6.95**	**6.50**	**6.20**	**5.98**	**6.07**	**6.52**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.00	0.15	0.79
	Vertical Slot						
Q1s	**Total Flow in Slot**	**18.06**	**21.67**	**25.28**	**28.89**	**29.61**	**31.19**
	Orifice						
Q1s	**Total Flow in Orifice**	**3.32**	**3.32**	**3.32**	**3.32**	**3.32**	**3.32**
	Horizontal Weir Section						
Q1	nonsubmerged Flow:	0.00	0.00	0.00	0.00	0.66	3.79
Q1sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.66**	**3.79**

WEIR 18							
WSE at Weir		**87.50**	**88.00**	**88.50**	**89.00**	**89.10**	**89.32**
Ho(floor)	**Upstream Head above FLOOR**	**2.50**	**3.00**	**3.50**	**4.00**	**4.10**	**4.32**
Q2solve	**Qweir2 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.8	4.8	4.8	4.8	4.8	4.8
Dpool	Min Pool Depth	**1.5**	**2.0**	**2.5**	3.0	3.1	3.3
EDF	**TOTAL Energy Disipation Factor**	**4.69**	**4.69**	**4.69**	**4.69**	**4.80**	**5.27**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.00	0.11	0.57

	Vertical Slot						
Q2slot	**Total Flow in Slot**	**18.06**	**21.67**	**25.28**	**28.89**	**29.61**	**31.19**
	Orifice						
Q2s	**Total Flow in Orifice**	**3.32**	**3.32**	**3.32**	**3.32**	**3.32**	**3.32**
	Triangular Weir Section						
Qvee2	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00	0.00
Qvee2sub	submerged flow:	0.00	0.00	0.00	0.00	0.00	0.00
Qveetrunc2	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00	0.00
Qveetrunc2sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00	0.00
Qvee2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section						
Qhorz2	nonsubmerged Flow:	0.00	0.00	0.00	0.00	0.66	3.79
Qhorz2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.66**	**3.79**

WEIR 19							
WSE at Weir		**88.30**	**88.82**	**89.33**	**89.85**	**89.97**	**90.31**
Ho(floor)	**Upstream Head above FLOOR**	**3.30**	**3.82**	**4.33**	**4.85**	**4.97**	**5.31**
Q3solve	**Qweir3 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.3	4.4	4.4	4.4	4.5	4.8
Dpool	Min Pool Depth	2.5	3.0	3.5	4.0	4.1	4.3
EDF	**TOTAL Energy Disipation Factor**	**4.46**	**4.44**	**4.43**	**4.43**	**4.66**	**5.74**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.00	0.00	0.00
	Vertical Slot						
Q3slot	**Total Flow in Slot**	**21.37**	**24.98**	**28.60**	**32.21**	**33.59**	**38.30**
	Triangular Weir Section						
Q3	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00	0.00
Q32sub	submerged flow:	0.00	0.00	0.00	0.00	0.00	0.00
Qt3	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00	0.00
Qt3sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00	0.00
Q3sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section						
Q3	nonsubmerged Flow:	0.00	0.00	0.00	0.00	0.00	0.00
Q3sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

WEIR 20							
WSE at Weir		**88.88**	**89.43**	**89.97**	**90.50**	**90.65**	**91.08**
Ho(floor)	**Upstream Head above FLOOR**	**3.88**	**4.43**	**4.97**	**5.50**	**5.65**	**6.08**
Q3solve	**Qweir3 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	3.7	3.8	3.8	3.9	4.0	4.2
Dpool	Min Pool Depth	3.3	3.8	4.3	4.8	5.0	5.3
EDF	**TOTAL Energy Disipation Factor**	**2.44**	**2.59**	**2.72**	**2.84**	**2.97**	**3.57**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.00	0.00	0.00
	Vertical Slot						
Q4slot	**Total Flow in Slot**	**21.37**	**24.98**	**28.60**	**32.21**	**33.59**	**38.30**
	Triangular Weir Section						
Q4	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00	0.00
Q42sub	submerged flow:	0.00	0.00	0.00	0.00	0.00	0.00
Qt4	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00	0.00
Qt4sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00	0.00
Q4sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section						
Q4	nonsubmerged Flow:	0.00	0.00	0.00	0.00	0.00	0.00
Q4sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Exit Port							
Forebay WSE		**89.17**	**89.82**	**90.49**	**91.16**	**91.36**	**92.00**
Ho(floor)	**Upstream Head above FLOOR**	**4.17**	**4.82**	**5.49**	**6.16**	**6.36**	**7.00**
Qexit_solve	**Qexit port - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Orifice	2.7	3.1	3.6	4.0	4.2	4.8
Dpool	Min Pool Depth	3.9	4.4	5.0	5.5	5.7	6.1
EDF	**TOTAL Energy Disipation Factor**	**0.83**	**1.16**	**1.54**	**1.99**	**2.20**	**3.03**
	Vertical Slot						
Qslot	**Total Flow in Slot**	**21.37**	**24.98**	**28.60**	**32.21**	**33.59**	**38.29**

APPENDIX H

Fishway Hydraulics for Alternative A

Alternative A - Level 1 Modifications (Alternative A-1)

Project: STEAMBOAT FALLS FISHWAY FEASIBILITY STUDY
Date: 12/1/2009

Summary of Fishway Type and Dimensions

Spillway Crest: Existing (Crest Elev. = 89.8 ft)
Exit Port: Double 2'Wx2'H Exit Ports,
Weir 20: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.5' Tall w/1' Tall Sill
Horizontal Weir with 6.5 ' Crest Length
Weir 19: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.0' Tall w/No Sill
Horizontal Weir with 8.5 ' Crest Length
Weir 18: Right side 1.5' wide Vertical Slot, 4.0' Tall w/0.5' Tall Sill
Horizontal weir above slot, 6.5' wide
Weir 17 (unifrom flow): Right side 1.5' wide Vertical Slot, 4.0' Tall w/1' Tall Sill
Drop between Weirs = 1.0 ft.

DESIGN INPUTS

Coefficients

Horiz. Weir Coeficient	**Cs**	= 0.602+0.075(h/P)	
V-Notch Weir coeficient	**Cv**	=0.607165-0.0008744669*Ø+6.103933x10^ $^{-6*}$Ø^^{2}	
Broad Crested Weir Coeficient	**Cb**	**0.64**	
Orrfice Coeficient	**Corifice**	**0.62**	
Vertical Slot Coeficient	**Cslot**	**0.60**	from Rajaratnam 1986
Gravity	g	32.2	ft/s2

Design Flows

Lowest Operating Flow	**Q_lp**	18.0	cfs (Min Depth = 2.5 ft)
Stage	**H_lp**	3.5	ft
Optimal Operating Flow	**Q_opt**	21.7	cfs (Depth=3ft, EDF=4 ft-lb/s/ft3)
Stage	**H_opt**	4.0	ft
Highest Operating Flow	**Q_hp**	35.9	cfs (Weir_17 EDF=5 ft-lb-s-ft3)
Stage	**H_hp**	4.6	ft

Bypass Spillway (broad crested weir)

Crest1 Width	Width1	9.6	ft
Crest1 Elev	El_1	89.8	ft
Crest2 Width	Width2	24.0	ft
Crest2 Elev	El_2	91.1	ft
Crest3 Width	Width3	10.0	ft
Crest3 Elev	El_3	92.1	ft

Weir_17 (Assume Uniform Flow at this Weir)

Floor Elevation	Elev1	84.00	ft
Total Weir Width	W	8.00	ft
Drop height between weirs	dH	1.0	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	**Wslot**	**1.50**	**ft**
Slot Height above Floor	Hslot	4.00	ft
Sill Height above Floor	Hsill	1.00	ft

Orifice Dimensions

Orifice Width	W1orifice	0.00	ft
Sill Height above Floor	H1orifice	0.00	ft

Horiz Weir Dimensions

Width	Length1	6.50	ft
Height above Floor	Height1	4.00	ft

Weir_18 (upstream of Weir_17)

Floor Elevation	Elev2	85.00	ft
Total Weir Width	W	8.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Alternative A - Level 1 Modifications (Alternative A-1)

Slot Dimensions

Slot Width	Wslot2	1.50	ft
Slot Height above Floor	Hslot2	4.00	ft
Sill Height above Floor	Hsill2	0.50	ft

Triangular Weir Dimensions

Side Slope	SS2	0.00	ft/ft
Height of crest above Floor	Hvee	4.00	ft
Coefficient of Discharge	Cd_vee2	0.62	

Horiz Weir Dimensions

Width	Length2	6.50	ft
Height above Floor	Height2	4.00	ft

Weir_19 (upstream of Weir_18)

Floor Elevation	Elev3	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot3	1.50	ft
Slot Height above Floor	Hslot3	4.00	ft
Sill Height above Floor	Hsill3	0.00	ft

Triangular Weir Dimensions

Side Slope	SS3	0.00	ft/ft
Height of crest above Floor	Hvee3	4.00	ft
Coefficient of Discharge	Cd_vee3	0.62	

Horiz Weir Dimensions

Width	Length3	8.50	ft
Height above Floor	Height3	4.00	ft

Weir_20 (upstream of Weir_19)

Floor Elevation	Elev4	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot4	1.50	ft
Slot Height above Floor	Hslot4	4.50	ft
Sill Height above Floor	Hsill4	1.00	ft

Triangular Weir Dimensions

Side Slope	SS4	0.00	ft/ft
Height of crest above Floor	Hvee4	4.50	ft
Coefficient of Discharge	Cd_vee4	0.62	

Horiz Weir Dimensions

Width	Length4	6.50	ft
Height above Floor	Height4	4.50	ft

Exit Port

Headgate Orifice Elev	Elev_Exit	88.0	ft
Orifice Width	Worifice	4.0	ft
Orifice Height	Horifice	2.0	ft

Alternative A - Level 1 Modifications (Alternative A-1)

Directions in Comments						
	Initial Guess of Ho	OK	OK	OK	OK	OK
	Total Residual (solve = 0)	0.00	0.01	0.00	0.00	0.00

Summary of Hydraulic Results

	Flow Designation	Q_lp	Q_opt			Q_hp
Bypass	**Streamflow over Spillway?**	Bypass	Bypass	Bypass	Bypass	Bypass
WSE_Forebay	**WSE in Forebay**	**90.00**	**90.64**	**91.06**	**91.55**	**92.00**
Qstream	**Total Streamflow**	**20.9**	**46.9**	**71.7**	**131.1**	**213.1**
QLadder	**Total Flow in Fish Ladder**	**18.0**	**21.7**	**25.0**	**30.0**	**35.9**
dH (Weir 18)	Drop over Weir_18	0.80	0.82	0.89	0.91	0.92
dH (Weir 19)	Drop over Weir_19	0.70	0.72	0.79	0.86	0.86
dH (Weir 20)	Drop over Weir_20	0.80	0.81	0.79	0.81	0.80
dH (Exit Port)	Drop across Exit Port	0.21	0.30	0.39	0.57	0.81
%Attraction	**Attraction Flow**	**86%**	**46%**	**35%**	**23%**	**17%**

Bypass Spillway

Q_spillway	**Bypass Flow over Spillway**	**2.84**	**25.25**	**46.75**	**101.10**	**177.22**
Crest 1 (broad)						
H_crest1	**Upstream Head above Spillway**	0.20	0.84	1.26	1.75	2.20
Q_crest1	**Total Flow in Slot**	**2.84**	**25.25**	**46.75**	**76.18**	**107.18**
Crest 2 (broad)						
H_crest2	**Upstream Head above Spillway**	0.00	0.00	0.00	0.45	0.90
Q_crest2	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**24.91**	**70.04**
Crest 3 (broad)						
H_crest3	**Upstream Head above Spillway**	0.00	0.00	0.00	0.00	0.00
Q_crest3	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Weir_17 (assume Uniform Flow)

WSE at Weir		**87.50**	**88.00**	**88.20**	**88.40**	**88.60**
Ho(floor)	**Upstream Head above FLOOR**	**3.50**	**4.00**	**4.20**	**4.40**	**4.60**
Uslot	Velocity in Slot	4.8	4.8	4.8	4.8	4.8
Dpool	Min Pool Depth	2.5	3.0	3.2	3.4	3.6
EDF	**TOTAL Energy Disipation Factor**	**3.91**	**4.02**	**4.39**	**5.00**	**5.69**
EDFweir	EDF of plunging flow	0.00	0.00	0.32	0.89	1.55
Vertical Slot						
Q1s	**Total Flow in Slot**	**18.02**	**21.67**	**23.11**	**24.59**	**26.00**
Orifice						
Q1orifice	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Horizontal Weir Section						
Q1	nonsubmerged Flow:	0.00	0.00	1.88	5.44	9.91
Q1sub	**Flow w/Submergance**	**0.00**	**0.00**	**1.88**	**5.44**	**9.91**

Weir_18

WSE at Weir		**88.29**	**88.82**	**89.09**	**89.31**	**89.52**
Ho(floor)	**Upstream Head above FLOOR**	**3.29**	**3.82**	**4.09**	**4.31**	**4.52**
Q2solve	**Qweir2 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.3	4.4	4.5	4.6	4.6
Dpool	Min Pool Depth	2.5	3.0	3.2	3.4	3.6
EDF	**TOTAL Energy Disipation Factor**	**2.67**	**2.88**	**3.44**	**4.04**	**4.68**
EDFweir	EDF of plunging flow	0.00	0.00	0.08	0.50	1.04
Vertical Slot						
Q2slot	**Total Flow in Slot**	**18.02**	**21.66**	**24.44**	**26.29**	**27.89**
Triangular Weir Section						
Qvee2	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qveetrunc2	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qveetrunc2sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Horizontal Weir Section						
Qhorz2	nonsubmerged Flow:	0.00	0.00	0.56	3.73	8.02
Qhorz2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.56**	**3.73**	**8.02**

Alternative A - Level 1 Modifications (Alternative A-1)

Weir_19						
WSE at Weir		**88.99**	**89.54**	**89.88**	**90.18**	**90.38**
Ho(floor)	**Upstream Head above FLOOR**	2.99	3.54	3.88	4.18	4.38
Q3solve	**Qweir3 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.0	4.1	4.3	4.5	4.5
Dpool	Min Pool Depth	3.3	3.8	4.1	4.3	4.5
EDF	**TOTAL Energy Disipation Factor**	**2.48**	**2.65**	**3.16**	**3.90**	**4.44**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.26	0.81
	Vertical Slot					
Q3slot	**Total Flow in Slot**	**18.02**	**21.67**	**25.00**	**27.99**	**29.36**
	Triangular Weir Section					
Q3	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q32sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt3	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt3sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q3sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Q3	nonsubmerged Flow:	0.00	0.00	0.00	2.04	6.55
Q3sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**2.04**	**6.55**

Weir_20						
WSE at Weir		**89.79**	**90.34**	**90.67**	**90.98**	**91.18**
Ho(floor)	**Upstream Head above FLOOR**	3.79	4.34	4.67	4.98	5.18
Q3solve	**Qweir3 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.3	4.3	4.3	4.3	4.3
Dpool	Min Pool Depth	**3.0**	3.5	3.9	4.2	4.4
EDF	**TOTAL Energy Disipation Factor**	**2.51**	**2.57**	**2.63**	**3.01**	**3.42**
EDFweir	EDF of plunging flow	0.00	0.00	0.16	0.42	0.84
	Vertical Slot					
Q4slot	**Total Flow in Slot**	**18.02**	**21.67**	**23.52**	**25.82**	**27.08**
	Triangular Weir Section					
Q4	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q42sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt4	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt4sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q4sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Q4	nonsubmerged Flow:	0.00	0.00	1.48	7.10	12.09
Q4sub	**Flow w/Submergance**	**0.00**	**0.00**	**1.48**	**4.21**	**8.84**

Exit Port						
Forebay WSE		**90.00**	**90.64**	**91.06**	**91.55**	**92.00**
Ho(floor)	**Upstream Head above FLOOR**	4.00	4.64	5.06	5.55	6.00
Qexit_solve	**Qexit port - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Orifice	2.3	2.7	3.1	3.8	4.5
Dpool	Min Pool Depth	3.8	4.3	4.7	5.0	5.2
EDF	**TOTAL Energy Disipation Factor**	**0.51**	**0.77**	**1.10**	**1.78**	**2.93**
	Vertical Slot					
Qport	**Total Flow through Exit Ports**	**18.02**	**21.67**	**25.00**	**30.03**	**35.91**

Alternative A - Level 1 Modifications (Alternative A-1) with Sediment at Weir 20

Project: STEAMBOAT FALLS FISHWAY FEASIBILITY STUDY

Date: 12/1/2009

Summary of Fishway Type and Dimensions

Spillway Crest: Existing (Crest Elev. = 89.8 ft)
Exit Port: Double 2'Wx3'H Exit Ports,
Seasonal Stoplog settings: WINTER Exit Port Invert Elev. = 88.0 ft
Weir 4: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.5' Tall w/1' Tall Sill
Horizontal Weir with 6.5 ' Crest Length
Weir 3: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.0' Tall w/No Sill
Horizontal Weir with 8.5 ' Crest Length
Weir 2: Right side 1.5' wide Vertical Slot, 4.0' Tall w/0.5' Tall Sill
Horizontal weir above slot, 6.5' wide
Weir 1 (unifrom flow): Right side 1.5' wide Vertical Slot, 4.0' Tall w/1' Tall Sill
Drop between Weirs = 1.0 ft.

DESIGN INPUTS

Coefficients

Horiz. Weir Coeficient	**Cs**	= 0.602+0.075(h/P)	
V-Notch Weir coeficient	**Cv**	=0.607165-0.0008744669*Ø+6.103933x10^ -6*Ø^2	
Broad Crested Weir Coeficient	**Cb**	**0.64**	
Orrfice Coeficient	**Corifice**	**0.62**	
Vertical Slot Coeficient	**Cslot**	**0.60**	from Rajaratnam 1986
Gravity	g	32.2	ft/s2

Design Flows

Lowest Operating Flow	**Q_lp**	18.06	cfs (Min Depth = 2.5 ft)
Stage	**H_lp**	3.5	ft
Optimal Operating Flow	**Q_opt**	21.67	cfs (Depth=3ft, EDF=4 ft-lb/s/ft3)
Stage	**H_opt**	4.0	ft
Highest Operating Flow	**Q_hp**	29.92	cfs (Weir_17 EDF=5 ft-lb-s-ft3)
Stage	**H_hp**	4.4	ft
Scouring Tubulence (EDFweir≥4)	**Q_scour**	52.03	cfs (EDF over weir = 4 ft-lb/s/ft3)
	H_scour	5.0	ft

Bypass Spillway (broad crested weir)

Crest1 Width	Width1	9.6	ft
Crest1 Elev	El_1	89.8	ft
Crest2 Width	Width2	24.0	ft
Crest2 Elev	El_2	91.1	ft
Crest3 Width	Width3	10.0	ft
Crest3 Elev	El_3	92.1	ft

Weir_17 (Assume Uniform Flow at this Weir)

Floor Elevation	Elev1	84.00	ft
Total Weir Width	W	8.00	ft
Drop height between weirs	dH	1.0	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	**Wslot**	**1.50**	**ft**
Slot Height above Floor	Hslot	4.00	ft
Sill Height above Floor	Hsill	1.00	ft

Orifice Dimensions

Orifice Width	W1orifice	0.00	ft
Sill Height above Floor	H1orifice	0.00	ft

Horiz Weir Dimensions

Width	Length1	6.50	ft
Height above Floor	Height1	4.00	ft

Weir_18 (upstream of Weir_17)

Floor Elevation	Elev2	85.00	ft
Total Weir Width	W	8.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Alternative A - Level 1 Modifications (Alternative A-1) with Sediment in Slot of Weir 20

Slot Dimensions

Slot Width	Wslot2	1.50	ft
Slot Height above Floor	Hslot2	4.00	ft
Sill Height above Floor	Hsill2	0.50	ft

Triangular Weir Dimensions

Side Slope	SS2	0.00	ft/ft
Height of crest above Floor	Hvee	4.00	ft
Coefficient of Discharge	Cd_vee2	0.62	

Horiz Weir Dimensions

Width	Length2	6.50	ft
Height above Floor	Height2	4.00	ft

Weir_19 (upstream of Weir_18)

Floor Elevation	Elev3	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot3	1.50	ft
Slot Height above Floor	Hslot3	4.00	ft
Sill Height above Floor	Hsill3	0.00	ft

Triangular Weir Dimensions

Side Slope	SS3	0.00	ft/ft
Height of crest above Floor	Hvee3	4.00	ft
Coefficient of Discharge	Cd_vee3	0.62	

Horiz Weir Dimensions

Width	Length3	8.50	ft
Height above Floor	Height3	4.00	ft

Weir_20 (upstream of Weir_19)

Floor Elevation	Elev4	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot4	1.50	ft
Slot Height above Floor	Hslot4	4.50	ft
Sill Height above Floor	Hsill4	4.50	ft

Triangular Weir Dimensions

Side Slope	SS4	0.00	ft/ft
Height of crest above Floor	Hvee4	4.50	ft
Coefficient of Discharge	Cd_vee4	0.62	

Horiz Weir Dimensions

Width	Length4	6.50	ft
Height above Floor	Height4	4.50	ft

Exit Port

Headgate Orifice Elev	Elev_Exit	88.0	ft
Orifice Width	Worifice	4.0	ft
Orifice Height	Horifice	2.0	ft

Alternative A - Level 1 Modifications (Alternative A-1) with Sediment in Slot of Weir 20

Directions in Comments

	Initial Guess of Ho	OK	OK	OK	OK	OK
	Total Residual (solve = 0)	0.00	0.00	0.00	0.00	0.00

Summary of Hydraulic Results

	Flow Designation					
Bypass	**Streamflow over Spillway?**	Bypass	Bypass	Bypass	Bypass	Bypass
WSE_Forebay	**WSE in Forebay**	**91.36**	**91.56**	**91.16**	**91.76**	**92.75**
Qstream	**Total Streamflow**	**92.5**	**124.6**	**68.2**	**159.7**	**N/A**
QLadder	**Total Flow in Fish Ladder**	**18.1**	**21.7**	**14.4**	**25.0**	**35.9**
dH (Weir 18)	Drop over Weir_18	0.80	0.82	0.77	0.89	0.92
dH (Weir 19)	Drop over Weir_19	0.70	0.72	0.67	0.79	0.86
dH (Weir 20)	Drop over Weir_20	2.15	1.73	2.59	1.49	1.55
dH (Exit Port)	Drop across Exit Port	0.21	0.30	0.13	0.39	0.81
%Attraction	**Attraction Flow**	**20%**	**17%**	**21%**	**16%**	**N/A**

Bypass Spillway						
Q_spillway	**Bypass Flow over Spillway**	**74.40**	**102.96**	**53.72**	**134.74**	**358.66**
	Crest 1 (broad)					
H_crest1	**Upstream Head above Spillway**	1.56	1.76	1.36	1.96	2.95
Q_crest1	**Total Flow in Slot**	**63.78**	**77.00**	**52.38**	**90.39**	**166.55**
	Crest 2 (broad)					
H_crest2	**Upstream Head above Spillway**	0.26	0.46	0.06	0.66	1.65
Q_crest2	**Total Flow in Slot**	**10.62**	**25.96**	**1.34**	**44.35**	**174.17**
	Crest 3 (broad)					
H_crest3	**Upstream Head above Spillway**	0.00	0.00	0.00	0.00	0.65
Q_crest3	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**17.94**

Weir_17 (assume Uniform Flow)						
WSE at Weir		**87.50**	**88.00**	**87.00**	**88.20**	**88.60**
Ho(floor)	**Upstream Head above FLOOR**	**3.50**	**4.00**	**3.00**	**4.20**	**4.60**
Uslot	Velocity in Slot	4.8	4.8	4.8	4.8	4.8
Dpool	Min Pool Depth	**2.5**	3.0	**2.0**	3.2	3.6
EDF	**TOTAL Energy Disipation Factor**	**3.91**	**4.02**	**3.76**	**4.39**	**5.69**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.32	1.55
	Vertical Slot					
Q1s	**Total Flow in Slot**	**18.06**	**21.67**	**14.44**	**23.11**	**26.00**
	Orifice					
Q1orifice	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Q1	nonsubmerged Flow:	0.00	0.00	0.00	1.88	9.91
Q1sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**1.88**	**9.91**

Weir_18						
WSE at Weir		**88.30**	**88.82**	**87.77**	**89.09**	**89.52**
Ho(floor)	**Upstream Head above FLOOR**	**3.30**	**3.82**	**2.77**	**4.09**	**4.52**
Q2solve	**Qweir2 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.3	4.4	4.2	4.5	4.6
Dpool	Min Pool Depth	**2.5**	3.0	**2.0**	3.2	3.6
EDF	**TOTAL Energy Disipation Factor**	**2.68**	**2.88**	**2.42**	**3.44**	**4.68**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.08	1.04
	Vertical Slot					
Q2slot	**Total Flow in Slot**	**18.06**	**21.67**	**14.45**	**24.44**	**27.89**
	Triangular Weir Section					
Qvee2	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qveetrunc2	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qveetrunc2sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Qhorz2	nonsubmerged Flow:	0.00	0.00	0.00	0.56	8.02
Qhorz2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.56**	**8.02**

Alternative A - Level 1 Modifications (Alternative A-1) with Sediment in Slot of Weir 20

Weir_19						
WSE at Weir		**88.99**	**89.54**	**88.44**	**89.88**	**90.38**
Ho(floor)	**Upstream Head above FLOOR**	**2.99**	**3.54**	**2.44**	**3.88**	**4.38**
Q3solve	**Qweir3 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.0	4.1	3.9	4.3	4.5
Dpool	Min Pool Depth	3.3	3.8	**2.8**	4.1	4.5
EDF	**TOTAL Energy Dissipation Factor**	**2.48**	**2.65**	**2.27**	**3.16**	**4.44**
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.00	0.81
	Vertical Slot					
Q3slot	**Total Flow in Slot**	**18.06**	**21.67**	**14.44**	**25.00**	**29.36**
	Triangular Weir Section					
Q3	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q32sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt3	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt3sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q3sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Q3	nonsubmerged Flow:	0.00	0.00	0.00	0.00	6.55
Q3sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**6.55**

Weir_20						
WSE at Weir		**91.15**	**91.27**	**91.03**	**91.37**	**91.94**
Ho(floor)	**Upstream Head above FLOOR**	**5.15**	**5.27**	**5.03**	**5.37**	**5.94**
Q3solve	**Qweir3 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	7.1	6.3	7.7	5.9	6.0
Dpool	Min Pool Depth	**3.0**	3.5	**2.4**	3.9	4.4
EDF	**TOTAL Energy Dissipation Factor**	**6.76**	**5.51**	**7.96**	**4.97**	**6.62**
EDFweir	EDF of plunging flow	4.18	3.66	4.55	3.45	4.24
	Vertical Slot					
Q4slot	**Total Flow in Slot**	**6.89**	**7.29**	**6.19**	**7.64**	**12.93**
	Triangular Weir Section					
Q4	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q42sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt4	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt4sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q4sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Q4	nonsubmerged Flow:	11.17	14.38	8.26	17.35	37.46
Q4sub	**Flow w/Submergance**	**11.17**	**14.38**	**8.26**	**17.35**	**22.98**

Exit Port						
Forebay WSE		**91.36**	**91.56**	**91.16**	**91.76**	**92.75**
Ho(floor)	**Upstream Head above FLOOR**	**5.36**	**5.56**	**5.16**	**5.76**	**6.75**
Qexit_solve	**Qexit port - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Orifice	2.3	2.7	1.8	3.1	4.5
Dpool	Min Pool Depth	5.1	5.3	5.0	5.4	5.9
EDF	**TOTAL Energy Dissipation Factor**	**0.38**	**0.63**	**0.20**	**0.95**	**2.56**
	Vertical Slot					
Qport	**Total Flow through Exit Ports**	**18.06**	**21.67**	**14.44**	**25.00**	**35.91**

Alternative A - Level 1 Fishway Entrance Weir Modifications

Project: STEAMBOAT FALLS FISHWAY FEASIBILITY STUDY
Date: 12/1/2009

DESIGN INPUTS

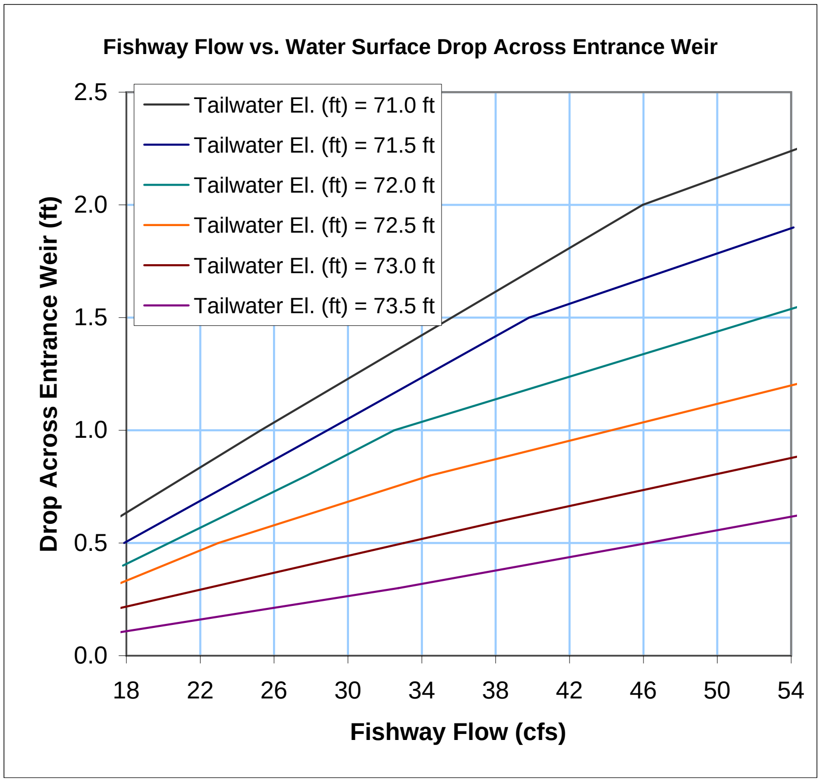
Coefficients			
Horiz. Weir Coefficient	**Cs**	= 0.602+0.075(h/P)	
Vertical Slot Coefficient	**Cslot**	**0.60**	from Rajaratnam 1986
Gravity	g	32.2	ft/s2

Entrance Weir

Floor Elevation	Elev	68.00	ft
Total Weir Width	W	8.00	ft
Residual Pool Depth	P	0	ft
Slot Dimensions			
Slot Width	Wslot	1.50	ft
Slot Height above Floor	Hslot	**5.00**	ft
Sill Height above Floor	Hsill	0.50	ft
Horiz Weir Dimensions			
Weir Length	Lweir	6.50	ft
Height above Floor	Hweir	5.00	ft

Summary of Hydraulic Results

Fishway Flow (cfs)	Ho above Floor (ft)	Surface Drop (ft)	Slot Flow (cfs)	Weir Flow (cfs)
Tailwater El. (ft) = 71.0 ft				
15.3	3.5	**0.5**	15.3	0.0
25.3	4.0	**1.0**	25.3	0.0
46.0	5.0	**2.0**	46.0	0.0
56.0	5.3	**2.3**	52.6	3.5
Tailwater El. (ft) = 71.5 ft				
17.9	4.0	**0.5**	17.9	0.0
28.9	4.5	**1.0**	28.9	0.0
39.8	5.0	**1.5**	39.8	0.0
54.1	5.4	**1.9**	48.8	5.3
Tailwater El. (ft) = 72.0 ft				
17.8	4.4	**0.4**	17.8	0.0
27.8	4.8	**0.8**	27.8	0.0
32.5	5.0	**1.0**	32.5	0.0
56.5	5.6	**1.6**	46.6	9.9
Tailwater El. (ft) = 72.5 ft				
17.0	4.8	**0.3**	17.0	0.0
23.0	5.0	**0.5**	23.0	0.0
34.5	5.3	**0.8**	31.0	3.5
58.9	5.8	**1.3**	43.6	15.3
Tailwater El. (ft) = 73.0 ft				
17.1	5.2	**0.2**	15.2	1.9
33.0	5.5	**0.5**	25.5	7.5
38.4	5.6	**0.6**	28.5	9.9
55.3	5.9	**0.9**	37.0	18.3
Tailwater El. (ft) = 73.5 ft				
17.3	5.6	**0.1**	11.6	5.7
32.7	5.8	**0.3**	21.0	11.8
46.2	6.0	**0.5**	28.1	18.1
59.6	6.2	**0.7**	34.4	25.1


Fishway Flow vs. Water Surface Drop Across Entrance Weir
Drop Across Entrance Weir (ft)
Fishway Flow (cfs)
Tailwater El. (ft) = 71.0 ft
Tailwater El. (ft) = 71.5 ft
Tailwater El. (ft) = 72.0 ft
Tailwater El. (ft) = 72.5 ft
Tailwater El. (ft) = 73.0 ft
Tailwater El. (ft) = 73.5 ft
0.0
0.5
1.0
1.5
2.0
2.5
18
22
26
30
34
38
42
46
50
54

Alternative A - Level 2 Modifications (Alternative A-2) Summer

Project: STEAMBOAT FALLS FISHWAY FEASIBILITY STUDY
Date: 12/1/2009

Summary of Fishway Type and Dimensions

Spillway Crest Elev. = 90.0 ft (Gate Raised)
Exit Port: Double 2'Wx3'H Exit Ports,
Seasonal Stoplog settings: SUMMER Exit Port Invert Elev. =88.0 ft
Weir 4: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.5' Tall w/1' Tall Sill
Horizontal Weir with 6.5 ' Crest Length
Weir 3: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.0' Tall w/No Sill
Horizontal Weir with 8.5 ' Crest Length
Weir 2: Right side 1.5' wide Vertical Slot, 4.0' Tall w/0.5' Tall Sill
Horizontal weir above slot, 6.5' wide
Weir 1 (unifrom flow): Right side 1.5' wide Vertical Slot, 4.0' Tall w/1' Tall Sill
Drop between Weirs = 1.0 ft.

DESIGN INPUTS

Coefficients

Horiz. Weir Coeficient	**Cs**	= 0.602+0.075(h/P)	
V-Notch Weir coeficient	**Cv**	=0.607165-0.0008744669*Ø+6.103933x10^ -6*Ø^2	
Broad Crested Weir Coeficient	**Cb**	**0.64**	
Orrfice Coeficient	**Corifice**	**0.62**	
Vertical Slot Coeficient	**Cslot**	**0.60**	from Rajaratnam 1986
Gravity	g	32.2	ft/s2

Design Flows

Lowest Operating Flow	**Q_lp**	18	cfs (Min Depth = 2.5 ft)
Stage	**H_lp**	3.5	ft
Optimal Operating Flow	**Q_opt**	21.7	cfs (Depth=3ft, EDF=4 ft-lb/s/ft3)
Stage	**H_opt**	4.0	ft
Highest Operating Flow	**Q_hp**	36	cfs (HW at El 92')
Stage	**H_hp**	4.6	ft
Scouring Tubulence (EDFweir≥4)	**Q_scour**	52.0	cfs (EDF over weir = 4 ft-lb/s/ft3)
	H_scour	5.0	ft

Bypass Spillway (broad crested weir)

Crest1 Width	Width1	10.0	ft
Crest1 Elev	El_1	90.0	ft
Crest2 Width	Width2	20.0	ft
Crest2 Elev	El_2	91.0	ft
Crest3 Width	Width3	10.0	ft
Crest3 Elev	El_3	92.0	ft

Weir_17 (Assume Uniform Flow at this Weir)

Floor Elevation	Elev1	84.00	ft
Total Weir Width	W	8.00	ft
Drop height between weirs	dH	1.0	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	**Wslot**	**1.50**	**ft**
Slot Height above Floor	Hslot	4.00	ft
Sill Height above Floor	Hsill	1.00	ft

Orifice Dimensions

Orifice Width	W1orifice	0.00	ft
Sill Height above Floor	H1orifice	0.00	ft

Horiz Weir Dimensions

Width	Length1	6.50	ft
Height above Floor	Height1	4.00	ft

Weir_18 (upstream of Weir_17)

Floor Elevation	Elev2	85.00	ft
Total Weir Width	W	8.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Alternative A - Level 2 Modifications (Alternative A-2) Summer Gate Settings

Slot Dimensions

Slot Width	Wslot2	1.50	ft
Slot Height above Floor	Hslot2	4.00	ft
Sill Height above Floor	Hsill2	0.50	ft

Triangular Weir Dimensions

Side Slope	SS2	0.00	ft/ft
Height of crest above Floor	Hvee	4.00	ft
Coefficient of Discharge	Cd_vee2	0.62	

Horiz Weir Dimensions

Width	Length2	6.50	ft
Height above Floor	Height2	4.00	ft

Weir_19 (upstream of Weir_18)

Floor Elevation	Elev3	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot3	1.50	ft
Slot Height above Floor	Hslot3	4.00	ft
Sill Height above Floor	Hsill3	0.00	ft

Triangular Weir Dimensions

Side Slope	SS3	0.00	ft/ft
Height of crest above Floor	Hvee3	4.00	ft
Coefficient of Discharge	Cd_vee3	0.62	

Horiz Weir Dimensions

Width	Length3	8.50	ft
Height above Floor	Height3	4.00	ft

Weir_20 (upstream of Weir_19)

Floor Elevation	Elev4	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot4	1.50	ft
Slot Height above Floor	Hslot4	4.50	ft
Sill Height above Floor	Hsill4	1.00	ft

Triangular Weir Dimensions

Side Slope	SS4	0.00	ft/ft
Height of crest above Floor	Hvee4	4.50	ft
Coefficient of Discharge	Cd_vee4	0.62	

Horiz Weir Dimensions

Width	Length4	6.50	ft
Height above Floor	Height4	4.50	ft

Exit Port

Headgate Orifice Elev	Elev_Exit	88.0	ft
Orifice Width	Worifice	4.0	ft
Orifice Height	Horifice	2.0	ft

Alternative A - Level 2 Modifications (Alternative A-2) Summer Gate Settings

Directions in Comments

Initial Guess of Ho	OK	OK	OK	OK	OK
Total Residual (solve = 0)	0.00	0.01	0.00	0.00	0.00

Summary of Hydraulic Results

	Flow Designation	Q_lp	Q_opt		Q_hp	WSE92'
Bypass	**Streamflow over Spillway?**	No	Bypass	Bypass	Bypass	Bypass
WSE_Forebay	**WSE in Forebay**	**90.00**	**90.64**	**91.06**	**91.55**	**92.00**
Qstream	**Total Streamflow**	**18.0**	**39.1**	**63.7**	**124.2**	**201.1**
QLadder	**Total Flow in Fish Ladder**	**18.0**	**21.7**	**25.0**	**30.0**	**35.9**
dH (Weir 18)	Drop over Weir_18	0.80	0.82	0.89	0.91	0.92
dH (Weir 19)	Drop over Weir_19	0.70	0.72	0.79	0.86	0.86
dH (Weir 20)	Drop over Weir_20	0.80	0.81	0.79	0.81	0.80
dH (Exit Port)	Drop across Exit Port	0.21	0.30	0.39	0.57	0.81
%Attraction	**Attraction Flow**	**100%**	**55%**	**39%**	**24%**	**18%**

Bypass Spillway						
Q_spillway	**Bypass Flow over Spillway**	**0.00**	**17.48**	**38.74**	**94.19**	**165.14**
	Crest 1 (broad)					
H_crest1	**Upstream Head above Spillway**	0.00	0.64	1.06	1.55	2.00
Q_crest1	**Total Flow in Slot**	**0.00**	**17.48**	**37.61**	**66.16**	**96.77**
	Crest 2 (broad)					
H_crest2	**Upstream Head above Spillway**	0.00	0.00	0.06	0.55	1.00
Q_crest2	**Total Flow in Slot**	**0.00**	**0.00**	**1.13**	**28.03**	**68.37**
	Crest 3 (broad)					
H_crest3	**Upstream Head above Spillway**	0.00	0.00	0.00	0.00	0.00
Q_crest3	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Weir_17 (assume Uniform Flow)						
WSE at Weir		**87.50**	**88.00**	**88.20**	**88.40**	**88.60**
Ho(floor)	**Upstream Head above FLOOR**	**3.50**	**4.00**	**4.20**	**4.40**	**4.60**
Uslot	Velocity in Slot	4.8	4.8	4.8	4.8	4.8
Dpool	Min Pool Depth	**2.5**	3.0	3.2	3.4	3.6
EDF	**TOTAL Energy Disipation Factor**	**3.91**	**4.02**	**4.39**	**5.00**	**5.69**
EDFweir	EDF of plunging flow	0.00	0.00	0.32	0.89	1.55
	Vertical Slot					
Q1s	**Total Flow in Slot**	**18.02**	**21.67**	**23.11**	**24.59**	**26.00**
	Orifice					
Q1orifice	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Q1	nonsubmerged Flow:	0.00	0.00	1.88	5.44	9.91
Q1sub	**Flow w/Submergance**	**0.00**	**0.00**	**1.88**	**5.44**	**9.91**

Weir_18						
WSE at Weir		**88.29**	**88.82**	**89.09**	**89.31**	**89.52**
Ho(floor)	**Upstream Head above FLOOR**	**3.29**	**3.82**	**4.09**	**4.31**	**4.52**
Q2solve	**Qweir2 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.3	4.4	4.5	4.6	4.6
Dpool	Min Pool Depth	**2.5**	3.0	3.2	3.4	3.6
EDF	**TOTAL Energy Disipation Factor**	**2.67**	**2.88**	**3.44**	**4.04**	**4.68**
EDFweir	EDF of plunging flow	0.00	0.00	0.08	0.50	1.04
	Vertical Slot					
Q2slot	**Total Flow in Slot**	**18.02**	**21.66**	**24.44**	**26.29**	**27.89**
	Triangular Weir Section					
Qvee2	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qveetrunc2	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qveetrunc2sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Qhorz2	nonsubmerged Flow:	0.00	0.00	0.56	3.73	8.02
Qhorz2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.56**	**3.73**	**8.02**

Alternative A - Level 2 Modifications (Alternative A-2) Summer Gate Settings

Weir_19						
WSE at Weir		88.99	89.54	89.88	90.18	90.38
Ho(floor)	Upstream Head above FLOOR	2.99	3.54	3.88	4.18	4.38
Q3solve	Qweir3 - Qladder (solve = 0)	0.00	0.00	0.00	0.00	0.00
Uslot	Velocity in Slot	4.0	4.1	4.3	4.5	4.5
Dpool	Min Pool Depth	3.3	3.8	4.1	4.3	4.5
EDF	TOTAL Energy Dissipation Factor	2.48	2.65	3.16	3.90	4.44
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.26	0.81
	Vertical Slot					
Q3slot	Total Flow in Slot	18.02	21.67	25.00	27.99	29.36
	Triangular Weir Section					
Q3	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q32sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt3	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt3sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q3sub	Flow w/Submergance	0.00	0.00	0.00	0.00	0.00
	Horizontal Weir Section					
Q3	nonsubmerged Flow:	0.00	0.00	0.00	2.04	6.55
Q3sub	Flow w/Submergance	0.00	0.00	0.00	2.04	6.55

Weir_20						
WSE at Weir		89.79	90.34	90.67	90.98	91.18
Ho(floor)	Upstream Head above FLOOR	3.79	4.34	4.67	4.98	5.18
Q3solve	Qweir3 - Qladder (solve = 0)	0.00	0.00	0.00	0.00	0.00
Uslot	Velocity in Slot	4.3	4.3	4.3	4.3	4.3
Dpool	Min Pool Depth	3.0	3.5	3.9	4.2	4.4
EDF	TOTAL Energy Dissipation Factor	2.51	2.57	2.63	3.01	3.42
EDFweir	EDF of plunging flow	0.00	0.00	0.16	0.42	0.84
	Vertical Slot					
Q4slot	Total Flow in Slot	18.02	21.67	23.52	25.82	27.08
	Triangular Weir Section					
Q4	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q42sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt4	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt4sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q4sub	Flow w/Submergance	0.00	0.00	0.00	0.00	0.00
	Horizontal Weir Section					
Q4	nonsubmerged Flow:	0.00	0.00	1.48	7.10	12.09
Q4sub	Flow w/Submergance	0.00	0.00	1.48	4.21	8.84

Exit Port						
Forebay WSE		90.00	90.64	91.06	91.55	92.00
Ho(floor)	Upstream Head above FLOOR	4.00	4.64	5.06	5.55	6.00
Qexit_solve	Qexit port - Qladder (solve = 0)	0.00	0.00	0.00	0.00	0.00
Uslot	Velocity in Orifice	2.3	2.7	3.1	3.8	4.5
Dpool	Min Pool Depth	3.8	4.3	4.7	5.0	5.2
EDF	TOTAL Energy Dissipation Factor	0.51	0.77	1.10	1.78	2.93
	Vertical Slot					
Qport	Total Flow through Exit Ports	18.02	21.67	25.00	30.03	35.91

Alternative A - Level 2 Modifications (Alternative A-2) Winter

Project: STEAMBOAT FALLS FISHWAY FEASIBILITY STUDY
Date: 12/1/2009

Summary of Fishway Type and Dimensions

Spillway Crest Elev. = 89.0 ft (Gate Lowered)
Exit Port: Double 2'Wx3'H Exit Ports,
Seasonal Stoplog settings: SUMMER Exit Port Invert Elev. =88.0 ft
Weir 4: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.5' Tall w/1' Tall Sill
Horizontal Weir with 6.5 ' Crest Length
Weir 3: Floor raised 1', Centered 1.5' wide Vertical Slot, 4.0' Tall w/No Sill
Horizontal Weir with 8.5 ' Crest Length
Weir 2: Right side 1.5' wide Vertical Slot, 4.0' Tall w/0.5' Tall Sill
Horizontal weir above slot, 6.5' wide
Weir 1 (unifrom flow): Right side 1.5' wide Vertical Slot, 4.0' Tall w/1' Tall Sill
Drop between Weirs = 1.0 ft.

DESIGN INPUTS

Coefficients

Horiz. Weir Coeficient	**Cs**	= 0.602+0.075(h/P)	
V-Notch Weir coeficient	**Cv**	=0.607165-0.0008744669*Ø+6.103933x10^ -6*Ø^2	
Broad Crested Weir Coeficient	**Cb**	**0.64**	
Orrfice Coeficient	**Corifice**	**0.62**	
Vertical Slot Coeficient	**Cslot**	**0.60**	from Rajaratnam 1986
Gravity	g	32.2	ft/s2

Design Flows

Lowest Operating Flow	**Q_lp**	18	cfs (Min Depth = 2.5 ft)
Stage	**H_lp**	3.5	ft
Optimal Operating Flow	**Q_opt**	21.7	cfs (Depth=3ft, EDF=4 ft-lb/s/ft3)
Stage	**H_opt**	4.0	ft
Highest Operating Flow	**Q_hp**	36	cfs (HW at El 92')
Stage	**H_hp**	4.6	ft
Scouring Tubulence (EDFweir≥4)	**Q_scour**	52.0	cfs (EDF over weir = 4 ft-lb/s/ft3)
	H_scour	5.0	ft

Bypass Spillway (broad crested weir)

Crest1 Width	Width1	10.0	ft
Crest1 Elev	El_1	90.0	ft
Crest2 Width	Width2	20.0	ft
Crest2 Elev	El_2	91.0	ft
Crest3 Width	Width3	10.0	ft
Crest3 Elev	El_3	92.0	ft

Weir_17 (Assume Uniform Flow at this Weir)

Floor Elevation	Elev1	84.00	ft
Total Weir Width	W	8.00	ft
Drop height between weirs	dH	1.0	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	**Wslot**	**1.50**	**ft**
Slot Height above Floor	Hslot	4.00	ft
Sill Height above Floor	Hsill	1.00	ft

Orifice Dimensions

Orifice Width	W1orifice	0.00	ft
Sill Height above Floor	H1orifice	0.00	ft

Horiz Weir Dimensions

Width	Length1	6.50	ft
Height above Floor	Height1	4.00	ft

Weir_18 (upstream of Weir_17)

Floor Elevation	Elev2	85.00	ft
Total Weir Width	W	8.00	ft
Residual Pool Depth	P	0	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Alternative A - Level 2 Modifications (Alternative A-2) Winter Gate Settings

Slot Dimensions

Slot Width	Wslot2	1.50	ft
Slot Height above Floor	Hslot2	4.00	ft
Sill Height above Floor	Hsill2	0.50	ft

Triangular Weir Dimensions

Side Slope	SS2	0.00	ft/ft
Height of crest above Floor	Hvee	4.00	ft
Coefficient of Discharge	Cd_vee2	0.62	

Horiz Weir Dimensions

Width	Length2	6.50	ft
Height above Floor	Height2	4.00	ft

Weir_19 (upstream of Weir_18)

Floor Elevation	Elev3	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot3	1.50	ft
Slot Height above Floor	Hslot3	4.00	ft
Sill Height above Floor	Hsill3	0.00	ft

Triangular Weir Dimensions

Side Slope	SS3	0.00	ft/ft
Height of crest above Floor	Hvee3	4.00	ft
Coefficient of Discharge	Cd_vee3	0.62	

Horiz Weir Dimensions

Width	Length3	8.50	ft
Height above Floor	Height3	4.00	ft

Weir_20 (upstream of Weir_19)

Floor Elevation	Elev4	86.00	ft
Total Weir Width	W	10.00	ft
Residual Pool Depth	P	1	ft
Effective Pool Length	Leff	12	ft
Weir Spacing On-Center	Loc	12.67	ft

Slot Dimensions

Slot Width	Wslot4	1.50	ft
Slot Height above Floor	Hslot4	4.50	ft
Sill Height above Floor	Hsill4	1.00	ft

Triangular Weir Dimensions

Side Slope	SS4	0.00	ft/ft
Height of crest above Floor	Hvee4	4.50	ft
Coefficient of Discharge	Cd_vee4	0.62	

Horiz Weir Dimensions

Width	Length4	6.50	ft
Height above Floor	Height4	4.50	ft

Exit Port

Headgate Orifice Elev	Elev_Exit	88.0	ft
Orifice Width	Worifice	4.0	ft
Orifice Height	Horifice	2.0	ft

Alternative A - Level 2 Modifications (Alternative A-2) Winter Gate Settings

Directions in Comments

Initial Guess of Ho	OK	OK	OK	OK	OK
Total Residual (solve = 0)	0.00	0.01	0.00	0.00	0.00

Summary of Hydraulic Results

	Flow Designation	Q_lp	Q_opt		Q_hp	WSE92'
Bypass	**Streamflow over Spillway?**	No	Bypass	Bypass	Bypass	Bypass
WSE_Forebay	**WSE in Forebay**	**90.00**	**90.64**	**91.06**	**91.55**	**92.00**
Qstream	**Total Streamflow**	**18.0**	**39.1**	**63.7**	**124.2**	**201.1**
QLadder	**Total Flow in Fish Ladder**	**18.0**	**21.7**	**25.0**	**30.0**	**35.9**
dH (Weir 18)	Drop over Weir_18	0.80	0.82	0.89	0.91	0.92
dH (Weir 19)	Drop over Weir_19	0.70	0.72	0.79	0.86	0.86
dH (Weir 20)	Drop over Weir_20	0.80	0.81	0.79	0.81	0.80
dH (Exit Port)	Drop across Exit Port	0.21	0.30	0.39	0.57	0.81
%Attraction	**Attraction Flow**	**100%**	**55%**	**39%**	**24%**	**18%**

Bypass Spillway

Q_spillway	**Bypass Flow over Spillway**	**0.00**	**17.48**	**38.74**	**94.19**	**165.14**
	Crest 1 (broad)					
H_crest1	**Upstream Head above Spillway**	0.00	0.64	1.06	1.55	2.00
Q_crest1	**Total Flow in Slot**	**0.00**	**17.48**	**37.61**	**66.16**	**96.77**
	Crest 2 (broad)					
H_crest2	**Upstream Head above Spillway**	0.00	0.00	0.06	0.55	1.00
Q_crest2	**Total Flow in Slot**	**0.00**	**0.00**	**1.13**	**28.03**	**68.37**
	Crest 3 (broad)					
H_crest3	**Upstream Head above Spillway**	0.00	0.00	0.00	0.00	0.00
Q_crest3	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Weir_17 (assume Uniform Flow)

WSE at Weir		**87.50**	**88.00**	**88.20**	**88.40**	**88.60**
Ho(floor)	**Upstream Head above FLOOR**	**3.50**	**4.00**	**4.20**	**4.40**	**4.60**
Uslot	Velocity in Slot	4.8	4.8	4.8	4.8	4.8
Dpool	Min Pool Depth	2.5	3.0	3.2	3.4	3.6
EDF	**TOTAL Energy Disipation Factor**	**3.91**	**4.02**	**4.39**	**5.00**	**5.69**
EDFweir	EDF of plunging flow	0.00	0.00	0.32	0.89	1.55
	Vertical Slot					
Q1s	**Total Flow in Slot**	**18.02**	**21.67**	**23.11**	**24.59**	**26.00**
	Orifice					
Q1orifice	**Total Flow in Slot**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Q1	nonsubmerged Flow:	0.00	0.00	1.88	5.44	9.91
Q1sub	**Flow w/Submergance**	**0.00**	**0.00**	**1.88**	**5.44**	**9.91**

Weir_18

WSE at Weir		**88.29**	**88.82**	**89.09**	**89.31**	**89.52**
Ho(floor)	**Upstream Head above FLOOR**	**3.29**	**3.82**	**4.09**	**4.31**	**4.52**
Q2solve	**Qweir2 - Qladder (solve = 0)**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Uslot	Velocity in Slot	4.3	4.4	4.5	4.6	4.6
Dpool	Min Pool Depth	2.5	3.0	3.2	3.4	3.6
EDF	**TOTAL Energy Disipation Factor**	**2.67**	**2.88**	**3.44**	**4.04**	**4.68**
EDFweir	EDF of plunging flow	0.00	0.00	0.08	0.50	1.04
	Vertical Slot					
Q2slot	**Total Flow in Slot**	**18.02**	**21.66**	**24.44**	**26.29**	**27.89**
	Triangular Weir Section					
Qvee2	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qveetrunc2	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qveetrunc2sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Qvee2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Horizontal Weir Section					
Qhorz2	nonsubmerged Flow:	0.00	0.00	0.56	3.73	8.02
Qhorz2sub	**Flow w/Submergance**	**0.00**	**0.00**	**0.56**	**3.73**	**8.02**

Alternative A - Level 2 Modifications (Alternative A-2) Winter Gate Settings

Weir_19						
WSE at Weir		88.99	89.54	89.88	90.18	90.38
Ho(floor)	Upstream Head above FLOOR	2.99	3.54	3.88	4.18	4.38
Q3solve	Qweir3 - Qladder (solve = 0)	0.00	0.00	0.00	0.00	0.00
Uslot	Velocity in Slot	4.0	4.1	4.3	4.5	4.5
Dpool	Min Pool Depth	3.3	3.8	4.1	4.3	4.5
EDF	TOTAL Energy Disipation Factor	2.48	2.65	3.16	3.90	4.44
EDFweir	EDF of plunging flow	0.00	0.00	0.00	0.26	0.81
	Vertical Slot					
Q3slot	Total Flow in Slot	18.02	21.67	25.00	27.99	29.36
	Triangular Weir Section					
Q3	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q32sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt3	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt3sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q3sub	Flow w/Submergance	0.00	0.00	0.00	0.00	0.00
	Horizontal Weir Section					
Q3	nonsubmerged Flow:	0.00	0.00	0.00	2.04	6.55
Q3sub	Flow w/Submergance	0.00	0.00	0.00	2.04	6.55

Weir_20						
WSE at Weir		89.79	90.34	90.67	90.98	91.18
Ho(floor)	Upstream Head above FLOOR	3.79	4.34	4.67	4.98	5.18
Q3solve	Qweir3 - Qladder (solve = 0)	0.00	0.00	0.00	0.00	0.00
Uslot	Velocity in Slot	4.3	4.3	4.3	4.3	4.3
Dpool	Min Pool Depth	3.0	3.5	3.9	4.2	4.4
EDF	TOTAL Energy Disipation Factor	2.51	2.57	2.63	3.01	3.42
EDFweir	EDF of plunging flow	0.00	0.00	0.16	0.42	0.84
	Vertical Slot					
Q4slot	Total Flow in Slot	18.02	21.67	23.52	25.82	27.08
	Triangular Weir Section					
Q4	nonsubmerged flow:	0.00	0.00	0.00	0.00	0.00
Q42sub	submerged flow:	0.00	0.00	0.00	0.00	0.00
Qt4	truncated nonsubmerged flow	0.00	0.00	0.00	0.00	0.00
Qt4sub	submerged truncated flow:	0.00	0.00	0.00	0.00	0.00
Q4sub	Flow w/Submergance	0.00	0.00	0.00	0.00	0.00
	Horizontal Weir Section					
Q4	nonsubmerged Flow:	0.00	0.00	1.48	7.10	12.09
Q4sub	Flow w/Submergance	0.00	0.00	1.48	4.21	8.84

Exit Port						
Forebay WSE		90.00	90.64	91.06	91.55	92.00
Ho(floor)	Upstream Head above FLOOR	4.00	4.64	5.06	5.55	6.00
Qexit_solve	Qexit port - Qladder (solve = 0)	0.00	0.00	0.00	0.00	0.00
Uslot	Velocity in Orifice	2.3	2.7	3.1	3.8	4.5
Dpool	Min Pool Depth	3.8	4.3	4.7	5.0	5.2
EDF	TOTAL Energy Disipation Factor	0.51	0.77	1.10	1.78	2.93
	Vertical Slot					
Qport	Total Flow through Exit Ports	18.02	21.67	25.00	30.03	35.91

APPENDIX I

Alternatives A - C
Concept Level Cost Estimates

Steamboat Falls Fish Passage Project

Engineers Opinion of Probable Construction and Project Cost - Based on December 2009 Concept Design

ALTERNATIVE A

LEVEL 1

Item	Item Description	Quantity	Unit	Unit Cost	Total
1	Mobilization and Demobilization	1	LS	$15,000	$15,000
2	Control of Water and Bypass	1	LS	$10,000	$10,000
3	Removal and Disposal of Gravel Deposition in Fish Ladder	1	LS	$10,000	$10,000
4	Plug and Abandon Existing 18' Long 36" Dia. Sluice Pipe with Concrete	5	CY	$1,800	$9,000
5	Demolition and Removal of Concrete Weirs	1	LS	$7,500	$7,500
6	Modifications to Weir 1 (reconstruct entrance weir)	1	EA	$5,000	$5,000
7	Modifications to Weirs 2-5 (sill plates, grouted ramps, orifice plugging, doweling)	4	EA	$3,000	$12,000
8	Modifications to Weirs 6-18 (sill plates, grouted ramps, orifice plugging)	13	EA	$1,500	$19,500
9	Modifications to Weirs 19-20 (concrete slab, new concrete slotted weirs, access ladder)	10	CY	$2,200	$22,000
10	Dual Panel Aluminum Access Hatch	1	LS	$10,000	$10,000
11	Concrete Cutoff Wall and Curb on Existing Fish Ladder Roof	8	CY	$2,000	$16,000
	Subtotal (Level 1):				**$136,000**
	Estimating Contingency @ 25%:				$34,000
	OPINION OF PROBABLE CONSTRUCTION COST (LEVEL 1):				**$170,000**
	Final Engineering and Design (Level 1):				$50,000
	Bidding Assistance (Level 1):				$5,000
	Construction Management (Level 1):				$30,000
	FINAL DESIGN AND CONSTRUCTION MANAGEMENT OPINION OF PROBABLE COST (LEVEL 1):				**$85,000**
	OPINION OF PROBABLE PROJECT COST (LEVEL 1):				**$255,000**

LEVEL 2

Item	Item Description	Quantity	Unit	Unit Cost	Total
1	Demolish and Remove Existing Concrete Crest	1	LS	$10,000	$10,000
2	Reconstruct Concrete Spillway	1	LS	$30,000	$30,000
3	Stainless Steel Hinged Crest Gate with Manual Actuator	1	EA	$60,000	$60,000
4	Stoplogs and Frames for Exit Ports	1	LS	$3,000	$3,000
	Subtotal (Level 2):				**$103,000**
	Estimating Contingency @ 25%:				$25,750
	OPINION OF PROBABLE CONSTRUCTION COST (LEVEL 1+2):				**$298,750**
	Final Engineering and Design (Level 1 and 2):				$65,000
	Bidding Assistance (Level 1 and 2):				$5,000
	Construction Management (Level 1 and 2):				$45,000
	FINAL DESIGN AND CONSTRUCTION MANAGEMENT OPINION OF PROBABLE COST (Level 1 and 2):				**$115,000**
	OPINION OF PROBABLE PROJECT COST (LEVEL 1+2):				**$414,000**

LEVEL 3

Item	Item Description	Quantity	Unit	Unit Cost	Total
1	AWS Rehabilitation (Auxiliary Intake Grille, Flow Control Valve and Floor Diffuser)	1	LS	$30,000	$30,000
2	Aluminum Access Hatch for AWS	1	EA	$7,500	$7,500
	Subtotal (Level 3):				**$37,500**
	Estimating Contingency @ 25%:				$9,375
	OPINION OF PROBABLE CONSTRUCTION COST (LEVEL 1+2+3):				**$515,625**
	Final Engineering and Design (Level 1, 2, and 3):				$80,000
	Bidding Assistance (Level 1, 2, and 3):				$5,000
	Construction Management (Level 1, 2, and 3):				$55,000
	FINAL DESIGN AND CONSTRUCTION MANAGEMENT OPINION OF PROBABLE COST (LEVEL 1, 2, and 3):				**$140,000**
	OPINION OF PROBABLE PROJECT COST (LEVEL 1+2+3):				**$656,000**

Cost do not include preparation of environmental documents, permitting, or consultation with agencies

Steamboat Falls Fish Passage Project

Engineers Opinion of Probable Construction and Project Cost - Based on December 2009 Concept Design

ALTERNATIVE B Bedrock Pools Fishway					
Item	***Item Description***	***Quantity***	***Unit***	***Unit Cost***	***Total***
1	Mobilization and Demobilization	1	LS	$30,000	$30,000
2	Control of Water and Bypass	1	LS	$10,000	$10,000
3	Bedrock Excavation and Disposal (Drilling and Chipping)	500	CY	$200	$100,000
4	Bedrock Excavation and Disposal (Mechanical Excavation)	1,500	CY	$75	$112,500
				Subtotal:	**$252,500**
				Estimating Contingency @ 25%:	$63,125
				OPINION OF PROBABLE CONSTRUCTION COST:	**$316,000**
				Final Engineering and Design:	$40,000
				Bidding Assistance:	$5,000
				Construction Management:	$50,000
				FINAL DESIGN AND CONSTRUCTION MANAGEMENT OPINION OF PROBABLE COST:	**$95,000**
				OPINION OF PROBABLE PROJECT COST:	**$411,000**

Cost do not include preparation of environmental documents, permitting, or consultation with agencies

Steamboat Falls Fish Passage Project

Engineers Opinion of Probable Construction and Project Cost - Based on December 2009 Concept Design

ALTERNATIVE C Bedrock Pools with Concrete Weirs					
Item	***Item Description***	***Quantity***	***Unit***	***Unit Cost***	***Total***
1	Mobilization and Demobilization	1	LS	$30,000	$30,000
2	Control of Water and Bypass	1	LS	$10,000	$10,000
3	Bedrock Excavation and Disposal (Mechanical Excavation)	2,000	CY	$75	$150,000
4	Concrete Weirs	100	CY	$2,000	$200,000
				Subtotal:	**$390,000**
				Estimating Contingency @ 25%:	$97,500
				OPINION OF PROBABLE CONSTRUCTION COST:	**$488,000**
				Final Engineering and Design:	$50,000
				Bidding Assistance:	$5,000
				Construction Management:	$40,000
				FINAL DESIGN AND CONSTRUCTION MANAGEMENT OPINION OF PROBABLE COST:	**$95,000**
				OPINION OF PROBABLE PROJECT COST:	**$583,000**

Cost do not include preparation of environmental documents, permitting, or consultation with agencies