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Potter Valley Project Feasibility Study: Capital Improvements




PREPARED FOR

Potter Valley Project Planning Agreement Parties
- California Trout
- Humboldt County
- Mendocino County Inland Water and Power Commission
- Round Valley Indian Tribes
- Sonoma County Water Agency

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Cover photos:
Clockwise from upper left: Potter Valley Powerhouse with maintenance to the pressure reducing valve; Scott Dam from the left abutment; Potter Valley Irrigation District canal with lateral head gate; Cape Horn Dam and upstream fish ladder.

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PREFACE

This Technical Memorandum was prepared for the Potter Valley Project (Project) Planning Agreement Parties (Parties) by the Consultant Team as part of the Feasibility Study Report. A feasibility study examines the practicability of a potential action or actions in meeting agreed upon common goals. The principal function of a feasibility study is to inform project proponents on cost and performance tradeoffs of potential project components and narrow down the possibilities to determine if the project should be pursued or not. Therefore, a feasibility study reflects a snapshot in time at the beginning of a path that starts with the broad cursory analyses of a feasibility study, transitions towards more refined analyses of an increasingly focused project plan and will hopefully end with implementation of the best possible project that meets programmatic goals in a cost-effective manner.

The purpose of this Technical Memorandum is to provide feasibility-level technical information on how potential Water Supply Scenarios and infrastructure options may affect both the Eel River and the Russian River from a physical, thermal, and ecological standpoint, and outline potential fisheries restoration opportunities within and outside the Potter Valley Project. As described in the Alternatives Development and Project Plan Technical Memorandum, various operational and infrastructure options were developed, then bundled into a range of alternatives consistent with "Dams Remain" and "Dam(s) Removed" categories as desired by the Parties. This Technical Memorandum is not intended to be an exhaustive or comprehensive analysis of all Project options and alternatives but describes the initial analyses that the Parties undertook to evaluate the feasibility of assuming ownership of the Project, and a potential Project Plan, that best met the Shared Objectives of the Planning Agreement.

This Technical Memorandum reflects the consultant work product and is intended to be purely informational and is thus not binding on any of the Parties. Initial infrastructure evaluations contained in this Technical Memorandum are based on conceptual designs of capital improvements and initial analyses of potential hydrologic and physical changes to the rivers. The initial evaluations incorporate limited input from the Parties, incorporate no input from resource agencies or other stakeholders, are based on rough cost estimates, and potential actions contained within the Project Plan are not optimized for the best benefit/cost tradeoffs. In addition, this Technical Memorandum will not be filed with FERC as the basis for compliance under the Integrated License Process or other FERC rules. While this Technical Memorandum has contributed to the information available to the Parties, the Parties have not solely relied on this document for justification for any decision the Parties have made or will make regarding FERC filings or cooperative agreements. More detailed studies will be conducted (and are currently being conducted) through development and implementation of the FERC study plans, as well as additional engineering and ecological studies outside of the FERC process. Accordingly, this Technical Memorandum reflects an initial step that will be expanded and built upon in the coming years with additional studies, analysis, synthesis, and ultimately decisions by the Parties on proceeding with a Project Plan for the Project.

1 INTRODUCTION

1.1 Background

The Potter Valley Project (Project; Federal Energy Regulatory Commission [FERC] Project No. 77) dates to the early 1900s with the construction of Cape Horn Dam (1908 completion), located in Mendocino County, followed by Scott Dam (1922 completion), located in Lake County, California. The Project was first licensed as a hydroelectric plant in 1922 by the Federal Power Commission (precursor to FERC). Pacific Gas and Electric Company (PG&E) acquired the Project from Snow Mountain Water and Power in 1930 and assumed the FERC license. The original license expired in 1972 and after a series of environmental reviews, FERC issued a license in 1983, which was amended in 2004 based on the NMFS Biological Opinion and covers operations through April 14, 2022. Locations of key project infrastructure in the Eel and Russian River watersheds are shown in Figure 1-1.

The Project consists of several major components, including (PG&E 2017):

- **Scott Dam and Lake Pillsbury:** Located near the headwaters of the Eel River watershed, Scott Dam is a concrete gravity dam that was constructed to provide water storage for the hydroelectric plant located at the north end of Potter Valley so that better balancing of power production throughout the year could be achieved. Since that time, stored water has been used for additional beneficial uses, including irrigation water supply for the Potter Valley Irrigation District (PVID) and minimum instream flow requirements in the Eel River and East Fork Russian River. Water not used by PVID flows into the Russian River system for potential use by municipal and agricultural water supply downstream of Lake Mendocino. Scott Dam does not include provisions for fish passage, and therefore represents a fish passage barrier to the upper Eel River watershed.
- **Cape Horn Dam, Van Arsdale Reservoir, and Van Arsdale Diversion:** Located 11 Miles downstream of Scott Dam, Cape Horn Dam is a concrete gravity and earthfill dam that operates as a forebay for the trans-basin diversion to the Russian River, with all nondiverted flow passing over the crest of the spillway-type dam crest without attenuation or storage. The dam includes a volitional fish passage facility located on the west bank. Cape Horn Dam was designed to provide adequate submergence on the diversion tunnel intake to provide water to the Potter Valley Powerhouse through gravity flow. Van Arsdale Diversion can divert up to 480 cubic feet per second (cfs) through the fish screen and up to 320 cfs through a tunnel to the Russian River system. However, the fish screen has been de-rated such that the current maximum diversion is 240 cfs.
- **Diversion Tunnels/Conduits and Potter Valley Powerhouse:** The diversion tunnels extend from just upstream of Cape Horn Dam and through the basin divide, terminating at the powerhouse located at the north end of Potter Valley. The diversion consists of several lengths of tunnel and wood stave conduit with a combined tunnel length of over 1 mile with a maximum capacity of 320 cfs. All flows passing from the Eel River basin to the Russian River Basin pass through the Van Arsdale Diversion. Power is generated at the Potter Valley Powerhouse with a total generation capacity of 10 megawatts (MW) and a peak output capacity of 9.2 MW.

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Figure 1-1. Geography and locations of key infrastructure in the Eel River and Russian River watersheds (modified from PG&E 2017).

On January 25, 2019, PG&E withdrew its Notice of Intent (NOI) and formally discontinued its efforts to relicense the Project. Subsequently, on June 28, 2019, Sonoma County Water Agency (Sonoma Water), Mendocino County Inland Water and Power Commission, County of Humboldt, and California Trout (collectively, NOI Parties) entered into a cooperative agreement to explore pathways to obtain a new license for the Project that meet eight shared objectives of the Two-Basin Solution and filed an NOI and Pre-Application Document to the FERC to file an application for a new license for the Project. The Round Valley Indian Tribes became a party to the agreement and a NOI Party shortly after the filing was made. As part of the agreement, and per the NOI filed with FERC, the NOI Parties have developed a Feasibility Study for the Project that will promote and advance the shared objectives. The work effort contained herein represents one component of that Feasibility Study.

1.2 Purpose

There are three central purposes of this Technical Memorandum:

1. Provide an overview of the existing infrastructure associated with the Project as it currently exists.
2. Develop high-level conceptual options to help meet the shared objectives under conditions of retaining, modifying or removing Scott Dam and/or Cape Horn dam(s). These options will help assess, along with the analyses conducted in associated technical memoranda, the feasibility of a Two-Basin Solution.
3. Provide a summary of high-level costs and risks associated with the existing facilities that will inform potential future options.

2 OVERVIEW OF EXISTING INFRASTRUCTURE

This section provides a review of existing infrastructure associated with the Project. The section focuses on the primary facilities that comprise the Project, including Scott Dam, Cape Horn Dam, the Van Arsdale Diversion structure and fish screens, the diversion tunnel and conduits, and the Potter Valley Powerhouse. This overview does not evaluate deficiencies or risks associated with existing Project infrastructure because the review of available information on existing Project infrastructure indicates that the project can continue to be safely operated with standard operations and maintenance practices.

A large portion of the information gathered from PG&E sources for the existing infrastructure assessment included Critical Energy/Electrical Infrastructure Information (CEII) designated by the FERC or the Secretary of the Department of Energy pursuant to section 215A(d) of the Federal Power Act. Per the FERC designation, CEII is specific engineering, vulnerability, or detailed design information about proposed or existing critical infrastructure (physical or virtual) that:

1. Relates details about the production, generation, transmission, or distribution of energy;
2. Could be useful to a person planning an attack on critical infrastructure;
3. Is exempt from mandatory disclosure under the Freedom of Information Act; and
4. Gives strategic information beyond the location of the critical infrastructure.

Specific descriptions and/or conclusions derivative to CEII or confidential PG&E information are not included in this Technical Memorandum to conform with Section 215A(d) of the Federal Power Act. In addition to the summary provided below, additional information on project facilities can be found in Chapter 4 of the Pre-Application Document (PG&E 2017).

2.1 Scott Dam

Scott Dam is located on the Eel River in Lake County, approximately 30 miles northeast of Ukiah, California. The reservoir created by Scott Dam (Lake Pillsbury) has an area of 2,308 acres and has a present-day maximum storage capacity of about 76,876 acre-ft and a usable storage capacity of 66,876 acre-feet (PG&E 2017). Scott Dam stores and releases seasonal runoff for power generation, minimum instream flow requirements, fisheries, water supply, and recreation. However, only power generation is listed as an authorized use under the existing FERC license. Releases are managed by the operator who is stationed at the Potter Valley Powerhouse, located approximately 14 miles from Scott Dam. Managed releases from the dam are generally between 70 to 300 cubic feet per second (cfs), and winter spills can exceed 30,000 cfs.

Scott Dam was constructed from 1920 to 1922. It is a concrete gravity dam that is approximately 805 feet long and 130 feet high. The original design of Scott Dam was modified during construction in 1920 when a large flood undermined a massive boulder that was intended to anchor the south dam abutment. The instability of this boulder required the dam design to add a deflecting angle on the south side of the river to avoid the unstable boulder and have the abutment key into a stable bank. In 1936, the apron was extended further by approximately eight feet with a flip bucket. The spillway training walls ("coping walls") were extended upwards with inward curving edges in 1936. A 28-foot-long concrete buttress was added to the apron in 1983, along with a 22-foot-long concrete apron extending downstream from the base of the new buttress.

2.1.1 Geology

Scott Dam is constructed across the Eel River at a constriction downstream of the wide Gravelly Valley and atop a tectonic lens of more competent strata within a sheared mélange. The mélange underlying the dam consists of an assemblage of shale, siltstone, and graywacke (a type of sandstone) with relict shear zones of clay and gouge derived from the ancient subduction zone. The abutments consist of a variable series of rocks, including graywacke, shale, meta-graywacke, and argillite.

The foundation geologic structure is broadly interpreted to be a series of bedrock strata in shear blocks or lenses that are bounded by shear zones; however, the complexity of the local structure and lack of distinct lithologic contacts are not well defined. Therefore, it is not possible to accurately project the geologic units across the dam.

2.1.2 Hydrology

Watershed hydrology above Scott Dam is captured by a network of gaging stations to monitor and record the storage and flow of water throughout the Project. Stations include a gage that measures reservoir elevation at Lake Pillsbury, three gages that measure diversion flows, two calculated diversion gages, and two gages that measure river flows below Scott and Cape Horn Dams. The hydrology of the Eel River watershed is typical of the Mediterranean climate on the north coast of California. Very large winter floods can occur during the late fall and winter, there is some snowmelt and seasonal spring runoff (although likely decreasing with future climate change), summer low flows, and fall freshets initiate the transition back into the winter high flow season. High flows can exceed 50,000 cfs, and summer baseflows can be below 15 cfs (Addley et al. 2019). Locations of key project infrastructure in the Eel and Russian River watersheds are shown in Figure 2-1. More hydrology information can be found in Section 3.2 of the Fisheries and Ecological Responses to Project Alternatives technical memorandum.

Project operations have typically been successful in meeting statutory flow requirements in the Eel River below Cape Horn Dam and release requirements to the East Branch Russian River as well as water supply obligations to Potter Valley Irrigation District. However, there are instances when PG&E has requested and received approval from FERC to temporarily modify either Eel River or Russian River minimum flow requirements. Because the release obligations are significant relative to the reservoir storage capacity, the reservoir is at risk of being drawn down to critically low levels if the reservoir does not fill in the spring and/or if refill is delayed due to a dry fall and early winter. Filling the reservoir in recent years has been challenging between the FERC license release obligations, delays in receiving DSOD permission to close the radial and slide gates that provide an additional 20,000 acre-feet of storage before April 1, and limited late spring inflow in drier water years. The FERC flow release variance requests fall into three categories:

- Short-duration flow modifications to conduct maintenance and/or testing of Project facilities;
- Medium-duration flow modifications to conduct capital improvements (e.g., wood stave conduit, tunnel repairs); and,
- Longer term (summer/fall) drought variance of minimum flow requirements due to dry water year conditions that cause low water storage projections at Lake Pillsbury in the fall (projected to draw down Lake Pillsbury <10,000 ac-ft minimum storage).

As an example, the temporary drought flow variance has been requested and approved by FERC in five of the eight years between 2013 to 2020, including:

- Drought flow variance starting in early December 2013
- Drought flow variance from January 2014 through March 2014
- Drought flow variance from June 2015 through December 2015
- Drought flow variance from July 2016 through October 2016
- Drought flow variance from April 2020 through October 2020

Project operations are modified by the drought variance to reduce summer diversions to the East Branch Russian River and/or reduce minimum flows to the Eel River. PVID also voluntarily transitions to a demand-based call for irrigation flows, which typically further reduces diversions to the East Branch Russian River. PG&E has been more proactive in requesting flow variances since 2014 to avoid the critically low levels Lake Pillsbury reached in 2014. PG&E analyses suggests that when reservoir levels drop below a water surface elevation of 1,773 feet (NGVD 1929 datum), there is increased risk of bank sloughing near the needle valve intake structure.

These examples underscore the real likelihood of multi-month, consecutive multi-year future drought variances that may be required under climate change, causing impacts to existing instream flow and water supply demands under existing FERC license requirements.

2.1.3 Operations and Maintenance

Scott Dam and Lake Pillsbury are operated to store and release seasonal runoff for power generation, minimum instream flow requirements, fisheries, water supply, and recreation. The Eel River main stem and Rice Fork of the Eel River are the two main sources of inflow for the reservoir, and there are no lakes or reservoirs upstream from Scott Dam. Spillway gates are normally closed between April 1 and November 1, and may be closed earlier than April 1 if PG&E receives approval from the Division of Safety of Dams. The spillway gates are fully open between November 1 and April 1 to accommodate flood flows. Releases from Scott Dam are managed by a roving operator, who visits the dam to operate some of the outlet controls and to provide routine maintenance and surveillance. The needle valve, Slide Gate #13, and one of the five radial gates can be remotely operated via SCADA contol. Other slide gates and radial gates must be managed on site by the operator.

Each year, starting in late winter, the reservoir is topped off and drawdown is forecasted by PG&E based upon expected inflows and the required minimum release schedules for all downstream needs as mandated in the FERC license conditions. As the year progresses, this storage forecast is updated at least monthly. A variety of hydrologic scenarios are included (ranging from very dry to very wet). If the reservoir storage forecast indicates that Lake Pillsbury is at risk of being drawn down to the minimum pool before December 31, the process for requesting a flow variance is initiated.

Non-flood releases must comply with the instream flow and ramping rate requirements of the FERC license, which may vary during the different months of the year and water year types. The FERC license minimum flow release requirements are typically 100 cfs from December 1 through May 31, to ensure adequate spawning and incubation for Chinook salmon and steelhead trout populations, and 60 cfs from June 1 through November 30. See PG&E (2017) Section 4.6 for further discussion of existing project operations.

2.1.4 Site Access

There are three primary access roads to Scott Dam: (1) Eel River Road (aka County Road) on the north side of the Eel River, (2) U.S. Forest Service Logging Road (i.e., Forest Route M8) on the south side of the Eel River, and (3) Elk Mountain Road, primarily to the north of the Eel River (Figure 2-1).

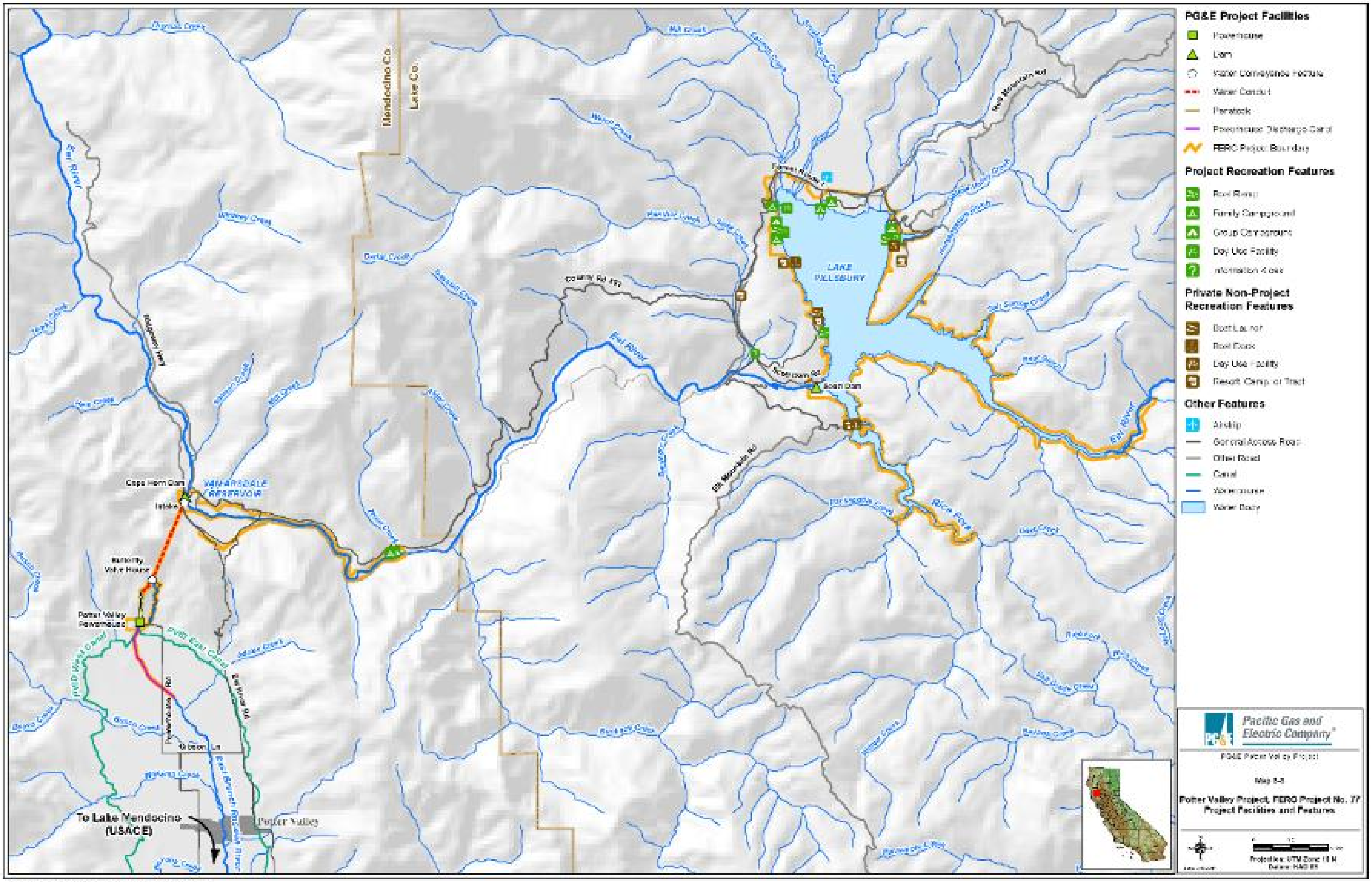

Figure 2-1. Geography and key access roads to Potter Valley Project infrastructure (modified from PG&E 2017).

Should major construction activities take place at Scott Dam (e.g., decommissioning, construction of fish passage facilities), construction access to the dam will likely need to be improved. This will require improvements to accommodate large track-mounted equipment that is either hauled or self-propelled to the site. In the case that construction activities take place near the south abutment of the dam, the existing access road to the south abutment may need to be rerouted. Alternatively, a barge system could be constructed on site and used for work near the south abutment, or to transport large equipment to that area.

Finally, the PG&E access road to the north abutment follows Soda Creek for about half a mile. This area of the access road is low-lying and adjacent to Soda Creek and quite near to the confluence with the Eel River. It is conceivable that the access road could become flooded, or potentially even washed out, during an extreme high-flow event on either the Eel River or Soda Creek.

2.1.5 Spillway

The 31-bay spillway is gated by five, 32-foot-wide by 10-foot-high, steel radial gates, and twenty-six 10-foot-high variable width (from 7.5 feet to 10.08 feet), steel slide gates. The spillway crest has a gross length of about 480 feet and a net length of 402 feet. When the spillway is activated, water converges rapidly in the spillway chute by curved training walls that begin above the spillway crest and terminate at the toe apron. The spillway chute terminates in an elevated lip. The apron was first extended in 1920 and then again in 1983. The river channel downstream is flanked by a concrete training wall on river right, extending over 125 feet downstream, and crib wall-retained rockfill on the river left.

2.2 Cape Horn Dam

Cape Horn Dam is a composite structure located on the Eel River in Mendocino County, California, approximately 23 miles northeast of Ukiah, California and 11 miles downstream of Scott Dam. Cape Horn Dam impounds Van Arsdale Reservoir and creates a forebay for the Van Arsdale Diversion.

Cape Horn Dam was constructed during the period 1905 to 1907 for the Snow Mountain Water and Power Company. In 1906 this company succeeded the original owners, the Eel River Power and Irrigation Company. In 1930, PG&E acquired the Project from Snow Mountain Water and Power and assumed the FERC hydropower license for the Project. Cape Horn Dam has upstream and limited downstream fish passage facilities, enabling salmon, steelhead, and Pacific lamprey to use the 11-mile reach between Cape Horn Dam and Scott Dam. Van Arsdale Reservoir has a surface area of about 65 acres. Original storage in Van Arsdale Reservoir was 1,140 acre-feet, but now storage is 390 acre-feet (PG&E 2017), so there has been approximately one million cubic yards of deposition in Van Arsdale Reservoir. Sediment is likely now routing through the reservoir in equilibrium. PG&E has historically dredged Van Arsdale Reservoir, but no longer performs dredging, rather lets sediment route on the inside of the river bend which maintains the diversion reliability.

2.2.1 Geology

Metavolcanic bedrock outcrops are seen continuously along the southwest bank of the river and in the channel. Terrace deposits overlie the bedrock on the northeast side of the river. Cape Horn Dam is located on a relatively competent part of a Franciscan metavolcanic formation in the Coast Range. The formation contains shale and metasiltstone layers, and limestone lenses, and minor amounts of serpentinized rock. The foundation rock, is a relatively strong metavolcanic of the Franciscan unit, is relatively massive and has resisted erosion well. This rock outcrops prominently on the west side of the river.

2.2.2 Operations and Maintenance

Cape Horn Dam serves three primary purposes, including:

1. Providing sufficient head on the Van Arsdale diversion;
2. Providing fish passage over Cape Horn Dam; and
3. Regulates minimum instream flows to the Eel River.

The provision of adequate head on the diversion is performed passively based on the elevation of the dam crest relative to the tunnel inlet. Provided that diverted flow rates through the tunnel are less than the total river flows entering Van Arsdale Reservoir, which they are operationally, the submergence on the tunnel is assured by the minimum backwater depth from the dam. This minimum depth of water on the tunnel is sufficient not only to convey the target flow rate through the tunnel, but also to do so without the formation of vortices, thereby suppressing significant air entrainment.

Cape Horn Dam has both upstream and downstream fish passage facilities, enabling salmon, steelhead, and Pacific lamprey to use the reach between Cape Horn and Scott Dam. The fish passage facilities were operated by the California Department of Fish and Wildlife (CDFW) until 2020, but are now operated by PG&E.

The project license establishes a very complex regime of minimum flows of the Eel River below Cape Horn Dam to support anadromous fish. The requirements are computed as an index flow subject to floor and cap limitations. See PG&E (2017) Section 4.7 for further discussion of existing project's instream flow operations.

2.2.3 Spillway

The spillway is an overflow structure with flashboards that can be installed seasonally (however, flashboards are no longer used by PG&E). Rating curves for the spillway with flashboards and without flashboards were developed in 1983. The spillway has adequate hydraulic capacity to pass all flood events up to and including the probable maximum flood.

2.3 Cape Horn Dam Fish Passage Facility

Cape Horn Dam has both upstream and limited downstream fish passage facilities, enabling salmon and steelhead to pass the dam. In addition, a recent temporary structure has been added that enables Pacific lamprey much improved upstream passage. Historically, staff from CDFW operated and maintained the facility. Those responsibilities were transitioned over to PG&E in 2020. Figure 2-2 presents a general overview of Cape Horn Dam fish passage facilities.

Figure 2-2. Cape Horn Dam Fish Passage Facility (Aerial Image Source: Google Earth).

2.3.1 Cape Horn Dam Downstream Fish Passage

Downstream fish passage is provided through two 2-foot wide by 4-foot tall remotely operated hydraulic roller gates located on a modified section of the dam crest at elevation 1,484.80 feet (5.5 feet below the dam crest; NGVD 1929 datum). This section is called the high-level fish water release. There is no guidance net system to this section. The gates can release up to 124 cfs total. The purpose of the release structure, which was built in 1987, is to provide a controlled fish and water release and to safely pass juvenile fish from Van Arsdale Reservoir downstream of the dam. When using the high-level fish water release, fish enter a steep concrete flume, and are projected over the concrete steps of the dam into a deep receiving pool located between the fish hotel and the toe of the dam. Once in that pool, fish need to negotiate one more step (i.e., upstream fish barrier) at the fish hotel with a 11.5-foot vertical drop barrier. When the vertical drop is negotiated, juvenile fish can then continue their journey downstream to the ocean.

For higher flow events (>124 cfs), most downstream migrating fish likely pass over the concrete overflow section of the dam and fall down the concrete steps that form the downstream face of Cape Horn Dam. When flow starts rising above the crest of the dam, there is very limited water depth over the concrete steps, potentially leading to juvenile fish impacting with the concrete steps. As the water level continues rising, water depth increases on each concrete step, leading to less degree of fish impact on the concrete during downstream passage. Similar to the low flow condition, after passing Cape Horn Dam, fish still need to negotiate the 11.5-foot vertical drop of the fish barrier at the fish hotel.

Some fish could pass downstream of the dam and the fish barrier by negotiating the upstream fishway. However, the upstream fishway has limited attraction flows and therefore potential migration delay, predation at and upstream of the fishway, and an existing fish trapping system located within the upstream fishway that may cause confusion to downstream migrating fish. Therefore, it is unlikely that many fish successfully navigate the upstream fishway for downstream passage.

The following elevations (NGVD 1929 datum) are important for discussion of potential Cape Horn Dam fish passage improvements in Section 3.3:

- Van Arsdale normal water surface elevation (no flash boards): 1,494.3 ft
- Top of concrete fish barrier: 1,461.0 ft
- Normal water level above the fish barrier: 1,459.7 ft
- Normal water level below the fish barrier: 1,449.5 ft
- Invert of high-level fish water release: 1,484.80 ft
- Invert of Eel River below fish barrier: 1433.1 ft
- Vertical fall between invert of the high-level fish water release and normal water level above the fish barrier: 26.6 ft
- Vertical fall between normal water level above and below the fish barrier: 11.5 ft

During low flow conditions, the vertical drop at the high-level fish water release and at the fish barrier are high (26.6 and 11.5 feet, respectively), and the impact velocity criteria is likely exceeded, which could stun fish and leave them vulnerable to predation. In addition, for recovered fish or fish that did not get stunned, they can become disoriented in the pool between the dam and the fish barrier, resulting in delay in migration and susceptibility to predation.

2.3.2 Cape Horn Dam Upstream Fish Passage

Before evaluating the facility, it is important to know the target fish species and their physiological limitations. The target species are Steelhead Trout (*Oncorhynchus mykiss*), Chinook Salmon (*Oncorhynchus tshawytscha*), and Pacific Lamprey (*Entosphenus tridentatus*). Sacramento Sucker (*Catostomus occidentalis*) is a native fish also of importance but will be considered a lower priority than the anadromous fish. Table 2-1. Swimming speed by species.presents the swimming speeds for the fish species listed above.

Table 2-1. Swimming speed by species.

Species	Sustained Speed (ft/s)	Burst Speed (ft/s)	Recommended Passage Velocity (ft/s)
Steelhead Trout	4.6-13.8[1,2]	13.8-26.5[1,2]	1.5-4.0[3,4,5]
Chinook Salmon	3.4-10.8[1,2]	22.4[1,2]	1.5-4.0[3,4,5]
Pacific Lamprey	0.5-2.0[6]	2.0-3.6[6]	<2.5
Sacramento Sucker	1.4[7]	2.8[7]	<2.8

Notes: ft/s – feet per second

[1] Bjornn, T.C. and D.W. Reiser 1991. Habitat Requirements of Salmonids in Streams Chapter 4 pages 83-138 in Meahan, W. editor. Influences of Forest and Rangeland Management of Salmonid Fishes and Their Habitat. American Fisheries Society Special Publication 10.

[2] NMFS (2008) Anadromous Salmonid Passage Facility Design, Section 10.2.1. Recommended velocities for Columbia and Snake River Fish Passage Facilities for upstream passage of juvenile salmon: 1.5 - 2.5 fps for 46-65 mm juveniles, 3 - 4.5 fps for 80-100 mm juveniles

[3] Recommended average maximum velocities for fish passage facilities. For structures with longer lengths (e.g., culverts and bifurcation structures under certain conditions) use NMFS Table 7.1

[4] NMFS 2001. Guidelines for Salmonid Passage at Stream Crossings - September 2001

[5] NMFS 2011, Anadromous Salmonid Passage Facility Design, National Marine Fisheries Service Northwest Region, July 2011. Section 4.2.2.12

[6] Moursund, R.A., D.D. Dauble, and M.J. Langeslay. 2003. Turbine intake diversion screens: investigating effects on Pacific lamprey. Hydro Review. 40-46pp.

[7] Myrick Christopher and Cech Joseph, 2000. Swimming performances of four California stream Fishes: Temperature effects. Environmental Biology of Fishes pp 289-295

There is a high variability in swimming speeds for those fish listed in Table 2-1**.** Steelhead and Chinook are the stronger swimmers. Pacific lamprey, while not the best swimmers, have a strong suction capacity and can negotiate near-vertical falls. The Sacramento Sucker is a weak swimmer and cannot negotiate passage the same way as Pacific lamprey or salmon. Were Sacramento Sucker to be considered, the hydraulic drop per pool in the fish ladder would need to be reduced from one foot down to about six inches.

The upstream fish passage facility is located on the west embankment/abutment. The fish ladder entrance is located downstream of the fish barrier, which itself is located approximately 90 feet downstream of the Cape Horn Dam, and is susceptible to clogging during high flow (i.e., wood debris and sediment will fill the lower pools). During high flow events where sediment and wood debris deposits, the facility becomes inoperable until cleaned out. This usually occurs during the steelhead migration period. The area between the dam and the fish barrier serves the following purposes: (1) energy dissipation, (2) reduction of vertical separation difference between the Van Arsdale Reservoir pool elevation and the Eel River water surface elevation by creating an intermediate step, and (3) improvement of conditions for upstream migrant fish to more readily locate the entrance(s) to the upstream fish ladder. Figure 2-3 presents a general plan of the upstream fish passage at Cape Horn.

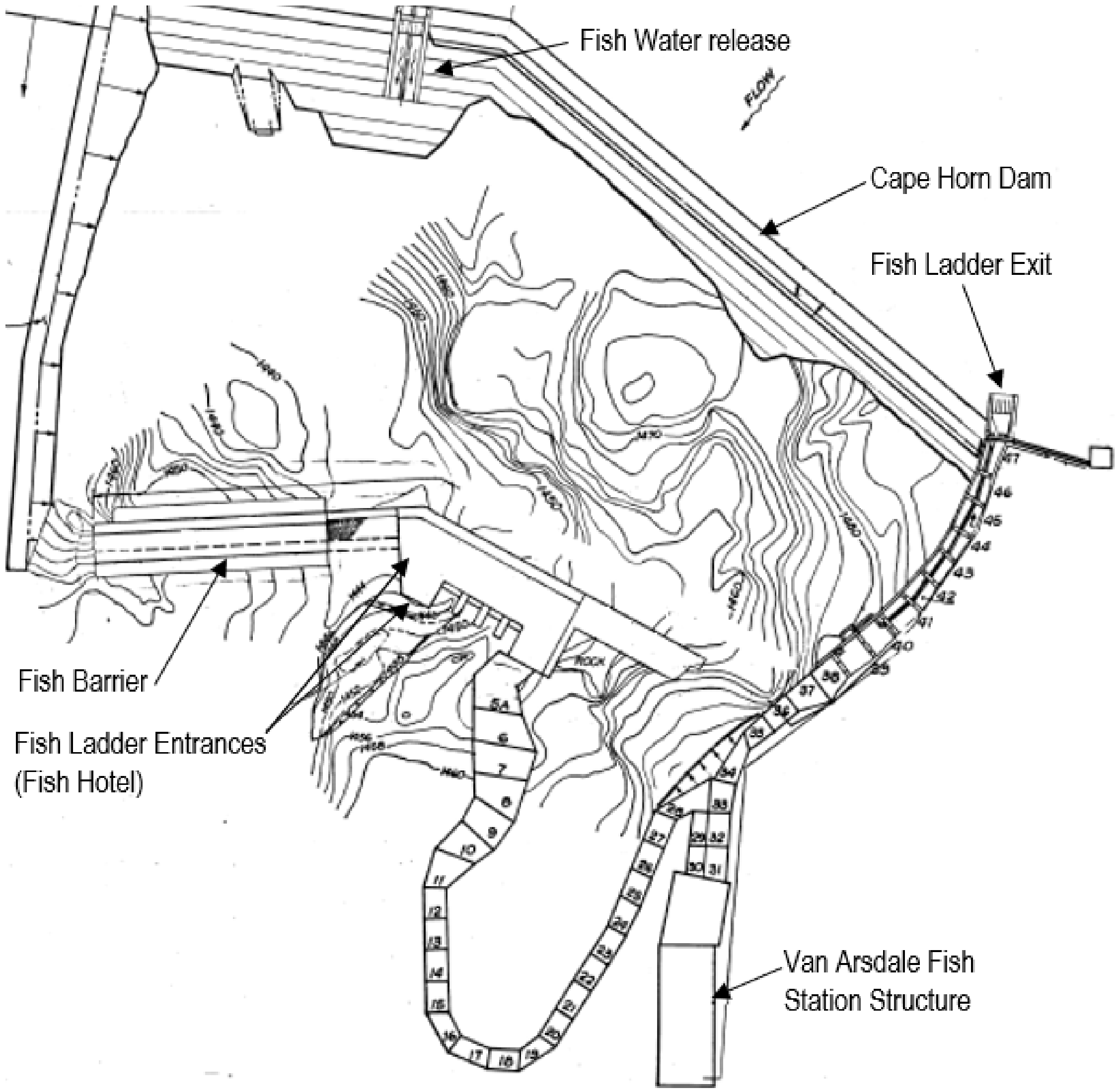

Figure 2-3. Cape Horn Dam upstream fish passage.

The fish ladder has different sections and does not have standard pools with a uniform cross section. The fish ladder has a total of 47 pools, 9 of which have a submerged orifice only (i.e., no weirs, all of the flow goes underneath through the orifices). The lower pools downstream of the Van Arsdale Fish Station (the Station) and up to Pool 38 are pool and weir ladder type with variable length, width, and depth, to accommodate the bedrock contour upon which that portion of the fish ladder is founded. Those pools have only weir flow and no orifice. The pool width and depth vary, but the average width is 6’-6”, with a weir length/width of approximately 4’-0”. The pool length is not provided but is estimated to be an average of 9’-4”. Water depth also seems to vary. Each weir is equipped with an 18-inch-tall wooden weir board. The water depth over each wooden weir board is estimated to be 1 foot. The minimum freeboard (height between water surface and the top of fish ladder walls) in the fish ladder pools is 3 feet per the design drawings. However, the freeboard was observed to be significantly less in the lower pools during a field visit in 2020. For example, the freeboard in pool 5 (located just upstream of the fish ladder entrance structure) has about 1 inch of freeboard. This is important for a few reasons: 1) it does not meet criteria; standard freeboard is typically at least 3 feet, 2) fish can jump out of the ladder and land on the dry ground where they will perish, and 3) increases predation potential, as predator have an easy access in and out of the ladder.

The fish ladder entrance structure (also known as the Fish Hotel) has three gated entrances with invert elevations at 1,444.0 feet, 1,447.5 feet and 1,449.0 feet, plus an extra pool. The slide gates for these entrances are manually operated. The entrances are 3 feet wide by 5 feet high. Within the Fish Hotel, stop log slots are provided to create additional pools and to address variable tailrace water surface elevations. However, there is no means by which to easily install or retrieve stop logs. The ladder exit is located adjacent to the west bank of the dam.

Based on a field visit conducted in January 2020, and in conversations with staff from PG&E, the following additional observations were made regarding the Fish Hotel:

- The Fish Hotel is overtopped about every ten years, or at a flow of around 4,500 cfs.
- At about 10,000 cfs, the Fish Hotel is completely under water.
- Dredging of the Fish Hotel happened twice in 2017 and once in 2019 causing a prolonged shutdown of the fish ladder. Bedload and wood debris filled the facility, likely due to both horizontal and vertical eddies that form at high flow.
- PG&E completed a capital improvement project in fall 2020 that installed operable gates at the fish hotel that can be closed immediately before high flow events to help prevent bedload and wood debris from entering the facility.

Attraction flow is a combination of ladder flow and auxiliary water supply (AWS) flow. The fish ladder flow ranges from 5 to 12 cfs (9-12 cfs, typical) and is controlled by a hydraulically operated slide gate at the headwall (i.e., fish ladder exit) at the west side of Cape Horn Dam. It is noted that the flow in the ladder between the lower section below the Station and the upper section above the Station is different as the Van Arsdale Diversion tunnel intake bypass drains into pool 28 and adds approximately 2 cfs. The fish ladder flow was calculated and seems to be closer to 13.3 cfs in the upper pools and 15.3 cfs in the lower pools (see Appendix 1). At a ladder flow of 12 cfs and an AWS flow of 88 cfs, the total attraction flow could be approximately 100 cfs. The AWS flow is supplied through the intake screens located on top of the fish barrier and four 24-inch diameter drop inlets, adding flow to the fishway entrance structure and mixing with the ladder flow through a wall diffuser. The AWS is gated and therefore can be adjusted, though it is not believed that any adjustments are made.

The Van Arsdale Fish Station straddles pools 30 and 31 and has been used in the past to collect eggs from adult Steelhead trout. Steelhead trout were automatically trapped with a finger weir as they ascended the fish ladder. The Station consists of a large tank for holding adult Steelhead trout, a residence for the CDFW attendant, and sufficient incubators to eye eggs for shipment. The Station has provided a dependable source of Steelhead trout eggs since 1907; however, CDFW closed the egg collection function of the Station approximately 15 to 20 years ago. In 2020, CDFW ended their operation of the Station and transferred operations to PG&E.
Pool 30 is equipped with a motion sensor video camera to enumerate and determine the sex of the fish at the finger weir. The Station is periodically used for genetics and passive integrated transponder (PIT)-tagging studies; thus, the fish ladder is equipped with PIT-tag detection.

The upstream fish passage facility is also outfitted with Pacific lamprey passage tubes, installed by USFWS and CDFW in 2016. The tubes, which are made from roughly 6- to 8-inch diameter flexible hosing, run from the entrance pool to the fish ladder exit. Flexible hosing is used to approximately pool 40, at which point rigid PVC pipes are used for the rest of the ladder, up to the exit. At the exit of the tubes, Pacific lamprey fall approximately 10 feet into the exit pool. Some portions of the flexible tube are near-vertical for approximately 10 feet. According to staff at both PG&E and CDFW, this installation is working well, and Pacific lamprey ascend the ladder in a matter of hours (Goodman, USFWS, pers. Comm.). It is hypothesized that Pacific lamprey are otherwise taking days or weeks to ascend the upstream fish ladder simply because the lower pools (i.e., approximately 35 pools) are not equipped with orifices. Thus, without the tubes, Pacific lamprey could need to overcome each weir (many vertical faces; sharp angles), which may force them to break suction and thus become vulnerable to fallback. The Pacific lamprey tube installation works very well but could be upgraded to reflect a more permanent solution that is also resilient to debris deposition at the fish hotel.

2.3.3 Summary of Cape Horn Dam Fish Passage Condition Assessment

The following sections provide an assessment of the Cape Horn Dam Fish Passage Facility (Facility) in terms of applicable regulations, current operations and maintenance requirements, and other risks associated with the facility. The following section also summarizes the areas of the Facility that are out of compliance with applicable fish passage regulations and the risks associated with other aspects of the Facility. In addition to some areas that are out of compliance with specific fish passage design criteria, after high flows sedimentation and debris accumulation cause the facility to shut down, causing periods of non-compliance (Table 2-2). Table 2-3 summarizes adult migration and the smolt outmigration windows for Chinook Salmon (fall-run) and Steelhead (summer run and winter run). Table 2-4 presents an overview of the criteria evaluation against the NMFS Anadromous Salmonid Passage Facility Design (NMFS 2011) for downstream fish passage, while Table 2-5 presents an evaluation based on upstream fish passage design criteria.

Table 2-2. Summary of Cape Horn Dam fish ladder outages for water year 2013-2019 due to sediment/woody debris deposition in Fish Hotel and lower fish ladder (from PG&E 2020).

Water Year	Outage event for water year	Beginning outage	Duration of fish passage outage (days)	Species impacted (*Italic* is primary species impacted; non-italic is secondary)
2013	1	12/2/2012	4	*Chinook salmon*, winter-run steelhead
2014	1	3/29/2014	6	*Winter-run steelhead*, summer-run steelhead
2015	1	12/11/2014	5	*Chinook salmon*, winter-run steelhead
2016	1	1/17/2016	6	*Winter-run steelhead*
	2	3/7/2016	3	*Winter-run steelhead*
	3	3/13/2016	4	*Winter-run steelhead*
2017	1	12/10/2016	10	*Chinook salmon*, winter-run steelhead
	2	1/8/2017	24	*Winter-run steelhead*
	3	2/9/2017	20	*Winter-run steelhead*
2018	1	4/7/2018	3	*Winter-run steelhead*, summer-run steelhead
2019	1	1/16/2019	9	*Winter-run steelhead*
	2	2/13/2019	8	*Winter-run steelhead*
	3	2/24/2019	21	*Winter-run steelhead*

Table 2-3. Adult Migration and Smolt Outmigration for Chinook Salmon and Steelhead from the Potential Ecosystem and Fisheries Responses to Project Alternatives Technical Memorandum.

Species	Life Stage	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon Fall-run	Adult Migration												
	Smolt Outmigration												
Steelhead (Summer-run and Winter-run)	Adult Migration (Winter-run)												
	Adult Migration (Summer-run)												
	Smolt Outmigration												
	Kelt (Adult) Outmigration												

Per VTN 1982, SEC 1998, CDFW, unpublished VAFS count data, Beak 1986 and Moyle et al. Per VTN (1982), SEC (1998), CDFW, unpublished VAFS count data, Beak (1986) and Moyle et al. (2017).

Table 2-4. Cape Horn Downstream Fish Passage Facility Assessment.

Description	NMFS Design Criteria	Assessment
Location	11.9.4.1. Outfalls must be located where the receiving water is of sufficient depth.	Per construction photo evaluation, sufficient water depth is assumed. In addition, the tailwater level is maintained due to the fish barrier construction.
Impact Velocity	11.9.4.2. Maximum impact velocity […] should be less than 25 ft/s.	Due to the vertical drop the impact velocity is always exceeded even at low flow. Does not meet criterion.
Flume Velocity	11.9.3.8 […] should be between 6 and 12 ft/s.	The flume velocity is within criteria for flows below 10 cfs and much greater the rest of the time. The gated flumes can pass up to 124 cfs. Does not always meet criterion.
Discharge and Attraction of Adult Fish	11.9.4.3 […] designed to avoid attraction of adult fish.	Due to the fish barrier adult fish are not attracted to the discharge flow. Meets criterion.
Vertical Drop Structure Minimum Height	5.5.2.1. must be 10 feet relative to the high design flow elevation in the tailrace.	The normal water level upstream of the barrier is 1,459.75 feet, while the normal water level in the tailrace is 1,449.50 feet. This equates to 10.25 feet at the normal design flow. While we do not know the drop height during high design flow, it is assumed that fish that could potentially pass the barrier would then be prevented from navigating upstream of Cape Horn Dam. Due to the vertical drop, it is assumed that impact velocity at the fish barrier is exceeded.

Notes: ft/s – feet per second

Table 2-5. Upstream assessment of Cape Horn Upstream Fish Passage Facility.

Description	NMFS Design Criteria	Assessment
Maximum Hydraulic Drop Between Fish Ladder Pools	4.5.3.1. must be 1 foot or less.	It is estimated to be 1-foot. Meets criteria.
Flow Depth	4.5.3.2. 1 foot of depth over the weir crest.	It is estimated to be 1-foot. Meets criteria.
Pool Dimension	4.5.3.3. Minimum of 8 feet long, 6 feet wide and 5 feet deep	The average pool length is 9'-4" and the average pool width is 6'-6", though about 22 of them are only about 4'-6" wide; however, no information could be found about minimum pool depth, and it is assumed that the pool depth criterion is not met– Typical section thru fish ladder). It is assumed **this criterion is not met**.
Turning Pools	4.5.3.4. length should be double of a standard fishway pool where the fishway bends more than 90 degree.	This could apply to pools 28, 30 and 31. Pool 28 is longer but not significantly. Pools 30 and 31 are part of the Station collection and are much longer than needed (~60 ft) It is assumed that **pool 28 does not meet this criterion**.
Pool Volume	4.5.3.5. the minimum water volume should be such that the energy dissipation factor of 4 ft-lb/sec.	The energy dissipation was calculated. Because of the variation in flow and pool size, some pool volume is sufficient while other (most) is insufficient, and the energy dissipation factor is exceeded. **This criterion is therefore not met.**
Freeboard	4.5.3.6 at least 3 feet at high design flow.	While the minimum freeboard is met in most pools, the lower ladder pools (say pool 5 through 15) have between 1-inch of freeboard to 2 feet). **This criterion is not consistently met.**
Lighting	4.5.3.8 ambient lighting is preferred, and, in all cases, abrupt lighting changes must be avoided.	Ambient lighting is provided throughout the fish ladder. At the fishway entrances five large openings above elevation 1,458.0 feet provide ambient lighting. Meets criterion
Change in flow Direction	4.5.3.9 where the flow changes direction more than 60 deg, 45deg vertical miters or a 2-foot vertical radius of curvature must be included.	This could apply to pool 28. **The criterion is not met.** The vertical corner is not mitered, nor does it have a vertical radius.
Design Low Flow	3.2 design low flow is the mean daily average streamflow that is exceeded 95% of the time.	Between 26 and 53 cfs for the fall run migration for Chinook and winter run migration for Steelhead, respectively.
Design High Flow	3.3 design high flow is the mean daily average streamflow that is exceeded 5% of the time.	Between 1,695 and 4,514 cfs for the fall run migration for Chinook and winter run migration for Steelhead, respectively.
Fishway Entrance Location	4.2.2.2 must be located at points where fish can easily locate the attraction flow and enter the fishway.	With the fish barrier, the fishway entrances are located at the upstream terminus. Meets Criteria.

Description	NMFS Design Criteria	Assessment
Attraction Flow	4.2.2.3. should be between 5% and 10% of the design high flow	The design high flow is between 1,695 and 4,514 cfs. The 5% is thus varying from 84 cfs to 225.7 cfs. The attraction flow is 100 cfs (i.e., 88 cfs from the AWS system and 12 cfs from the ladder flow). The attraction flow while low is within acceptable ranges.
Fishway Entrance Hydraulic Drop	4.2.2.4 must be maintained between 1 and 1.5 feet and designed to operate from 0.5 to 2.0 feet of hydraulic drop	It is assumed that the hydraulic drop at the fishway entrance is 1-foot. However, this hydraulic drop the maximum entrance velocity (typically taken as 6 ft/s) is exceeded. In addition, with the entrance gates being operated manually. It is assumed that **optimum entrance conditions are not met.**
Fishway Entrance Dimensions	4.2.2.5 width should be 4 feet, and the entrance depth should be at least 6 feet.	All entrances are 3 feet wide by 5 feet tall. While **this criterion is not met**, the entrance size is directly dependent on the attraction flow, low and high design flow, and hydraulic drop. The fishway entrance dimensions may be acceptable if the other parameters are met. The calculated entrance velocity was found to be 6.6 ft/s (which is greater than typical maximum entrance velocity).
Additional Entrances	4.2.2.6 if the site has multiple zones where fish accumulate, each zone should have a minimum of one entrance.	The fishway has three entrances, all located at the upstream terminus. Meets criteria.
Flow Conditions	4.2.2.8 streaming flow	The flow condition through the fishway entrances is streaming flow (i.e., not plunging). Meets criteria
Fishway Entrance Orientation	4.2.2.9 low flow entrances should be oriented nearly perpendicular to streamflow and high flow entrances should be oriented to be more parallel to streamflow.	Entrance 1 (invert elevation 1,444.0 feet) for low flow is oriented perpendicular to the flow; Entrances 2 and 3 (invert elevations 1,447.5 ft and 1,449.0 ft, respectively) for high flow are oriented parallel to the flow. Meets criteria.
Entrance Pools	4.2.2.11 the entrance pool combines ladder flow with AWS flow through diffuser gratings to form entrance attraction flow.	No information is provided on the diffuser material and size in the drawings. The AWS diffuser velocity was calculated and seems to be less than the maximum 1.0 ft/s for vertical diffusers. Assumed to meet criteria.
Transport Velocity	4.2.2.12 Transport velocities between the fishway entrance and first fishway weir […] must be between 1.5 and 4.0 ft/s.	This criterion was observed in the field and seems to meet criteria.

In the absence of better information, the Fish Passage Working Group of the Jared Huffman Ad Hoc Committee had assumed that the Cape Horn Dam fishway is functioning at current regulatory standards (CDFW and NMFS), effectively passing fish upstream and downstream. However, while the upstream and downstream fishways meet some criteria, some criteria are not met. Of primary importance is solving the sediment / debris plugging that causes the Facility to shut down during the steelhead migration window. Full compliance with NMFS fish passage design criteria may require more accommodations for safe downstream passage. The development of a downstream passage design is discussed below in Section 3.3.1.

For the upstream fish passage facility, it is expected that some modifications will be required to meet NMFS fish passage criteria. Upgrades would be necessary to meet CDFW and/or NMFS criteria including modifications to avoid the vertical drop over the Fish Hotel, lengthening of Pool 28, adding mitered corners in Pool 28, modifications to pool volumes, modifications to the fish ladder to reduce entrance velocities and increase entrance dimensions, and further modifications to allow fish passage after large flood events (rather than plugging of the fish ladder with debris and sediment). In addition, replacement of the existing lamprey tube installation with a more permanent solution that is also resilient to debris deposition at the fish hotel would improve reliability of Pacific lamprey passage.

2.4 Potter Valley Project Diversion Facility

This section presents a general description of the existing Van Arsdale Diversion facility, which includes the Van Arsdale diversion structure, tunnels, conduits, and penstocks, and discusses their operation, in addition to providing an assessment of their current condition and any known risks associated with their future operations and maintenance.

The following sub-sections provide general descriptions of the Van Arsdale Diversion structure facility and the tunnel, wood stave conduit and penstock system that diverts water from the Eel River to the Potter Valley Powerhouse and the East Branch Russian River. A discussion of typical operations and maintenance is also provided. Figure 2-4 shows the conduits and infrastructure near the Potter Valley Powerhouse.

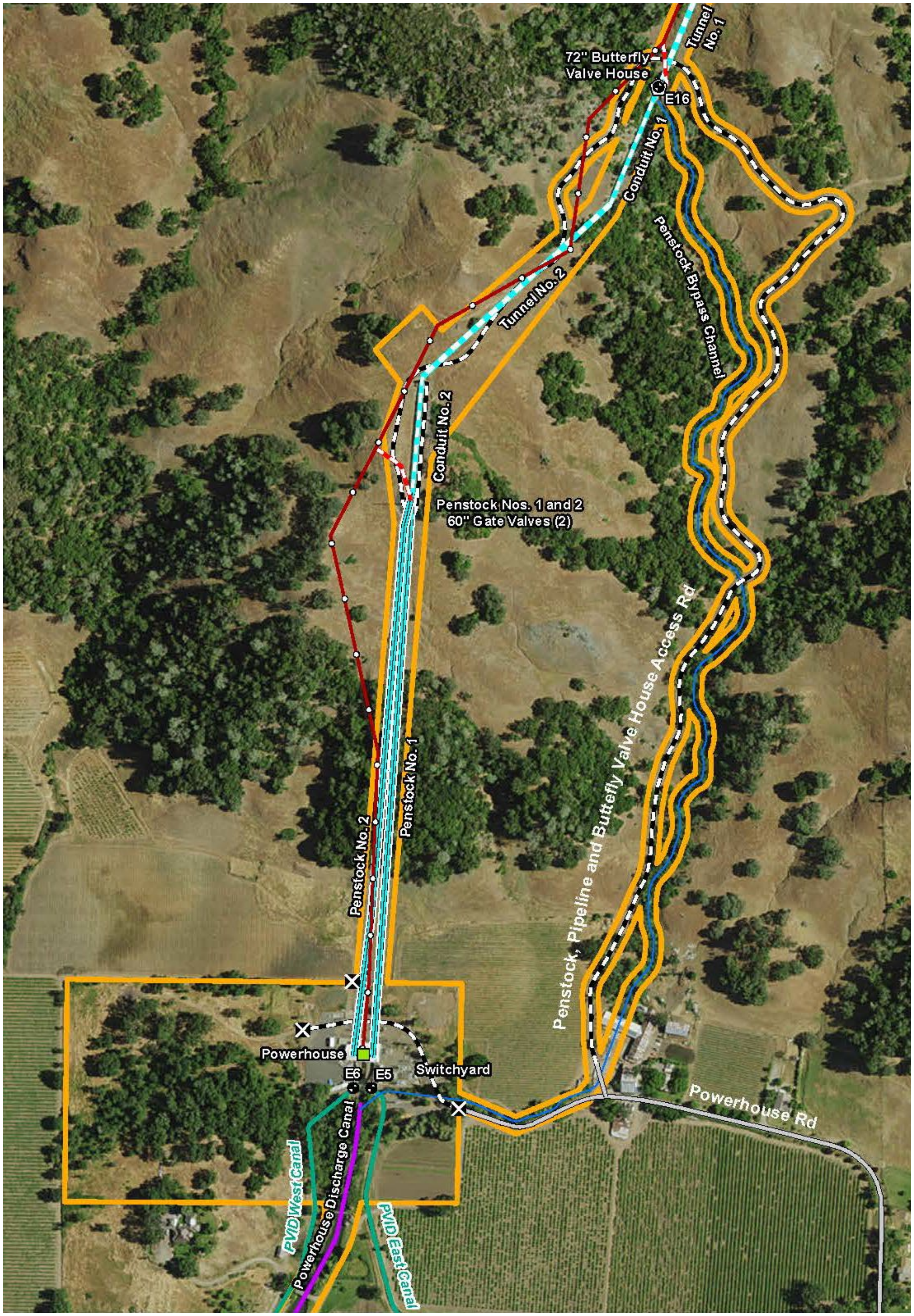

Figure 2-4. Potter Valley Powerhouse, Penstock Bypass Channel and Powerhouse Discharge Canal (from PG&E 2017).

2.4.1 Van Arsdale Diversion Structure

The Van Arsdale Diversion is a critical feature of the Project, because its primary goal is to reliably divert and convey water to the powerhouse in Potter Valley. Therefore, it must also screen debris and fish from entering the tunnel, penstocks and turbines. Cape Horn Dam serves as a forebay for the diversion of as much as 320 cfs to the powerhouse. However, the fish screens have been "derated" and can pass only a maximum of 240 cfs (PG&E 2017).

The Van Arsdale Diversion diverts water from the southwest bank of the Eel River approximately 400 feet upstream of Cape Horn Dam and conveys it to the Potter Valley Powerhouse, approximately 1¾ miles to the south. At the entrance to the diversion tunnel, the intake consists of an inclined trash rack equipped with a trash rake, two fish screen bays, an inclined plane fish screen in each bay, a 10-foot diameter Archimedes screw pump, a fish return channel, and a bypass pipe.

The fish return channel leads to a secondary fish screen which reduces the fish return flow from 4 cfs to 2 cfs. The secondary fish screen discharges into the Cape Horn Dam Forebay. This reduced 2 cfs flow carries screened fish through a series of fish return pipes to a half-round ogee spillway and a baffled flume, where it discharges into the fish ladder just downstream of the Van Arsdale Fish Station structure. A fish return pipe discharging into an upstream fish ladder is both uncommon and problematic, due to: 1) the flow within the fish ladder changes with the operation of the Archemedes screw lifts, which changes the hydraulics and could create delay in fish passage, 2) releasing debris in the ladder could create injury to fish and could potentially result in debris accumulation in the Fish Hotel), 3) it creates delay to downstream migration as juvenile fish are not passed downstream of the dam, but only a portion of it, after which they need to navigate the rest, and 4) upstream steelhead migrants could feed on juvenile fish.

Each of the inclined-plane fish screens is approximately 82 feet long and 8 feet wide and is composed of wedge wire screening material with 1/8-inch slotted openings. The screens are cleaned by an automated compressed air sparging system that blows debris off the screens from below. The debris is then carried by water flowing over the top of the screens to the fish bypass system. The fish screens were constructed in 1994–1995 and went into operation in December 1995. Following the initial period of operation, Steiner Environmental Consulting (SEC) conducted a series of flow and fish passage acceptance tests of the screens from February through June 1996 (SEC 1996). These tests were conducted to determine if the screens satisfied specific and general guidelines that had been developed by PG&E, California Department of Fish and Wildlife (CDFW), NMFS, and U.S. Fish and Wildlife Service (USFWS). The results of the tests indicated that the screens met the majority of the acceptance criteria (SEC 1996). Issues that were identified as needing attention to fully satisfy the acceptance criteria were later addressed.

The fish screens and fish return system remain in continuous operation from October through July, except during periods of high runoff when flows are 7,000 cfs or greater, at which time diversion is ceased to avoid damage to the screens. During August and September, the fish screens and the return system may be taken out of service for maintenance as long as entrainment below the powerhouse is monitored one day (24-hour duration) per week when the diversion is unscreened to document the absence of fish. Typically, one screen is taken off-line at a time to be cleaned, allowing diversion to occur through the other screen, and thus avoiding fish entrainment. Continuous and regular annual maintenance activities can last as long as 17 days (PG&E 2020), with corresponding reductions in total water diverted to the Potter Valley during those periods.

The air sparging system was observed to be working during the January 23rd, 2020 site visit. However, air sparging alone does not seem to be sufficient as PG&E performs annual maintenance to clean the screen manually. It was noted during the site visit that some fish passage engineers believe that the air sparging system may be contributing to algae growth (that can only be removed by brushing). Algal blooms upstream of Cape Horn Dam have been noted as a water quality problem in the past (Asarian and Higgins 2018), as evidenced in Figure 2-5.

Figure 2-5. View of Van Arsdale Reservoir during an algal bloom.

In addition to routine outages consisting of inspections and maintenance of the fish screen equipment and fish return channel, non-routine outages are sometimes prevalent at the facility. As an example, in 2019, seven non-routine outages occurred that lasted a combined 70 days. Reasons for these non-routine outages were centered around issues with the screw pump.

2.4.2 Diversion Tunnels, Conduits, and Penstocks

In addition to the diversion structure itself, the Van Arsdale Diversion facility is composed of the following elements (PG&E 2017):

- Tunnel 1: Tunnel 1 connects with the Van Arsdale Diversion structure and is a 5,826-foot long, 7’-2” high by 6’-0” wide bottom and 5’-0” wide top, timber-lined tunnel with a 6’-0” x 6’-6” electric motor-operated slide gate. The tunnel grades downward to the south at approximately 0.3 percent.
- Conduit 1: This is an approximate 7-foot diameter steel and wooden stave pipeline that connects Tunnel 1 and Tunnel 2. It consists of the following:
    - 50-foot length steel pipe;

    - 72-inch hydraulic cylinder-operated butterfly valve;
    - 367-foot long, 7 ft diameter wood stave conduit; and
    - A 39-foot-long steel pipe transition to Tunnel 2, from 7-7.25 ft diameter.
- Tunnel 2: This section of tunnel is approximately 807-feet long, circular, and has sections that are steel-lined and concrete- and steel-lined, with diameters that vary from 7'-0" to 7'-3".
- Conduit 2: This section of conduit connects Tunnel 2 to the Potter Valley Powerhouse penstocks and is 367 ft long. Conduit 2 consists of:
    - An 8-foot length of steel pipe transition, 7-7.25 ft diameter;
    - A wood stave conduit, 7 ft diameter by 359-foot long; and,
    - Two 60-inch diameter gate valves.
- Potter Valley Powerhouse Penstocks 1 and 2: These penstocks connect Conduit 2 to the Potter Valley Powerhouse Units 1, 3, and 4, and consist of:
    - Penstock 1: A buried steel pipe, 62- to 48-inch diameter, 1,793-foot long, supplying Unit 1; and,
    - Penstock 2: A buried steel pipe, 62- to 48-inch diameter, 1,812-foot long, supplying Unit 4.

Normal operations include diverting water from Van Arsdale Reservoir through the diversion screens, tunnels, conduits and penstocks to the Potter Valley Powerhouse to generate power and deliver water to PVID for agricultural use. Excess diversion water is routed down the East Branch Russian River, some of which is used for downstream Russian River water needs.

2.4.3 Summary of Diversion Facility Condition Assessment for Fish Passage

The following section presents an overview of the evaluation of the diversion facility against NMFS diversion and bypass design criteria (Table 2-6).

Table 2-6. Assessment of Van Arsdale Diversion Facility with National Marine Fisheries Service (NMFS) design criteria.

Description	NMFS Criteria	Assessment
Existing Screens	11.4 If a fish screen was constructed prior to [2011] but constructed to NMFS criteria [1989] or later, approval of these screens may be considered providing that all six […] conditions are met.	Per 11.4.1.1, the entire screen facility does not function as designed, since it was derated to 50% capacity due to mechanical limitations. Does not meet criterion.
Approach Velocity	11.6.1.1 The approach velocity must not exceed 0.4 ft/s for active screens, or 0.20 ft/s for passive screens	The design approach velocity is 0.4 ft/s. However, due to mechanical limitations, which are believed to be related to the screen cleaning system (i.e., air sparging system), the screen was derated to 50% capacity, effectively setting the approach velocity to 0.2 ft/s and thus abandoning the screen cleaning system. Meets criterion as long as the diverted flow is reduced to 240 cfs total.
Effective Screen Area	11.6.1.2 The minimum effective screen area must be calculated by dividing the	The design flow per screen is 240 cfs, and the maximum diversion flow is 331 cfs (powerhouse capacity). The revised

Description	NMFS Criteria	Assessment
	maximum screened flow by the allowable approach velocity.	approach velocity is 0.2 ft/s. The total effective screen area is 1,200 sf. At 240 cfs total flow, the screen area is appropriately sized. Note that the facility cannot pass the 331 cfs maximum and can pass only 120 cfs per screen, which renders the cleaning of the screen difficult when one screen is taken off-line to be cleaned. As a whole, because the facility does not meet the design intent this criterion is not met.
Flow Distribution	11.6.1.4 Providing adjustable porosity control on the downstream side of screens […] may be required.	No information is provided on the existence and sizing of the porosity plate.
Inclined Screen Face	11.6.1.6 must be oriented less than 45 deg vertically with the screen length oriented parallel to flow.	The angle as measured from the drawings is approximately 10 deg. Meets criterion.
Slotted or Rectangular Screen Openings	11.7.1.2 Slotted or rectangular screen face openings must not exceed 1.75 mm (approximately 1/16 inch) in the narrow direction.	The screen is wedge wire with 1/8-inch slotted openings. Therefore, the openings are two times larger than required. Does not meet criterion.
Screen Material	11.7.1.4 Must be corrosion resistant.	While no information could be found on the screen material, wedge wire screen is typically stainless steel. It is assumed this criterion is met.
Structural Features	11.8.1.2 Structural features must be provided to protect the integrity of the fish screens from large debris.	The screen surface is submerged, placed behind a training wall, has a log boom, and trash rack. Meets criterion.
Bypass General	11.9.3.1 provide conditions that minimize turbulence, the risk of catching debris, and the potential for fish injury.	The bypass is equipped with a baffled flume. The baffled flume increases turbulence and increases potential fish injury. Does not meet criterion.
Bypass Flows and Pressure	11.9.3.3 bypass flows should be open channel. If required by site conditions, pressures in the bypass pipe must be equal to or above atmospheric pressures. Pressurized to non-pressurized transitions should be avoided.	The bypass flow is open channel for some distance and piped (assumed partially full) and non-pressurized. Meets criterion.
Bends	11.9.3.4 Radius of curvature must be greater than or equal to 5 pipe diameters.	No sufficient information is provided to determine if this requirement is met.
Bypass Velocity	11.9.3.8 velocity should be between 6 and 12 ft/s for the entire operational range.	The flow changes from 4 ft/s to 2 ft/s after the secondary screen. The bypass is first a tunnel, then a channel, then a pipe, then an ogee and then a baffled flume. Without specific hydraulic information it is difficult to determine if this criterion is met. However, because of cross-sectional changes and different slopes, it is assumed that this criterion is not met.
Hydraulic Jump	11.9.3.12 There should not be a hydraulic jump within the bypass.	There is a hydraulic jump in the bypass at the bottom of the half-round ogee spillway section where it connects to

Description	NMFS Criteria	Assessment
		the baffled flume. Does not meet criterion.
Bypass outfall – Impact Velocity	11.9.4.2 Impact velocity should be less than 25 ft/s.	Based on field measurements, photo evaluation, and calculations it seems that these criteria are met.

The diversion structure meets some but not all criteria. Modifications would need to be made to meet NMFS criteria, that are not met in Table 2-6 above. Current facility risks include annual maintenance, reduced power generation, and risk of entraining fish during maintenance.

2.5 Potter Valley Powerhouse

The following section offers a general description of the Potter Valley Powerhouse, its typical operations, recent historical and expected future maintenance projects at the powerhouse, and an assessment of the condition of the powerhouse and appurtenant facilities.

The overall layout of the Potter Valley Powerhouse and appurtenances is depicted schematically in Figure 2-6. The powerhouse is a steel-frame structure approximately 101 feet long by 53 feet wide. The powerhouse encloses three Francis turbine generating units that operate on a static head between Van Arsdale Reservoir and Potter Valley of ±475.5 feet. Table 2-7 was modified from PG&E (2017) to present the pertinent information related to the Potter Valley Powerhouse.

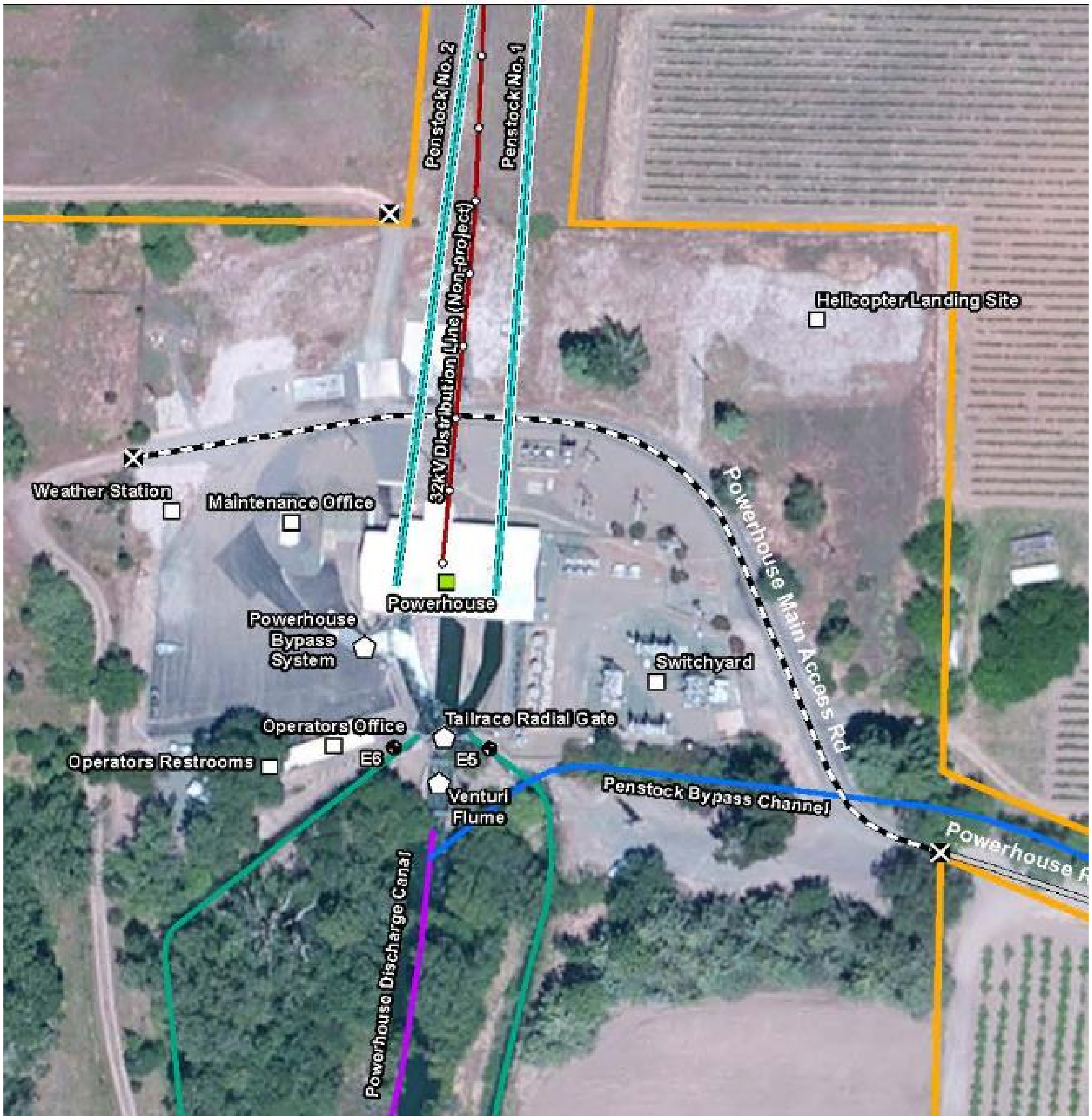

Figure 2-6. Schematic of Potter Valley Powerhouse and flow measurement locations E5 and E6 (adapted from PG&E 2017).

Table 2-7. Potter Valley Powerhouse specifications.

Overall Powerhouse	
First Date of Operation	April 1, 1908
Static Head	475.5 feet
Total Maximum Flow	331 cfs
Total Prime Mover Capacity	10,813 kW
Total Generator Capacity	10,019 kW
Peak Output	9,200 kW
Penstock No. 1	
Length	1,793 feet long

Type	Riveted-steel pipe
Diameter	Varying from 62 inches at the gate valve to 48 inches at the powerhouse
Penstock No. 2	
Length	1,812 feet long
Type	Riveted-steel pipe
Diameter	Varying from 62 inches at the gate valve to 48 inches at the powerhouse
Unit 1	
First Date of Operation	February 9, 1939
Installed Capacity, Generator	4,400 kW
Type of Turbine	Single horizontal reaction turbine
Horsepower	6,500
R.P.M.	720
Minimum Hydraulic Capacity	45 cfs
Maximum Hydraulic Capacity	170 cfs
Unit 3	
First Date of Operation	March 1, 1910
Installed Capacity, Generator	2,559 kW
Type of Turbine	Single horizontal reaction turbine
Horsepower	4,000
R.P.M.	450
Minimum Hydraulic Capacity	25 cfs
Maximum Hydraulic Capacity	85 cfs
Unit 4	
First Date of Operation	September 15, 1917
Installed Capacity, Generator	3,060 kW
Type of Turbine	Single horizontal reaction turbine
Horsepower	4,000
R.P.M.	450
Minimum Hydraulic Capacity	25 cfs
Maximum Hydraulic Capacity	85 cfs

Notes:
cfs – cubic feet per second
kW – kilowatt
R.P.M – rotations per minute

2.5.1 Operations

Operation of the Potter Valley Powerhouse is constrained by five primary factors: 1) hydrology, 2) dispatch protocol (operations related to instream flows, water contract deliveries to PVID), 3) Scott Dam target storage curves, 4) powerhouse capacity, and 5) diversion and tunnel capacity.

Hydrology determines the overall availability of water from the Eel River and is therefore a necessary, but not sufficient condition for the provision of a given amount of water to the Potter Valley Powerhouse. During an extremely dry summer, for example, when little to no water is flowing into Lake Pillsbury, it is this hydrologic condition that could trigger a drought variance and limit the diversion.

Should sufficient water be available, dispatch protocol is considered. The dispatch protocol for PG&E is based on minimum instream flows on the Eel River, East Branch Russian River flows by season and by water year classification, a buffer of 5 cfs as a contingency, and PVID water contract obligations. Minimum flows in the East Branch Russian River are depicted in Table 2-8, along with PVID diversions, the buffer flow, and the total diversion flow rates. Operation of Scott Dam and the Van Arsdale Diversion must also meet Eel River instream flow requirements (PG&E 2017).

Table 2-8. Potter Valley Powerhouse dispatch protocol.

Period		Minimum Flow of the East Branch Russian River (cfs)			PVID Flows (cfs)	Buffer (cfs)	Total Diverted Flow (cfs)		
		Classification					Classification		
From	Through	Normal	Dry	Critical			Normal	Dry	Critical
Sep 16	Oct 15	35	35	5	50	5	90	90	60
Oct 16	Apr 14	35	35	5	5	5	45	45	15[a]
Apr 15	May 14	35	25	5	50	5	90	80	60
May 15	Sep 15	75	25	5	50	5	130	80	60

Notes: cfs – cubic feet per second
[a] No power production below 40 cfs

With the dispatch protocol assigned, the next consideration is the target storage curve at Lake Pillsbury (PG&E 2017, see Figure 5.1-2). If the storage in Lake Pillsbury is at or below the target storage curve, then additional diversions beyond the dispatch protocol are not allowed. If the storage is above the target storage curve, then additional diversions may occur at PG&E's discretion up to 240 cfs total diversion (as limited by the derated fish screens). These discretionary flows above the target storage curve are typically possible in late October through early March, although some years there are no discretionary flows at all. PG&E also has the ability to bypass up to 125 cfs around the powerhouse when the powerhouse is undergoing maintenance. Overall, the equipment and powerhouse are in a condition normal and customary to powerplants of this size and vintage.

3 INFRASTRUCTURE MODIFICATION OPTIONS

This section presents a number of options that could modify, replace or remove existing infrastructure following PG&E's decision to no longer pursue FERC relicensing for the Project. These options include modifications to Scott Dam for both upstream and downstream fish passage, fish passage improvements at Cape Horn Dam, modifications at the Van Arsdale Diversion, alternative diversions in the absence of Cape Horn Dam, changes to the Potter Valley Powerhouse and its operation, different removal scenarios of both Scott and Cape Horn Dam, and water supply options to Russian River users (including PVID) if Scott Dam were to be removed, but diversion retained.

Costs were developed for most of these modifications but are not discussed in each section. A summary of risks and very approximate costs as described in Section 4.

3.1 Scott Dam – Upstream Fish Passage

Scott Dam is a complete barrier to native fish species, preventing access to upstream habitat for federally Endangered Species Act (ESA)-listed anadromous salmonids.

Should Scott Dam remain, and continue to operate as a storage reservoir, options for upstream fish passage will be challenging and costly. Nevertheless, there are options that could work based on successful implementation for passage infrastructure in the Pacific Northwest, despite the challenges. Based on work previously executed by the Fish Passage Working Group of the Jared Huffman Ad Hoc Committee, as well as work done for this Feasibility Study, this section presents the following options for upstream fish passage at Scott Dam:

- Natural Fishway
- Conventional and Modified Conventional Fishway
- Trap and Haul
- Hopper System
- Whooshh™ System

3.1.1 Natural Fishway

The natural fishway concept is based largely from the concepts outlined in Fish Passage Working Group (2019). A natural fishway would include an excavated channel alignment around Scott Dam that would contain appropriately sized streambed material placed in such a way as to mimic the configuration in a natural streambed. The channel could be lined with an impermeable bottom and filled in with properly sized alluvial material to "roughen" the channel and to create pools and riffles/steps to dissipate energy and provide hydraulic drops that can be negotiated by upstream migrants. The lining is important for a few reasons:

1. Liners are somewhat amorphous and can therefore accommodate a certain level of slow-moving hillslope failure.
2. Making the channel water-tight will not only minimize pumping costs but will also minimize dam safety concerns associated with introducing a channel with flowing-water adjacent or near to an existing dam abutment.
3. Making the channel watertight will not further degrade slope stability of the fish channel itself.

A natural fishway would generally be from several hundred to several thousand feet long and could attempt to include a relatively low gradient for optimal fish passage. The alignments considered in Fish Passage Working Group (2019) included:

1. North Bank "Long" alignment: 3,500-feet long, 2.3% average slope
2. South Bank "Long" alignment: 2,100-feet long, 3.7% average slope
3. South Bank "Wraparound" alignment: 780-feet long, 9.1% average slope

The North Bank alignment would not extend past the confluence of Soda Creek and the Eel River. In all alignments an upstream exclusion barrier would be required across the Eel River to help fish find the entrance to the new channel and eliminate the risk of having fish bypass the entrance, and travel to Scott Dam tailwater pool where fish could be stranded. The barrier could be a picket-type barrier, a velocity (weir-type) barrier, a vertical drop structure, or some other suitable exclusion barrier that will stop migration to the dam, minimize attraction to water coming from the dam, and help guide fish to the entrance of the natural fishway. The length of this barrier would be about 400-feet long or more and must be designed to accommodate the range of flows (5% and 95% exceedance) expected in the Eel River during the migratory window.

Due to the large fluctuation in reservoir pool elevations during the fish passage window, the invert of the fishway exit would be located just below the maximum design pool level. At low pool, therefore, the exit would be perched, requiring a false weir and slideway to convey fish from the fishway exit into the reservoir in a safe and timely manner. Continuous pumping would be needed to operate both the slideway and the fishway, when the reservoir drops below maximum design pool level. Therefore, a pump station with a screen intake would be required to pump the natural fishway flow when the reservoir drops below the maximum pool elevation. The pumped flow would be introduced in the natural fishway through a floor diffuser at the apex between the natural fishway and the ramp to the reservoir. The floor diffuser could be located in a trap holding pool equipped with finger weir to minimize fall back, and a false weir to attract fish to the ramp. The false weir would be plumbed to the natural fishway water supply and equipped with a valve to turn the flow on and off. The false weir flow would be approximately 2 cfs, which would merge with the rest of the natural fishway flow to make 22 cfs total, minus the small flow required to wet the ramp to the reservoir.

Hydraulic calculations were performed on the North Bank “Long” alignment presented by Fish Passage Working Group (2019). The original concept assumed a discharge of 22 cfs, a channel width of 20 feet, and a slope of 2.3%. Assuming a Manning’s roughness coefficient of 0.04, which could be suitable for large cobble and boulder-type step-pools, the average depth in the fishway could be under 5 inches in a plane-bed configuration. Therefore, in order to achieve, say, a 1-foot depth over each of the steps, the weir equation was used to back-calculate the weir length. Assuming a weir coefficient of 3.0, a depth of 1.0 feet can be achieved over the steps with a 7-foot-long weir. In this case, the velocity over the weir or step could be approximately 3.0 ft/s. Therefore, the initial channel width is considered too wide for this target flow rate. On the other hand, the flow rate itself may be too small, depending on the attraction flow required at the fishway entrance. An AWS may therefore be required, depending on the outcome of fish attraction studies that could need to be conducted prior to design.

Certainly, there are advantages to a natural fishway approach to upstream fish passage at Scott Dam. These advantages include:

- Fish volitionally migrate through a semi-natural, low gradient channel;
- Utilizing natural materials adapted to the landscape as much as possible likely reduces the costs for construction and maintenance;
- No penetration of the dam required;
- Possible habitat within the channel and channel margin itself (e.g., potential establishment of benthic macroinvertebrate communities); and
- Potential low capital cost alternative.

Drawbacks to this approach include:

- Power to the dam would be required to run the pumps;
- The need to pump water into the slideway and fishway for several (potentially up to ten) months out of the year. Although the power demand for pumping will change depending on both pumped flow rates and total dynamic head, a demand of 22 cfs over 35 feet of head, assuming 75% pump system efficiency, will require approximately 86 kW of power. Over a month's time, assuming $0.25/kWh, the total pumping cost for the month could be about $15,000. This would increase with an AWS system;
- A large (>400-foot) exclusion barrier could be needed across the Eel River;
- The channel footprint could be relatively large, increasing its vulnerability to geologic instability;
- Although a natural channel could roughly follow the contours of the surrounding topography downstream of the dam, thereby lessening the overall cut required, a potentially significant cut may be needed that is close to the dam. Regardless of whether the new fishway channel is lined or not, excavating and/or cutting a new channel close to the dam will introduce additional dam safety hazards;
- Ravines are located just downstream of the dam on both sides of the river that may require an aqueduct-type structure;
- Only the long alignment options for the North Bank and South Bank fishways have slopes less than the NMFS-recommended maximum of 6 percent;
- In all cases the total length is substantially greater than the NMFS-recommended maximum of 150 feet for roughened channels;
- Although larger bed material will be retained in the fishway, fines will tend to wash out of the natural fishway. Re-introduction of fines will be very limited, leading to a poorly graded grain size distribution. This will tend to take away some of the benefits of this approach (e.g., benthic habitat) and will force some of the water to flow sub-surface, requiring more pumped water than otherwise;
- NMFS sees the design method for roughened channel as an emerging technology. NMFS says: "Any site utilizing a constructed roughened channel must include an annual (at a minimum) monitoring plan at least until after a 50-year stream flow event has occurred. Monitoring must include an assessment of passage conditions and/or maintenance of original design conditions and repaired as necessary to accomplish design passage conditions. see roughened channel as experimental technology and require annual observation and potential maintenance" (NMFS 4.10.2.2).

3.1.2 Conventional and Modified Conventional Fishway

The Fish Passage Working Group (2019) evaluated the potential construction of a conventional fishway for volitional upstream and downstream passage at Scott Dam. Two different options for a conventional fishway were explored, including a conventional fish ladder design proposed by Mead & Hunt (2018), and a modified conventional fish ladder based on the Mead & Hunt design to facilitate passage at a wider range of reservoir elevations. The modified conventional fish ladder could eliminate the need for a trap and haul component part of the year. The two options were generally similar but varied in location, construction materials, and several specific design features. The modified conventional fishway could facilitate volitional passage (no trapping or handling) and could require little if any change to current reservoir operations.

This description focuses on the modified conventional fishway because the conventional fishway is not a standalone solution, would likely require the use of a trap and haul component part of the time, and would likely require fish handling (non-volitional)

Mead & Hunt, on behalf of PG&E, developed a pool and weir fishway, on the south abutment of the dam, with most of the pools located downstream of the dam, and all exit pools located upstream of the dam (Figure 3-1). The two sections of fish ladder are connected by a 48-inch diameter penetration bored through the dam. The upper pool of the section of ladder downstream of the dam is at the same elevation as the lowest lake level under which the ladder could be operated. The section of ladder upstream of the dam is separated from the reservoir by a concrete perimeter wall that forms an exit gallery. Each exit pool has a gated opening through the perimeter wall that can be opened or closed as lake levels change, so that the pool most closely matching the lake level could be accessible to migrating salmonids. A drop pool at the upper end of this section of ladder provides for downstream passage at lake levels between 1,818 and 1,828 feet (NGVD 1929 datum). The intent of the Mead & Hunt design is to use a weir and orifice ladder for upstream and downstream fish passage. It should be noted that using an upstream fish ladder for downstream migrants is not conventional. As with upstream fish passage, downstream fish passage should be safe, timely, and efficient. Because of the lack of velocity attraction for the downstream migrant to navigate to the upstream fish ladder, it is inefficient and un-timely. In addition, because of the number of pools that downstream migrant fish need to negotiate, it is also inefficient and untimely. Lastly, because of the residence time of downstream juvenile migrants in the fish ladder together with large-bodied fish, downstream migrants could fall prey to upstream migrant or predators in the fish ladder, which is unsafe. In other words, using an upstream fish way for downstream fish passage is neither safe, timely, nor efficient. In addition, weir and orifice ladders are less forgiving to forebay water elevation fluctuations. The fishway would also likely have to rely on a guide net system to help guide out-migrants to the exit gallery.

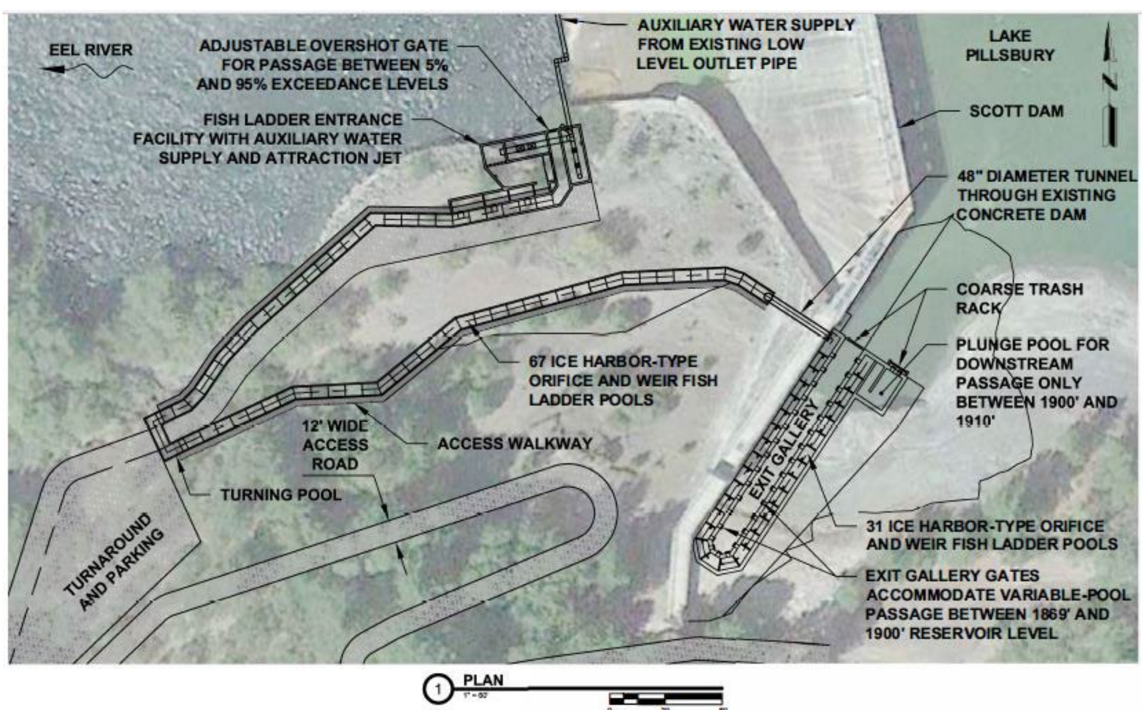

Figure 3-1. Mead & Hunt (2018) Modified Conventional Fishway Alternative for Scott Dam.

Mead & Hunt (2018) concluded that the most feasible and cost-effective fish ladder design could be challenging to build, complicated to operate, very costly, and could have uncertain effectiveness, particularly due to the difficulty of attracting out-migrants to the ladder and the risk of predation during this process. The ladder construction could require extended drawdown for work within the reservoir with a risk of flooding, uncertain impacts upon dam/bank stability, disruptions of water supply, recreational impacts, and other potential consequences. While the ladder system is conventional, there is great uncertainty related to the effectiveness of attracting out-migrants in the reservoir to the ladder, even with the use of guide nets. Upstream migrants could also be delayed with competing flow signals and the lack of an effective barrier downstream of the dam. The complexity of operating the ladder over the wide range of forebay level variations is not only labor intensive and non-self-regulating but could also lead to passage delays which increase the risk of predation and increase the risk of exposing the juveniles to stressful or lethal temperatures on the lower Eel River (thermal trap).

The following comments/recommendations are made based on our review of the Mead & Hunt (2018) design:

- Mead & Hunt (2018) proposes to use the upstream fish ladder for downstream fish passage. However, it should be noted that upstream fish ladders are not conventionally used for downstream fish passage. Mead & Hunt accurately state that attracting out-migrants could be a challenge due to the limited “attraction” (i.e., ladder) flow, even with the use of guide nets. It is recommended that guide nets not be used and instead conduct an evaluation of separate downstream fish passage alternatives. In addition, if using the ladder for downstream fish passage, the ladder could create turbulent flow which is not preferred per NMFS 11.9.3.1.
- The weir and orifice ladder type, while well-suited to passing Chinook salmon and Steelhead, requires stable water surface elevation in the forebay to operate effectively. A vertical slot ladder is recommended instead. The vertical slot ladder has a few advantages over a weir and orifice ladder in this application:
    - They are passable to a greater number of fish species;
    - The slots could prevent fish from getting stuck in some exit pools with changing reservoir elevation and could provide greater flexibility in switching the exit pools; and
    - They auto-adjust to different water level.
- Mead & Hunt (2018) suggests that ladder type selection is too early to make, that the footprint could be the same for different types, and that the vertical slot adds construction complexity. Ladder type selection will be important as the vertical slot ladder typically requires more flow and thus longer pools to meet the energy dissipation factor, which directly affects cost.
- Per review of the overall plan, ladder pool length appears to be a standard 8 foot 6 inches. Note that for longer ladders (i.e., typically more than 20 pools) it is good practice to add resting pools (i.e., pools 1.5 times longer than the standard pools) after every 10 pools. This is useful to help the overall NMFS goal of safe, timely, and efficient fish passage, by helping fish rest and reduce the risk of rejecting the ladder.
- While the exit pools appear to be of conventional design, we are not aware of any existing ladder with such a large number (i.e., 31) of exit pools. As Mead & Hunt (2018) stated, this could increase the operational complexity of the facility. Mead & Hunt (2018) also stated that it could be labor intensive and non-self-regulating. A few comments are provided below related to the exit gallery:

  - The large number of gates could require the gates to operate with electric operator controlled by reservoir level and preset conditions in a Programmable Logic Control. This will ensure that the ladder is operated optimally.
  - As it relates to safety and FERC requirements, the large number of gates increases the risk that a gate may not be functioning correctly. For dam penetration, FERC typically requests that there are two modes of closure to shut flow through the dam. A few possibilities to achieve this could be to 1) have two gates at each exit pool (i.e., one inside the pool, and the other outside the pool) or 2) have one gate at each exit pool (outside) and one at the entrance of the 48-inch diameter tunnel (as proposed by Mead & Hunt (2018) and recommended here).
  - The exit gallery could be located in the landslide area and could require a large excavation just upstream of the dam. The massive boulder just upstream of the dam face could require slope stability management.
- Ladder alignment:
  - On the south abutment, there is a tilt meter, piezometers, and three drain lines, all of which could be in the way of the upstream fish ladder alignment.
  - Access to the dam is limited. Alternative construction access to the dam could be required to the south side of the dam. Extensive improvements could be needed as the south bank of the dam is a slide area; any new access could require slope stabilization. By all accounts, the landslide has been there since the dam was constructed.
  - The ladder entrance could be built in close proximity to a crib wall. This feature is important for the slope stability and will need to be maintained during the construction of the upstream fish ladder. The ladder alignment will need to account for this feature.
- It is recommended that the 48-inch diameter tunnel be changed to a rectangular section, 7 feet tall (including 2-feet of freeboard) by 30-inch wide, to meet the NMFS transport channel velocity criteria. Structural stability analysis would be required during design in either case. A rectangular channel has a few advantages over a circular tunnel:
  - The circular tunnel creates a large restriction in flow, which could increase the transport velocity to approximately 4.7 ft/s over a distance of 46 feet, which may create an obstacle to fish. In any case, this velocity is higher than the NMFS recommended maximum of 4 ft/s.
  - The tunnel as designed creates a step up and down (i.e., floor invert of the downstream pool is 1,778.8 ft (NGVD 1929 datum), while the invert of the tunnel is 1,784.2 ft; this is a 5.4 feet step which would be difficult for Pacific lamprey to manage). Note that the floor slope should be continuous, and any step would need to be equipped with a ramp.
- The fish ladder entrance includes attraction flow (22 cfs), plus the ladder flow (16 to 22 cfs) plus a High Velocity Jet (10 cfs). It also includes added flow through the use of a chimney to accommodate changing tailwater elevation. This system provides a significant amount of operational flexibility that maximizes attraction and regulates operation. We recommend the fishway entrance be gated to allow for maintenance, and to adjust orifice opening to maintain an optimal hydraulic drop.

Building the fish ladder exit gallery between the dam and the massive boulder upstream of the dam face will clearly be difficult. It is assumed that the massive boulder would need to be modified for the installation of the exit gallery, such as by breaking the boulder into smaller manageable pieces. This can be accomplished with controlled explosives or drilling in the boulder and using some expanding agents to minimize risks associated with explosives near the dam.

An alternative to the Mead & Hunt (2018) design is to provide a conventional ladder on the downstream side of the dam with enough pools to rise over the dam rather than through it. The top fish ladder pool could be supplied with flow pumped from the reservoir and could serve as a trapping pool. This could provide a “no hole” option through the dam and eliminate the complexity of the large number of exit pools. However, this would be a pumped system, which would not increase the ladder height. Fish ascending the conventional ladder could reach the top pool and be trapped through the use of a finger weir. The trapping pool could be equipped with a false weir to allow access to the forebay through a flume. The pool could also be equipped with a mechanical crowder to help passing fish. Figure 3-2 presents a similar pool used at the USACE Foster Dam Trap and Haul Facility, though while the top pool could be similar, the function of it serves a different purpose at Foster Dam. Advantages of this “no hole” option are the following:

- It removes a large perceived risk from dam safety (FERC + DSOD) to create a penetration through the dam;
- It removes some of the large landslide mitigation cost (from excavating on the upstream side of the dam to build the exit gallery);
- It removes the complexity to operate a large number of exit gates;
- It works well with fluctuation forebay elevation; and
- Simplify the design; and design approach can be used with a partial dam demolition (i.e., same concept but different height).

The disadvantages of the “no hole” option are as follows:

- It relies on pumped flow and not gravity;
- While fish can pass through the system volitionally, upstream fish passage could be lost with loss of power (though pump and power redundancy could be built in the design); and,
- Additional height of the ladder.

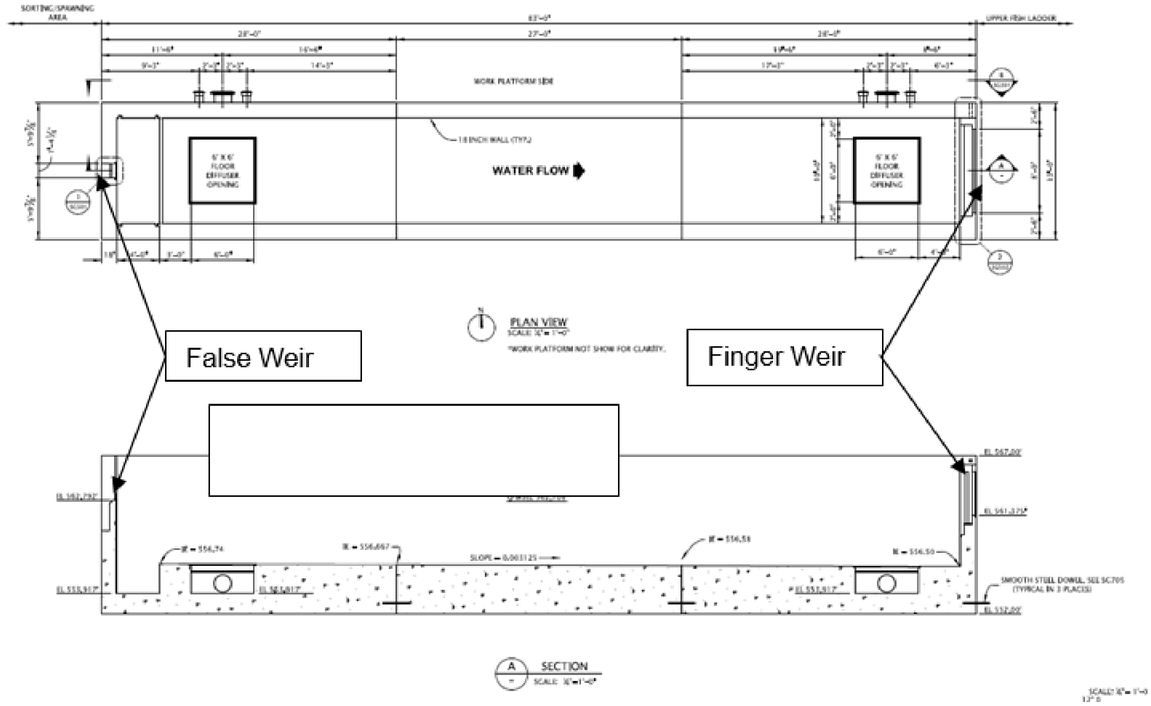

Figure 3-2. Foster Dam Trapping Pool (mechanical equipment not shown).

3.1.3 Trap and Haul

The Fish Passage Working Group explored trap-and-haul approaches that could require actively collecting, loading, and transporting fish upstream and downstream above and below dam infrastructure. Two general options were assessed under this scenario: (1) collecting upstream migrating fish at Cape Horn Dam or (2) collecting upstream migrating fish at Scott Dam. In both cases, facilities could be developed to collect fish migrating upstream, loaded and transported upstream, and placed at the top of Scott Dam or transferred onto a barge for release in the reservoir.

The first option could be to maximize collection of potential upstream-migrating fish by trapping fish at Cape Horn Dam fish ladder. Upstream-transported fish would be released at the mouth of one of the Lake Pillsbury tributaries to minimize risks with navigating through the reservoir. Fish could be loaded onto a truck for transport to a barge located at Lake Pillsbury. The barge could transport fish across the reservoir to the mouth of one or more select tributaries. Pool 30 in the Cape Horn Dam fish ladder could be modified to include a vee-trap and a new holding pool. The holding pool could be equipped with a crowder to crowd fish to a hopper. The hopper could be lifted and placed on a fish transport truck, using a monorail crane, to allow water to transfer. Sorting would not be provided to remove complexity and increase efficiency. The trap and haul facility could include a truck fill station which would be piped to an existing 4-inch diameter supply line. A Vaki Riverwatcher could be used to enumerate and identify fish species. In summary, the existing ladder could be retrofitted to 1) be used as a trap and haul facility, such that pools above and including Pool 31 could only be used for water conveyance, and 2) have the possibility to bypass the trap and haul and be able to revert back to a volitional passage system.

The second option is to capture upstream migrant fish at Scott Dam with a new trap and haul facility rather than at Cape Horn Dam. This reduces risks associated with the longer transportation route from Cape Horn Dam and allows adult fish to use the mainstem and tributary habitat between the two dams. Additionally, adult fish could be released into Lake Pillsbury rather than at the mouth of a selected tributary. The facility could be located at the base of Scott Dam, on the south bank, at the upstream terminal. To provide fish attraction flow, a tap off the existing outlet pipe on the right bank, upstream of the needle valve could be included together with a tee and an isolation valve. A 24-inch pipe could be routed along the downstream face of the spillway. The facility could have an entrance pool together with 8 fishway pools to deal with tailwater variation, and a trapping pool. An efficient design could be to modify Pools 30 and 31 as shown on Appendix 2, to serve as a trap holding pool. The trap holding pool could be equipped with a crowder and a hopper system. The hopper could be lifted onto a fish transport truck, and fish transferred through water-to-water transfer. The trapping pool would be equipped with a vee-trap or finger weir. The trapping pool could be either equipped with a hopper system or a false weir. The hopper system could only be used if sorting is not necessary. However, if sorting is required, fish passing the false weir could be sorted through manual sorting using a sorting table and fish transport portal/pipe, or mechanically using a pneumatic sorting system. Once sorted, fish could be placed in a fish transport truck and driven to their release site(s).

3.1.4 Hopper System

The hopper system could be based on the hopper system from Foster Dam, Oregon. At Foster Dam, fish ascend a fish ladder to the face of the dam, where they enter a holding pool equipped with a finger weir and a crowder. Fish are then crowded in a hopper, and the hopper is lifted to the top of the dam with the use of a hoist system, and then taken across the dam with the use of a monorail, to finally be lowered to the forebay where fish are released. The hopper system at Foster Dam was discontinued due to fish falling back through the turbine intake located adjacent to the release location, and due to new sorting requirements.

At Scott Dam, the system could look similar but with a few differences. At Foster Dam, the AWS was supplied through a pump system from the tailrace. At Scott Dam, the AWS could be supplied by gravity by tapping into the needle valve pipe or introducing a siphon pipe between the reservoir and the AWS diffuser. If the needle valve is used, the engineer will need to determine if only a portion of the flow or all of the flow could be used for fish attraction, (preferred). The flow would be diffused in an entrance pool through a floor or wall diffuser and used for attraction. The entrance pool would be gated to accommodate tailwater elevation and flow variation, while maintaining optimum entrance conditions. A vertical slot ladder, with 1-foot hydraulic drops, and just enough pools to locate the holding pool above the 100-year flood level would be provided. The ladder flow would also be tapped from the needle valve pipe. The holding pool and hopper system would be similar to Foster Dam (Figure 3-3). The hopper would be designed to allow water to transfer to a barge. Fish would then be barged to the selected tributary(ies). No sorting would be provided. The hopper system would be located on the right bank, close to the existing needle valve. A large cofferdam would be required to build the facility. In addition, extension of 3-phase power transmission from the existing sub-station at the Potter Valley Powerhouse approximately 14 miles away would also be required.

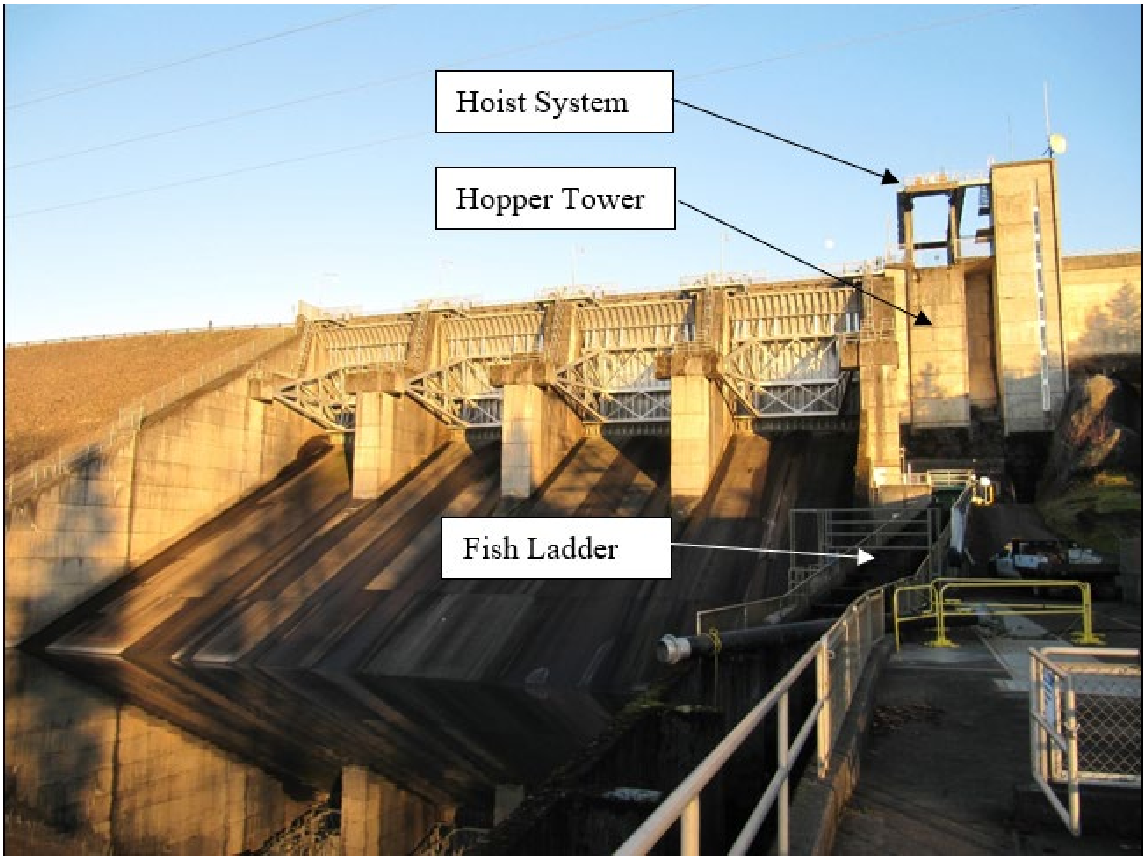

Figure 3-3. Foster Dam Hopper System.

3.1.5 Whooshh System

Whooshh Innovations created the Whooshh system (sometimes referred to as the fish cannon), which moves fish through a flexible, pressurized tube, safely transporting them from one area to another, oftentimes over large vertical obstacles like dams. There are two basic configurations of a Whooshh system considered for Scott Dam fish passage: 1) a floating platform configuration and 2) a land-based configuration. Both options would provide volitional passage.

In the floating platform configuration, the Whooshh system could be placed on a sectional barge located in the tailrace. Specific siting and orientation relative to flows and fish location will need to be determined. The sketch provided in Figure 3-4 offers a potential siting.

Figure 3-4. Potential siting of a Floating Platform Configuration Whooshh System.

In the land-based configuration, fish could have to ascend a short ladder or Alaskan Steeppass type baffle Denil-fishway to get to an elevation sufficiently high to have the equipment platform located safely above flood stage (Figure 3-5). The ladder could thereby accommodate the full range of tailrace elevation fluctuations. An entrance similar to the modified conventional upstream fish passage from Mead & Hunt (2018) could be used. The attraction flow could be provided from connection to the needle valve and delivered to the entrance pool via pipeline across the tailrace. Due to the water level variation in the tailrace of 4 feet (from 1,801 feet and 1,805 feet) and flood level (top of wall of entrance pool 1,812 feet) minus about 6 feet of freeboard in the trap holding pool, approximately seven to eight fish ladder pools would be required to locate the trap holding pool above high tailwater.

Figure 3-5. Potential Configuration of a Land-Based Whooshh System.

Fish entering the new entrance pool would ascend the short ladder to the trap holding pool, and then be attracted to a false weir that serves to partially dewater and also singulate the fish for passage. The fish then slide down a wetted surface through a scanner (FishL Recognition™) to automatically count, size, and image each fish and direct them through sorting gates to a transport chute sized for that fish. Each chute consists of an accelerator which acts as an airlock that introduces the fish to an appropriate diameter migration tube which safely conveys the fish to its destination. The equipment could be situated on a concrete pad constructed and dedicated to the Whooshh System. It would be relatively easy to enclose the top of the ladder and the equipment in a modular building for security and weather protection.

A high volume, low pressure blower is used to provide cooled air at the accelerator entrance to facilitate loading of the fish into the tube. The tube is lubricated by a water spray introduced every 6 feet along the tube providing a wet, smooth, low friction envelope along which the fish are pushed by the air stream. Temperature inside the migratory tube is regulated throughout the system to minimize thermal stress on the fish. Fish typically travel through the tube at about 25 feet per second. At the distal end of the tube the fish are directed through an appropriate re-entry configuration that delivers them head-first into the water. Fish typically travel at less than 10 ft/s when they reenter the water. It is recommended that the exit is in water that is a minimum of 4.5 feet deep, and there are no obstacles in the water within 8 feet of the re-entry point to prevent injury to the fish.

Because the upstream passage solution is required to accommodate a number of species of differing dimensions and quantities, multiple transport tube sizes are recommended. Tube sizes are selected to provide tolerance to the sorting algorithms by accommodating overlap in detected fish sizes.

Ancillary components include several control cabinets, the air chiller and blower components, and communications for remote monitoring. Importantly, 3-phase power will be required at the site, we assume that providing 3-phase power to the site will require extending transmission approximately 14 miles from Potter Valley Powerhouse to Scott Dam.

3.2 Scott Dam – Downstream Fish Passage

Lake Pillsbury is a closed system, in that downstream fish passage below Scott Dam through the needle valve is not expected for surface-oriented juvenile salmonids due to the depth of the needle valve. It is also expected that reservoir predation could be high from known predators in Lake Pillsbury such as largemouth bass (*Micropterus salmonides*) and pikeminnow (*Ptychocheilus oregonensis*). In addition, a study in the Willamette Basin by U.S. Geological Survey found that parasitic copepods infection decreases the survival rate of juvenile Chinook salmon. In other words, the survival rate of juvenile salmonids from the tributaries migrating through Lake Pillsbury during spring freshets are likely to be low. Therefore, downstream fish passage at Scott dam will be complicated and costly, and its efficiency and reliability are limited due to the lack of project-specific information to make an informed design. It is recommended that scientific studies be carried out to determine the risks associated with various alternatives. These studies should at the minimum include:

- Evaluating predation risk in Lake Pillsbury;
- Evaluating parasitic copepodids infestation risk in lake Pillsbury; and
- Identify which tributaries have the best upstream habitat and determine the expected flows in those tributaries.

This section presents the following options:

- Fish Passage via Spillway
- Fish Passage via Floating Surface Collector
- Fish Passage via Fixed Surface Collector
- Fish Passage via Variable Intake Surface Collector
- Collection at Head-of-Reservoir or in Tributaries

We know that "downstream" anadromous fish can take on many different life history forms and importantly for fish collection and passage, different *sizes*:

- For stream-type Chinook and steelhead that reside in freshwater as either 1- or 2-year-olds prior to emigrating downstream to ocean environments as true smolts, one should assume smolt sizes of between 75-175+ mm (3-7+ inches);
- Some stream-type Chinook and steelhead reside in natal freshwater environments for variable periods of time before migrating downstream to reside in lower mainstem river systems (generally warmer and more productive systems) for some period of time before undergoing smoltification and emigrating to ocean environments as true smolts. Therefore, designers should assume that fish could be as small as newly emergent fry (25+ mm) to over 175 mm (~ 1-7+ inches);
- For both Chinook and steelhead, some fish "decide" to stay in freshwater environments their entire lives (often termed *resident* or *residual*) and continue to follow a "transient" migratory behavior (not a defined upstream or downstream behavior). These fish can range in size from 150-300+ mm (6-12+ inches);

- Steelhead routinely spawn in freshwater natal streams and then migrate back to either estuarine and/or ocean environments before returning again to freshwater as "repeat" spawners (1-3+ repeat events are common). Adults migrating downstream after spawning are termed "kelts" and can be 900+ mm (3 foot+) depending on stock.

3.2.1 Fish Passage via Spillway

Downstream fish passage through spillways is often the primary passage for many dams. Three different metrics are typically used to evaluate a spillway's effectiveness at passing downstream migrants: survival rate, mortality rate, and injury rate. Based on past projects, the accepted rates are:

- Survival Rate: >98% per year.
- Mortality Rate: <2% per year
- Injury Rate: <5% per year

The spillway configuration and resulting hydraulics directly impacts those rates. Three spillway types were evaluated: free-overfall, smooth, and stepped ogee-shaped spillways by Bestgen et al. (2018), who found that the mean survival rate was high in all spillway models (97% to 100%) for all species, size-classes, and flow conditions, except in the free-overfall spillway. Therefore, for the smooth ogee-shaped spillway of Scott Dam, a high survival rate through the center gates can be expected.

Mortality rate for juvenile salmonids varies greatly from one location to another: between 0% and 4% for the Bonneville, McNary, and John Day dams on the Columbia River, 8% at the Glines Canyon Dam and 37% at the Lower Elwha Dam on the Elwha river for juvenile salmonids (Bell and Delacy, 1972; Ruggles and Murray, 1983). In other words, those rates are inherent to the dam and hard to design around, and post-construction evaluation would be required to demonstrate that those rates are met, with no guarantees that they could be.

To add to the complexity, it is possible that the mortality rate could be met but not the injury rate. An injury rate greater than 5% could be perceived as increased indirect mortality, and thus the whole downstream system could be considered non-compliant. Injuries are often attributed to impact and adverse hydraulics. While the shape of the spillway at Scott Dam is not ideal for fish survival, due to the side deflector walls, minor reoperation to first use the gates near center and north end could reduce risk of injury. The flip bucket would need to be modified to remove the potential "washing machine" effect (i.e., high turbulence), and also to promote drainage and avoid stranded fish. Juvenile salmonids are surface- and shore-oriented. However, during spill conditions, it is assumed that the juvenile fish would be directed to the open gates located in the middle of the spillway.

For Lake Pillsbury, the downstream migration period for juvenile Chinook salmon and steelhead peaks in April and May but could extend to June or July (Table 2-3). During that time the reservoir has a high chance of spilling, as can be seen in Figure 3-6..

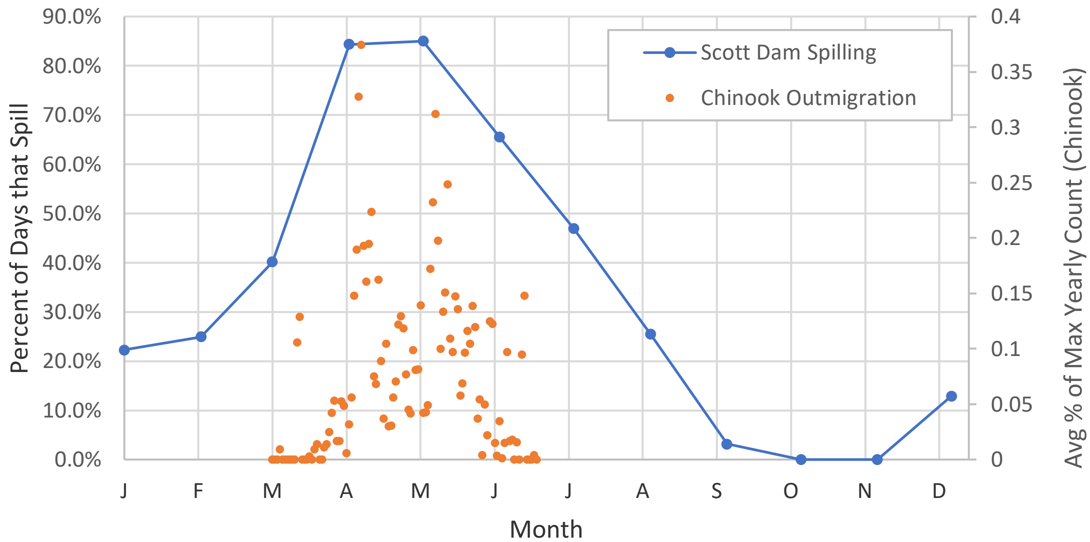

Figure 3-6. Scott Dam spilling versus Chinook Salmon outmigration timing.

This suggests that fish passage could be provided through the spillway during the typical spilling period, which corresponds to outmigration, and that when using the center gates a high survival expectancy could be achieved. During spill and flood events, we assume that juvenile fish could travel through the reservoir to the dam faster and reside in Lake Pillsbury for a shorter time, which could reduce risk of predation and/or parasitic copepod infection. However, relying on spills alone to pass juvenile salmonids may not be sufficient because the reservoir may be filling rather than spilling, and if there is no spilling, there is no downstream fish passage other than through the needle valve. Therefore, supplemental juvenile fish passage would need to be provided.

3.2.2 Fish Passage via Floating Surface Collector

To provide downstream fish passage at Scott Dam, a floating surface collector (FSC) could be used. The FSC is a system that has been used with success in the Pacific Northwest. It includes a few critical components, such as guidance nets, attraction pumps, V-screens (including tuning baffles and screen cleaners), and a bypass. The facility would accommodate the regular forebay elevation changes and would be capable of operating throughout the entire normal forebay operating range which varies from 1,869 feet to 1,910 feet, or a vertical variation of 41 feet. The FSC would be sized for an attraction flow of 1,000 cfs, based on success observed at North Fork Dam on the Clackamas River in Oregon. While it is possible to have two V-screens each sized for 500 cfs each, which would provide flexibility in operation, the sizing of the facility was done using one V-screen sized for the full flow of 1,000 cfs, similar to the North Fork FSC (see Figure 3-7.). No fish sorting is assumed on the FSC.

Figure 3-7. Floating Surface Collector at North Fork on the Clackamas River, Portland General Electric.

3.2.2.1 Guidance Nets

The guidance nets could be similar to the guidance nets suggested by Mead & Hunt (2018). The guidance nets would be located upstream of the dam to guide fish towards the FSC. The guidance nets would reduce exposure of out-migrating salmonids to the spillway and outlet. Netting is typically 3/32-inch to ¼-inch mesh opening. It would not have to extend to the bottom of the forebay but would need to extend at least 1.5 times the screen depth or 27 feet. The netting upstream of the spillway could extend from the north shore of the lake approximately 400 feet upstream of the dam and terminate at the entrance of the FSC.

3.2.2.2 Attraction Pumps

Attraction flow into the FSC could be provided by six submersible horizontal propeller pumps, each capable of delivering up to 200 cfs (5 operational pumps + 1 backup). The submersible horizontal propeller pumps are commonly used for this application because they can pump large volumes of water at very low head. The pumps could be located on the FSC behind the screen system. This pump system would require between 0.5 and 1.0 MW of power and would need to be operational during the entire outmigration period to attract fish into the FSC. Therefore, the energy demand of an FSC with a 1,000 cfs attractant flow would be very high. It is possible to operate the pumps at a lower rate part of the year to try to match flow and out-migration periods. However, the energy demand cannot be met with the existing 10-kilowatt propane generator. The closest known source of 3-phase power is at the Potter Valley Powerhouse and would need to be extended to Scott Dam requiring a 14-mile transmission line installation.

3.2.2.3 Fish Screens

The screen system would include the following components: 1) fish collector entrance, 2) the primary screen, 3) the secondary screen, 4) the weir, and 5) the screen cleaning system. The screen is assumed to be sized for 1,000 cfs. The screen system would be formed of vertical panels meeting the NMFS criteria for approach velocity, maximum clear spacing, and material. The screen system would have the following characteristics:

- The overall screen system length would be 128 feet and 30 feet wide.
- The fish collector entrance would be 30 feet wide by 18 feet deep. Because of the minimum draft of 18 feet, the FSC should be located such that when the reservoir level is down to the low level of 1,787 feet (NGVD 1929 datum) there is still about 25 feet of water depth.
- The water temperature profile will need to be evaluated as the fish collector entrance depth may need to be deeper to reach down to cooler water where fish may be located during higher reservoir temperature.
- The primary screen would include two sets of vertical panels forming a vee shape (hence the reference to a V-screen). The primary screen is located immediately downstream of the fish collector entrance and immediately upstream of the secondary screen. The primary screen would be full height (i.e., 18 feet) and would pass the bulk of the flow (about 86%). The width between the vertical panels would change to form the vee from 18.0 feet wide down to a 2.0-foot-wide throat.
- The secondary screen is located immediately downstream of the primary screen (i.e., throat) and before the weir. The secondary screen is a 2.0-foot-wide channel. The floor ramps up from elevation 1,810.3 to 1,826.21 (NGVD 1929 datum) during high reservoir level, and the screen panel varies in height from 8.0 feet to 2.0 feet.
- The weir height would be adjustable to pass a constant bypass flow ranging from 20 to 25 cfs. The capture velocity will be approximately 7.4 ft/s.
- The vertical screens (both primary and secondary) would be equipped with a brush cleaning system to keep the screen surface free of debris. The brushing arms would be retractable and kept above the water surface when not cleaning and could be lowered when cleaning is initiated. Cleaning would be initiated based on time (pre-set value) or head differential built up, whichever comes first.
- The screen panels would be 4 feet wide each due to structural supports. In addition, every screen panel would be installed with an adjustable baffle system, to ensure that the sweeping velocity increases along the face of the screen.

3.2.2.4 Fish Bypass

Fish collected at the FSC would be returned to the river through a NMFS-compliant bypass pipe. The pipe would be 30-inch nominal HDPE pipe with smooth interior and fittings. The pipe would be at a 2 percent slope and would be about 1 mile long. The water depth would be 40-percent of the bypass pipe diameter, and the velocity would be below 12 ft/s. The layout of the pipe would need to be evaluated to ensure that there is access along the pipe for maintenance or cleanout. The pipe could be buried under an access road or supported on piers depending on geotechnical information and general arrangement. The pipe outlet could be located in the tailrace of Scott Dam. The impact velocity of juvenile salmonids exiting the pipe was calculated to ensure that it would be below the maximum impact velocity. During low tailwater, the impact velocity would be 21.5 ft/s, and during high tailwater, the impact velocity would be 14.4 ft/s.

A sampling facility, monitoring, or evaluation facility is not assumed at this point in the evaluation. If such a facility is required for post-construction biological evaluation in the long or short term, it is recommended that an offline raceway be provided. The raceway would contain fish screens and weirs that would allow fish to be held in the raceway and for fish-free water to be returned to the bypass pipe. Fish could be worked-up with manual push crowders and processed onsite for truck transport or returned to the bypass pipe. The facility could be designed so that it can be in bypass mode or fishing mode.

3.2.3 Fish Passage via Fixed Surface Collector

During preliminary evaluation of potential infrastructure modification options, it was determined that a fixed surface collector is impractical at this site due to the large variation in reservoir elevation and high-water temperatures. Further investigation was not carried out.

3.2.4 Fish Passage via Variable Intake Surface Collector

As the name implies, a variable intake surface collector includes a group of gated entrances at variable depths in the reservoir to account for the variation in reservoir water surface elevation. The following describes two examples of such a collector system:

- Meade & Hunt (2018) proposed to use the upstream fish ladder exit gallery to serve as the variable intake surface collector to pass fish downstream; however, this is not described further here as using an upstream fish ladder for downstream fish passage is uncommon due to hydraulic conditions which are not conducive to downstream migration in a safe, effective, and timely manner;
- The helix collector downstream fish passage system at Cle Elum Dam in Washington State, designed by the U.S. Bureau of Reclamation (Figure 3-8.).

Based solely on the Cle Elum Dam design, a variable intake surface collector could include the following important components: an inlet structure, a helix-shaped bypass structure, a downstream passage conduit, and an outlet. The system could be designed to operate for passive downstream passage at different water surface elevations. The inlet structure could have a number of intakes to accommodate different water surface elevations. For the Cle Elum project, there are 6 intakes to account for the reservoir variation of 68.5 feet. Therefore, for the Lake Pillsbury vertical variation of 41 feet, it is assumed that 4 intakes could be required. There could be about 3 feet of overlap between each intake to allow for continuous operation. The helix could be very similar to the Cle Elum Dam design but could require significant numerical modeling and perhaps also physical modeling to determine the size of the conduits and the diameter of the helix. The helix could be on the order of 105 feet tall. The Bureau of Reclamation did significant physical and numerical modeling and found that the helix could be used to provide stable and continuous downstream fish passage while dropping fish more than 80 feet in elevation through a sloping rectangular channel. Once fish have dropped the elevation of the dam (i.e., to the bottom of the helix), fish then enter a downstream passage conduit and could be released downstream of Scott Dam. To determine the flow range and the sizing of the different components could require a significant effort and is deferred to later stages of design. It is assumed that the helix could be located on the north bank of Lake Pillsbury by the end of the access road to Scott Dam, and that guidance nets could be used in a similar way as described for Section 3.2.2.1.

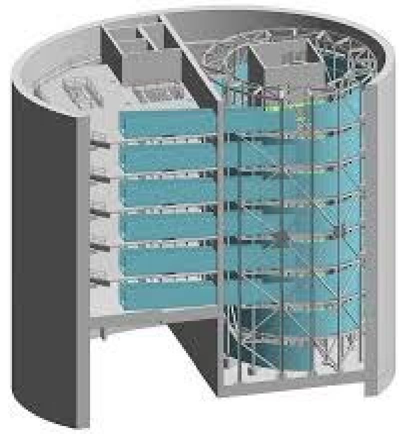

Figure 3-8. Cle Elum Dam – Helix Design downstream fish passage system (U.S. Bureau of Reclamation).

3.2.5 Collection at Head-of-Reservoir or in Tributaries

Another possible downstream fish passage alternative could be to collect juvenile salmonids and steelhead kelts at the head-of-reservoir or within primary tributaries and transport via truck or barge for safe passage downstream.

Figure 3-9 presents possible locations to collect downstream migrants and kelts at the head-of-reservoir or in primary tributaries. The head-of-reservoir is defined as the farthest upstream location where the water level is directly controlled by the reservoir operations. This location will vary longitudinally along the river thalweg, depending on reservoir level. A mobile fish collector may have the ability to follow the head of reservoir across the full range of reservoir operations. For a fixed location collector, head of reservoir is defined by the lowest reservoir level at which the collector can function.

For downstream movement of trapped juveniles and steelhead kelts, there are two options considered: 1) transporting the fish downstream from the trap (collection) facility via truck and returning them to the river downstream of Scott Dam, or 2) transporting the fish downstream to the face of the dam via barge, then transporting them to the Eel River via truck or via a return bypass pipe from the dam crest to the tailrace pool immediately below Scott Dam.

It is important to understand the structure of Lake Pillsbury and the tributaries entering the reservoir. The reservoir is not longitudinal with one main tributary but has two main branches (Eel River and Rice Fork) and multiple tributaries (e.g., Salmon Creek, Smokehouse Creek). This adds to the complexity of capturing fish at the head of reservoir. Additional studies would be necessary to advance any of the proposed alternatives, and that in all cases, access for construction, operation, and maintenance will be a challenge. Data collection will be key to determine power source, winter access, debris loading and sediment loading, as well as localized hydrology. Topographic and bathymetric surveys as well as geotechnical exploration should be included in any additional data collection program.

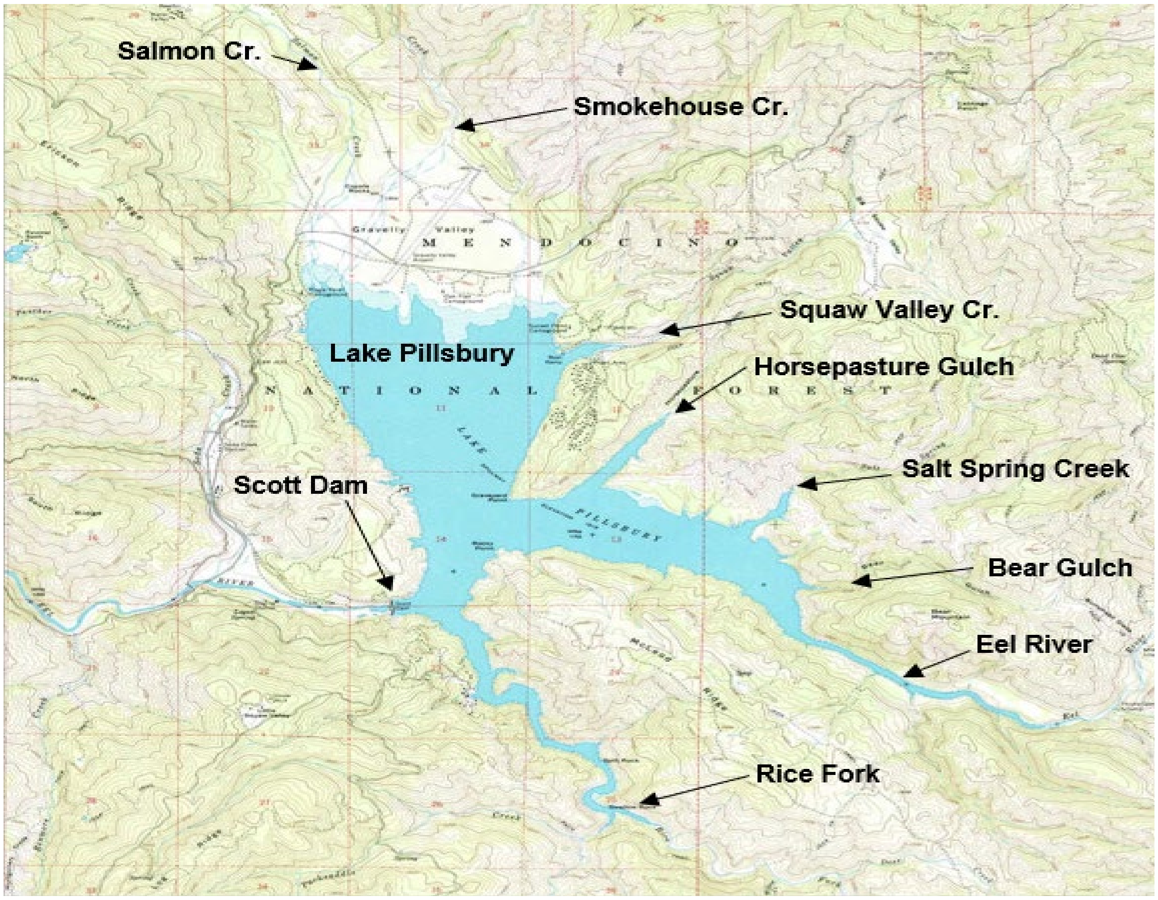

Figure 3-9. Lake Pillsbury and primary tributaries.

3.2.5.1 Fixed Location in Reservoir

A Floating Surface Collector (FSC) is one technology that is considered feasible for a fixed location. The FSC description is presented above in Section 3.2.2 and adjusted for use at the head of the reservoir on the Eel River and Rice Forks as follows:

- The bypass flow containing fish could be directed into a handling facility on the floating structure. Fish can then be counted, separated by size and species, and placed into holding vessels. Transport of the fish to their final destination could be via a barge to the dam. Once at the dam fish could be loaded onto a fish transport truck and driven for release below the dam or put in a bypass pipe similar to the one presented in Section 3.2.2.4.
- One large FSC is not feasible due to the multiple tributaries, so multiple smaller FSCs, sized for the tributary flow or a combination of tributaries flow would be required.

3.2.5.2 In-Tributary

In-tributary locations generally are defined as in-river sites located upstream of the influence of reservoir operations and reservoir backwater effects. At these locations, water level is only a function of the tributary flow rate. A limitation of in-tributary collection systems is that in order to achieve high fish collection efficiency, it may be necessary to divert and dewater the entire tributary flow during fish migration. This is generally not feasible, particularly in rivers with flashy hydrology (high peak flows) that occur during the spring freshet when many juvenile fish are moving downstream.

It is assumed that installing a collection facility in each tributary shown in Figure 3-9 would not be feasible due to the large number of tributaries. Instead, it is assumed that only primary tributaries would be selected. As a preliminary evaluation, the watershed area of different tributaries was computed. The Rice Fork watershed is 96.4 square miles and the watershed for the Eel River is 152.5 square miles, while the watershed for Squaw Valley, Smokehouse, and Salmon Creeks is only 39.6 square miles. Hydrology associated with the watershed, as well as spawning potential and rearing habitat, would need to be evaluated in the selected the tributaries. However, for this exercise, only the Rice Fork and the Eel River were assumed for deployment of in-tributary fish collectors. It is possible that in-tributary collection using screw traps could be used in the other tributaries to increase fish collection efficiency.

Off-channel collectors refers to the location of an in-tributary collector entrance and dewatering system outside of the bank-to-bank width of the tributary river, such as in a side channel or over-bank location (AECOM and BioAnalysts, 2010). The collectors consist of a diversion structure (concrete ogee with a fixed-crest dam or an adjustable-crest dam such as an inflatable rubber dam), dewatering screens (V-screens or horizontal screens), and a fish-handling facility. However, the screens are located off-channel, downstream of a head gate structure. There are many examples of off-channel facilities that exclude fish from irrigation or power plant intake canals and then safely return them to the river. However, these facilities are typically not exclusively built for the purposes of juvenile fish collection. Most variants of these facilities are defined by the type of dewatering system employed. For example, the Leaburg Diversion (Eugene Water and Electric Board) uses a V-screen for a hydroelectric power plant canal. Similarly, the Anderson-Cottonwood Irrigation District uses a V-screen on an irrigation canal on the Sacramento River. These existing facilities all provide direct return of fish to the river via fish bypass and return pipes. Other technologies, such as vertical traveling screens and inclined flat plate screens are also prevalent. It is assumed that a horizontal screen could work well if a site with sufficient space can be located (Figure 3-10.).

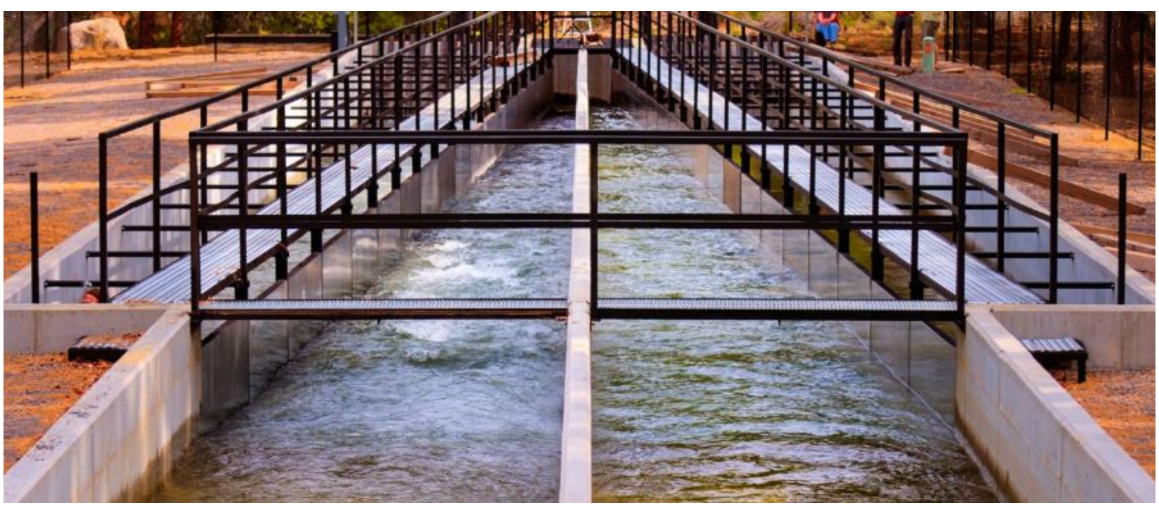

Figure 3-10. Horizontal Screen by Farmers Conservation Alliance.

In-tributary collection systems come with many significant challenges, including:

- Access, particularly during the winter;
- Site selection;
- Geomorphology – sediment transport and deposition at the intake locations may prevent fish access to the collection system;
- Geotechnical;
- Power – providing electrical power to tributaries is likely infeasible, and keeping generators running may also prove challenging; and
- Hydrology.

The main advantage of this alternative is:

- Juvenile salmonids and steelhead kelt could be collected in the tributaries, limiting issues related to reservoir predation and high reservoir temperatures.

3.2.5.3 Mobile Technologies

Mobile technologies include various types of fish traps (e.g., rotary screw traps) that can be deployed in variable and/or multiple locations, either in-tributary or in-reservoir. Portable traps provide a low-cost means of trapping at multiple site locations and collecting data on run-timing and fish size. These data may assist in determining the feasibility of implementing a larger, more permanent collection system in the future. The collection efficiency would need to be tested as it will be site specific, will depend on the technology used, and would depend on the orientation, configuration, and number of traps as well as the life stage of the downstream migrating fish. If the combined collection efficiency is high, a series of multiple, portable trapping systems may be used as a full-scale system to collect juvenile fish.

The advantages of using small traps for fish sampling are their low cost, portability, ability to collect fish in free-flowing and slack-water environments, and simple mechanics (which do not require highly trained field crews, power, and costly support facilities to operate). The disadvantages of these traps generally have been low juvenile fish collection efficiencies, the inability to operate the traps during high flows when the majority of migrants may be present, and the high risk of trap damage from debris. Four types of traps are described below: Merwin trap, rotary screw trap, scoop trap, and dipper trap. The Merwin trap and dipper trap could be deployed at the head of the reservoir, while the rotary screw trap and scoop trap could be deployed in the tributaries. Additional studies would be needed to determine if all eight tributaries would need to be equipped with the technology or only a few primary tributaries.

Merwin Trap: A Merwin trap is a floating system that utilizes long net leads to guide fish to the trap (Figure 3-11). They are generally used in low velocity areas such as reservoirs and lakes to collect fish migrating near the shore. Merwin traps were used at Mossyrock Reservoir (Riffe Lake) in the late 1960s and early 1970s to collect juvenile fish for transport and release below Mayfield Dam on the Cowlitz River (Hager and DeCew 1970). Merwin traps located at the head of the reservoir and near the dam were used to collect sub-yearling and yearling Chinook, Steelhead and Coho, respectively. From 1968 through 1973 yearly catches ranged from 11,000 to 321,000 juvenile salmonids, with the vast majority being Coho salmon. No direct estimates of fish collection efficiency were made for the traps at this project. The system was abandoned as the resource agency did not feel sufficient numbers of fish were collected to maintain the run over time. The basic design of Merwin traps has not changed much in the past 40 years; however, the materials have improved, which has increased their durability.

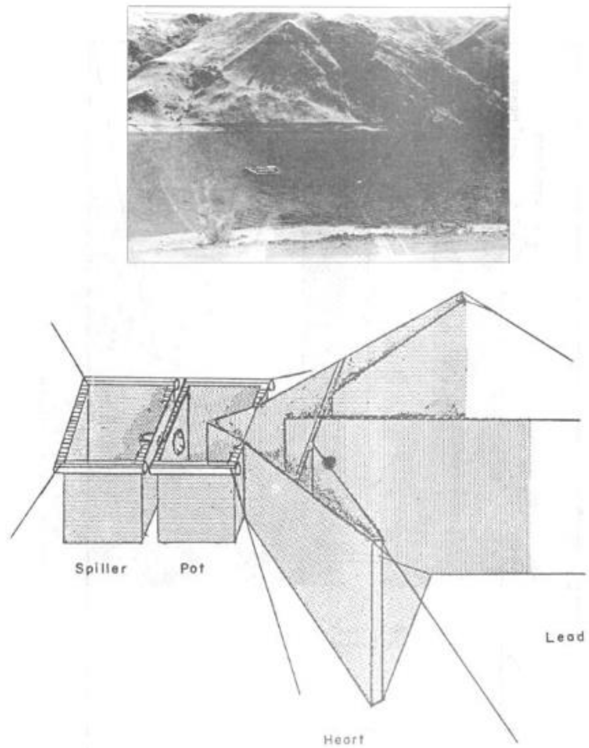

Figure 3-11. Example of a Merwin Trap (reproduced from Raymond and Collins, 1975).

Rotary Screw Trap: Rotary screw traps employ an Archimedes screw built into a screen-covered cone mounted on a floating platform. The large end of the cone is oriented into the flow and half of the screw is submerged. The moving water forces the screw to turn and thus the cone. This process traps any fish entering the cone and deposits them in a holding box located at the rear of the trap. Sufficient water velocity (>1.5 feet per second) is needed in order to turn the screw that collects fish from the river (Figure 3-12). Rotary screw traps may employ screws anywhere from a few feet to 10 feet in diameter, though most are in the 4- to 8-foot range. They can also be deployed in series. These traps are usually used to sample a subset of the migrants passing through an area for evaluation purposes, though they can be used with a picket fence to direct fish to the screw. Fish collection efficiency is generally quite low (<5%) and can be highly variable dependent on such factors as debris, site conditions, flow and size of fish being collected. On the Lewis River, WA, a screw trap was operated during low summer flows (<1,000 cfs) and was able to capture between 10% and 40% of the juvenile Coho, Chinook and Steelhead entering Swift Reservoir (PacifiCorp 2005). The length of the fish collected ranged from 30-190 mm. During higher flows, the trap was susceptible to debris problems that made it inoperable during peak juvenile migration periods.

Figure 3-12. Rotary Screw Trap at Upper Garry River, Canada.

Scoop Trap: Self-cleaning scoop traps can be used in riverine environments where water velocity is higher than 3 ft/s and depth is greater than 5 feet (Figure 3-13). A set of traveling screens is used to remove debris entering the trap. Net leads (or louvers) can be used to guide fish to the scoop, thereby increasing fish-capture efficiency. According to Raymond and Collins (1975), fish trapping efficiency has ranged from 3 to 15 percent.

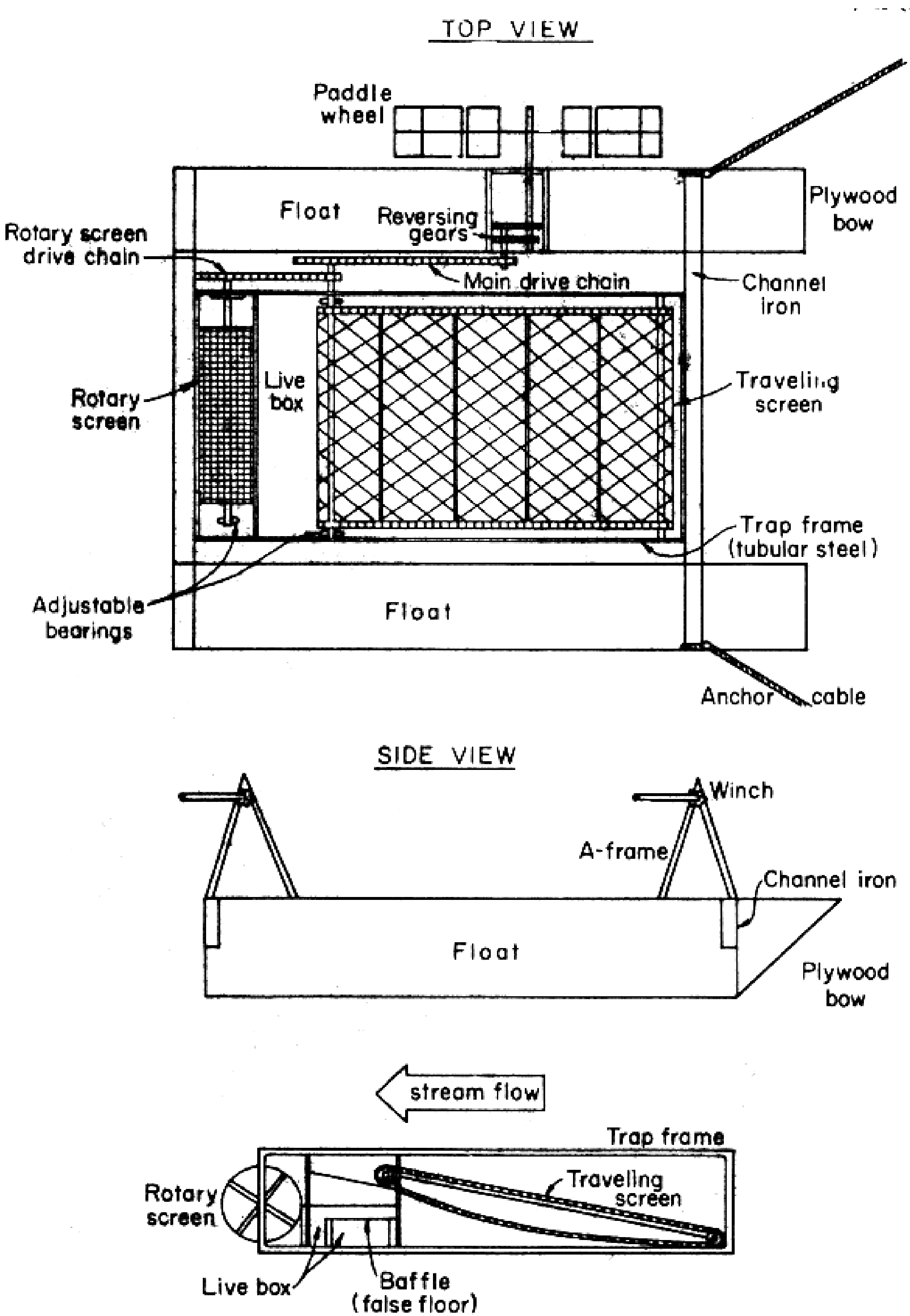

Figure 3-13. Scoop Trap (reproduced from Raymond and Collins 1975).

Dipper Trap: A dipper trap is similar to a screw trap, as it uses a continuously rotating scoop to remove fish from the water and transfer them to a trough. The trap works best in riverine environments where flows are less than 3 ft/s (Figure 3-14.). Because debris can be an issue for the trap, some dipper traps incorporate traveling screens to move accumulated debris to the downstream end of the trap, where it is removed. Data collected in Idaho (Eagle Creek) on a dipper trap equipped with a louver system showed that from 14 to 91 percent of marked fish were recaptured in the system. Collection efficiency on average was greater than 50 percent, and it appeared to be higher in the fall when flows were lower. Louver angle affected the size of fish actually collected in the trap, with a 10- to 15- degree angle working the best for all size classes collected with fish length greater than 53 mm (Krcma and Raleigh, 1970). Flow velocities in the upper Eel River and Rice Fork in late winter and spring would be greater than 3 feet per second and have high debris loads. Therefore, a dipper trap may be challenging to maintain, and other options may be more effective.

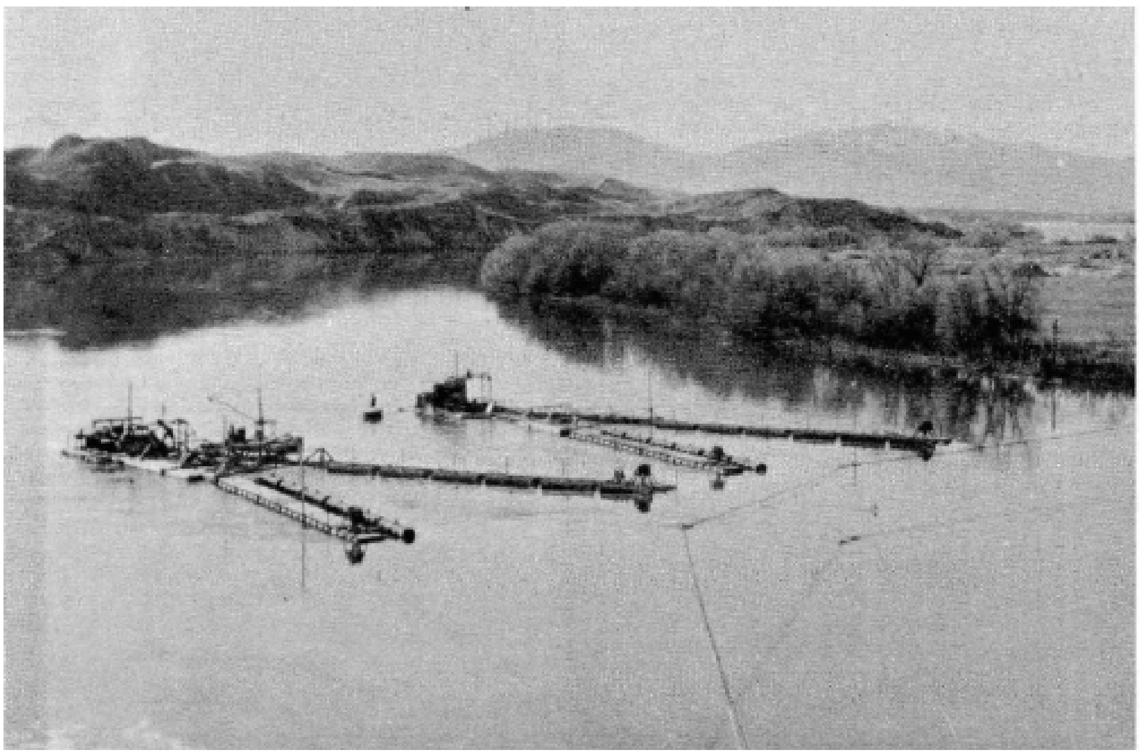

Figure 3-14. Migrant Dipper Traps, Snake River (Krcma and Raleigh 1970).

3.3 Cape Horn Dam Fish Passage Improvements

The following section describes the potential improvements that could be made to the Cape Horn Dam fish passage system for both upstream and downstream fish passage. These improvements specifically address the flooding issues at the fish hotel and the non-compliance of the existing ladder described in Section 2.3. Based on conversations with PG&E and CDFW staff, there is consensus that the fish facility would need to be modified to provide adequate upstream and downstream fish passage and avoid sediment and wood deposition in the fish ladder during high flows.

Most of the Cape Horn Dam passage improvement concepts were included in work undertaken by PG&E, the Fish Passage Working Group, or were relayed in conversations with CDFW or NMFS staff; as a result, the list of potential improvements is not comprehensive. A more exhaustive examination of potential passage improvements will be undertaken in a future phase of work.

3.3.1 Downstream Fishway

The Fish Passage Working Group assumed that the Cape Horn Dam high water release and fish ladder is functioning at current regulatory standards (CDFW and NMFS), effectively passing both adult and juvenile fish (kelts) downstream. However, the current downstream fishway only conveys all juveniles when Cape Horn Dam is not spilling. The high-water release and fish ladder passes up to 124 cfs, so higher flows spill over the dam, along with any juveniles and steelhead kelts that do not travel down the fishway. Very high flows that spill over the dam are deeper and may be safe enough for juveniles and kelts to navigate however disorientation and injury may cause elevated predation rates. A floating surface collector was considered for the site but would likely not work well given the shallow depth, debris loading, and seasonally large amounts of algae growth.

In some survival studies of downstream fish passage at step dams similar to Cape Horn Dam, survival rates can still be relatively high, but not as high as with downstream fish passage over an ogee weir. Therefore, one possible option to improve downstream passage at low and high flows would be to notch the top of Cape Horn Dam down by about two feet between the right abutment and the high-level fish water release. The cut section could then be modified from a step profile to an ogee or ramp. The new profile and the new crest could be designed to accommodate typical flows during the migration periods, provide safe passage downstream, and better route sediment downstream past the Fish Hotel.

3.3.2 Upstream Fish Ladder

While the upstream fish passage system at Cape Horn Dam may be functioning effectively much of the time, it has been noted by CDFW staff that fish are rejecting the upper ladder, and the lower portion of the fish ladder and Fish Hotel is vulnerable to debris loading during flood events. Therefore, the following items are recommended to bring the existing ladder into compliance and reduce down time and duration due to debris loading:

- The existing ladder has variable pool dimensions and variable flow rates between the upper and lower ladder. It appears that the energy dissipation factor is not met in at least 22 pools. The concrete weirs and stop log slots also seem to be in poor condition. It is recommended to cut the concrete weirs and recast them in place with new stop log slots, as well as adjust the weir length.
- To meet the energy dissipation factor in each pool, the ladder flow would need to be adjusted (i.e., reduced).
- When recasting the concrete weir walls, provide a 2-inch wide by 4-inch-high opening on each side to provide a slot for Pacific Lamprey and Sacramento Suckers at the interface of the weir wall and the fishway walls at the floor level. These slots have been used with success at other facilities (USFWS – Coleman National Fish Hatchery, California). All the weir walls would need to be equipped with these Pacific Lamprey slots.
- The upper eight pools should be modified from the submerged orifice configuration to match the rest of the ladder. It is understood that the divider walls probably are required for structural reasons. Buttress beams should be used instead. In the event that the tunnel diversion bypass continues to discharge into Pool 28, the weir length below and above this discharge point will need to be adjusted to maintain similar hydraulic head conditions.

- The Pacific lamprey system is known to work well, therefore, this system could be kept and improved upon, by placing it under a grating system in pools 5 through 15 to protect it from flood events.
- Pool 28 is a turning pool, and its length needs to be adjusted (enlarged). The weir walls of pools 29 and 30 could be cut and moved to enlarge pool 28.
- In Pool 28, install a 2-foot vertical radius of curvature in the vertical corner where the flow changes direction by more than 90 degrees.
- The freeboard of each pool would need to be reviewed to ensure that a minimum of 3 feet is provided. This is especially true for the lower pools from Pool 5 to about Pool 15.
- Pools 5 through at least Pool 15 should be equipped with grating above the fishway to minimize the possibility of debris accumulation inside the pools. This will enable the fishway to be put back in service in a short amount of time after a high flow event.
- It is recommended to decrease the length of Pools 30 and 31 to reduce the length of the fishway to be more efficient for fish passage.
- A finger weir is currently used at the entrance of Pool 30 for the purposes of forcing fish out of the water for the motion sensing camera. It is recommended to remove the finger weir (which renders passage more difficult to fish), remove the tarp tent (which provides some darkness for better motion detection but also creates an abrupt lighting change), and install in Pool 30 (or Pool 31) a Vaki Riverwatcher fish counter, or similar, with video capability. This system could provide reliable data for fish passage monitoring. The Riverwatcher has the following capabilities:
    - Counts fish with more than 98% accuracy.
    - Measures the size of each fish with more than 95% accuracy.
    - The control unit stores an image of every fish that passes the scanner, so the counting can be verified afterwards.
    - The date and time of day that each fish passes the scanner is recorded.
    - The water temperature is measured at frequent intervals.
    - Power can be supplied from solar panels and a deep cycle battery.
    - The Riverwatcher can be used to trigger a video camera.
- Install level sensors to control AWS flow and fishway entrance gate positions.
    - The AWS system (with the drop inlets) is directly dependent on water levels in the forebay of the fish hotel and is dependent on the AWS gate position. To know when to close or open the AWS gate, the following rating curve was developed (Figure 3-15.). Knowing water levels will support the operator to set the AWS gate position optimally. Note that during high forebay water levels, the AWS system has the capacity to easily exceed the AWS design flow of 88 cfs.
    - The entrance velocity is exceeded at 100 cfs (i.e., AWS flow of 88 cfs, plus 12 cfs of ladder flow), with one entrance gate fully open. With the rating curve above and level sensors in the tailrace and inside the Fish Hotel, the operator will be able to accurately determine the head differential at the entrances. The operator, with the help of a look-up table and gate opening indicator, could set the entrance gates in the optimum position.
    - Because the Fish Hotel is submerged from time to time during high flows, it does not make sense to automate the gate actuators.

- The AWS wall diffusers could not be observed; however, it is assumed that the material and diffuser maximum opening size does not meet current NMFS criteria. It is assumed that the AWS wall diffusers will need to be replaced.

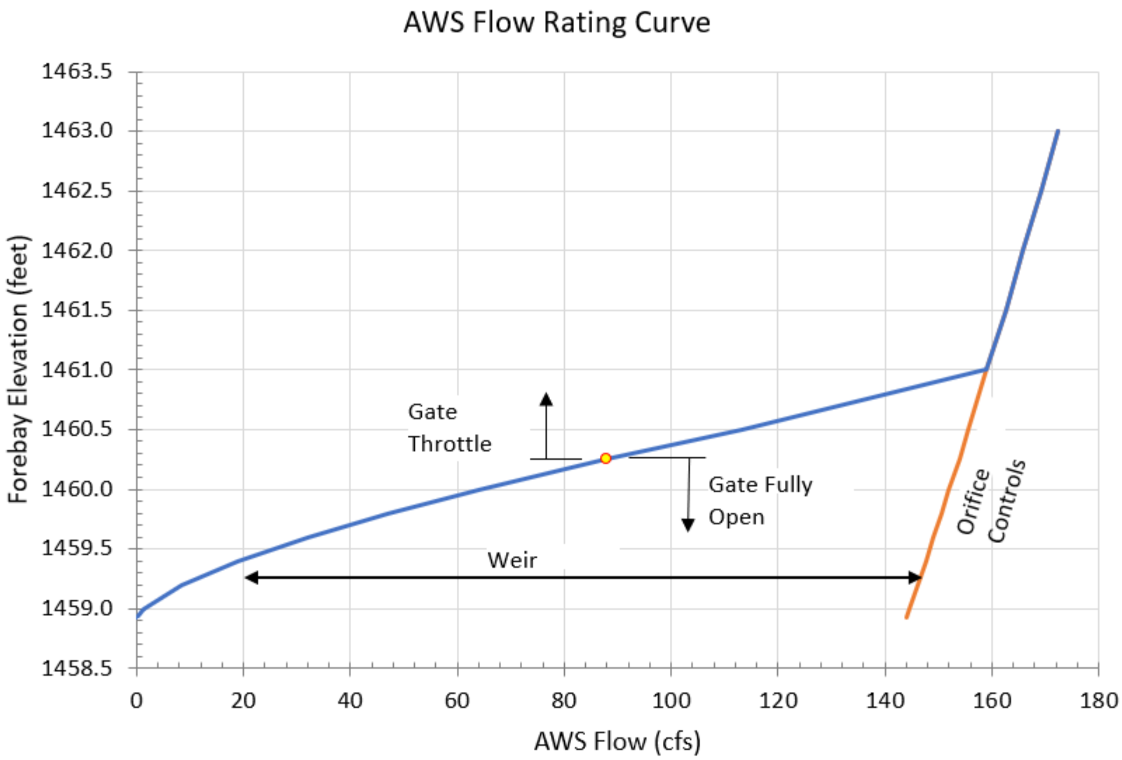

Figure 3-15. AWS flow rating curve for the Fish Hotel (NGVD 1929 Datum).

3.3.3 Fish Hotel

The Fish Hotel should be modified to better accommodate or reduce risk of high flow damage to the facility due to sediment and debris. NMFS and CDFW developed the following four options following a recent site visit (NMFS 2019):

1. Ladder Extension: Construct a Denil fish ladder that could connect to the existing fish ladder above the lower pools to cut off flow to the lower pools and Fish Hotel during high-flow events.
2. Hotel Roof Modification: Construct an awning-like extension of the Fish Hotel roof over the fish ladder entrance to minimize or reduce risk of debris and sediment deposition in the fish hotel.
3. Barrier Wall: Construct a barrier wall immediately upstream of the Fish Hotel to shunt water and sediment and debris over to the main river channel during high flows.
4. Fishway Entrance Closure Panels: Bulkheads or gates could be added to the Fish Hotel to seal all openings in the structure when high river flows are forecast. These are currently being implemented and should be completed by November 2020.

PG&E contracted with Mead & Hunt to develop a solution for Item #4, and a conceptual design was presented to NMFS and CDFW. The retrofit should reduce the amount of sediment and debris that enter the Fish Hotel during high flows. The objective of this conceptual design is to prevent sediment and debris from entering the facility by introducing a series of steel doors that could close off the otherwise open portals above the entrance bays of the facility on the ascending limb of a high flow event, then operated on the receding limb after sediment and wood transport has ceased.

The structure has seven large openings. The Mead & Hunt design includes steel double doors at six of the openings. The doors would typically stay open to provide ambient lighting but could be closed ahead of a flood event. Access is currently provided at two of the openings, to access manual gate operators. Similar type access grating could be added at the other three openings. Space in the grating (or removal grating sections) could be provided to be able to continue operation and allow installation or removal of stop logs to accommodate tailwater fluctuation. At the location of the two manual gate operators, the gate wheel could be in the way of shutting the steel doors. Mead & Hunt propose to modify the existing gate operator with a 90-degree operator or bevel gear or provide a slot in the door. The sixth opening is the large opening by fishway pool 5. This opening could also be closed with steel doors. The steel door would come in two sections. One section would be single leaf door, and the other section would be a bi-fold door. The gap between the bottom of the steel door and the fishway weir could be closed with stop logs. To eliminate the risk of flotation when the structure is submerged, Mead & Hunt propose to leave an air gap under the structure's roof and the top of the steel doors. The air gap height is not specified, but it is assumed that it could be kept to a minimum.

In addition to the Mead & Hunt design, we offer the following observations:

- The seventh opening in the Fish Hotel is not mentioned by Mead & Hunt, which is the side entrance for operator access. This opening is currently equipped with a man door which is made of vertical pickets. All openings should receive the same treatment (i.e., steel doors).
- Debris and sediment also deposit in the lower fishway pools. A potential solution is to install a sluice gate in the outside wall of pool 5. The operator would need to be tucked away to not be damaged during the flood. The sluice gate would be 2 feet high by 3 feet wide. The lower pools from pool 5 to pool 15 would be equipped with grating.

3.4 Van Arsdale Diversion

Cape Horn Dam is the mechanism by which water is impounded and ultimately diverted through the diversion structure and tunnel. The diversion structure refers to the screen and fish bypass facility with its appurtenances. The following sub-sections investigate several options for a Van Arsdale Diversion, including providing modifications to the existing diversion structure, modifying Cape Horn Dam, and several alternate diversion methods, including introducing a radial collector well field, an infiltration gallery, vertical screen, or a cone screen diversion system. The focus is on maintaining water diversion capabilities and reliability if Scott Dam is removed, with the understanding that these options could also be implemented if Scott Dam remains.

3.4.1 Modification of Existing Van Arsdale Diversion

There are a few changes that are recommended for the existing diversion structure. At a minimum, the bypass pipe from the Archimedes screw pump would need to be modified. Per the current configuration, the bypass does not meet NMFS criteria (see Section 2.4.3). While CDFW has historically operated the facility and has not taken issue with the facility, the bypass pipe should be modified to comply with NMFS criteria.

The bypass is not a true bypass in the proper sense. Rather, it is a fish return for fish that have been trapped beyond the screen structure and lifted in the Archimedes screw pump. The bypass flow is approximately 4 cfs, but about 2 cfs are returned to Van Arsdale Reservoir, with the remaining 2 cfs discharging to the fish ladder in Pool 27. The intent is that fish are placed in an area where they can then readily move downstream. Instead of this configuration, it is recommended that the flow split is completely removed and that the full flow is put back into Van Arsdale Reservoir. During low flow periods, fish could be directed to the high-level fish water release structure with the rest of the fish that did not get trapped by the Van Arsdale Diversion structure. During high flow periods, fish returned to the reservoir could pass downstream over Cape Horn Dam with the rest of the juvenile out-migrant fish. The advantage to this modification is that the fish ladder flow at Cape Horn Dam would remain constant and juvenile fish would no longer be discharged to the fish ladder, which is not only inefficient, but has high turbulence, and likely has a high injury rate due to the Parshall flume/baffle flume and impact velocity. In addition, fish being discharged to the ladder experience delayed migration, as they need to travel down the ladder and exit the ladder. During that added time, there may be possible predation in the fish ladder pools.

If Scott Dam is removed, based on water supply modeling conducted under the Ad-Hoc Committee (Addley et al 2019), capacity of the Van Arsdale Diversion was assumed be increased to divert up to 300 cfs to meet water supply and environmental flow needs on the Russian River (and could be increased up to 320 cfs based on tunnel capacity). Because the intake screen has been derated to 240 cfs due to the cleaning system, the intake screen is currently considered a passive screen. Changing the screen cleaning system from air sparging to a brushing system to bring it to an active screen designation is not feasible for this project due to the near-horizontal configuration of the screens. Instead, it is assumed that the facility will continue to operate as a passive screen (i.e., the air sparge system would not be used on a regular basis, but only after high-debris load events). Therefore, the screen footprint may need to increase by 300 square feet. To do so, the front of the structure may need to be reconfigured to extend the screen and translate the rack system further into the reservoir by approximately 20 feet.

3.4.2 Modified Diversion at Cape Horn Dam

If Scott Dam were removed, continued reliable functioning of the Van Arsdale Diversion would either need to 1) retain Cape Horn Dam and the existing diversion infrastructure, 2) substantially modify Cape Horn Dam to enable continued function of the existing Van Arsdale Diversion, or 3) remove Cape Horn Dam and substantially modify the Van Arsdale Diversion. Based on the age of Cape Horn Dam and poor fish passage performance, there may be risks and drawbacks with future operation and maintenance of Cape Horn Dam that would inhibit future water supply and fish passage reliability. Some of these risks and drawbacks could be reduced or eliminated if a new dam of similar dimensions replaced the existing Cape Horn Dam. However, there may be water supply and fish passage risks that could still be present at varying levels of Cape Horn Dam were to be replaced by a new diversion dam. The tangible benefits and risks to replacing the dam, therefore, are not entirely known at this time.

Providing more reliable fish passage to the existing Cape Horn Dam is discussed in Section 3.3. Major modifications to the existing Cape Horn Dam could be considered. As an example, an array of bladder weirs, sluice gates, tainter gates, or some other similar system could be used in a modified or newly constructed Cape Horn Dam to provide the option to partly drain Van Arsdale Reservoir. Doing so could achieve the following objectives: 1) maintain the ability to divert water through the diversion tunnels, 2) potentially improve water quality in Van Arsdale Reservoir by intermittently flushing the “dead pool”, and 3) help route sediment through the reservoir under conditions of Scott Dam removal. If improvements are made at the existing diversion structure (e.g., periodic draining/flushing of sediments), corresponding improvements in reservoir water quality might be expected. Finally, if Scott Dam were removed, the incoming sediment from Lake Pillsbury deposits and the upper watershed could temporarily deposit in Van Arsdale Reservoir and require mechanical removal over a short time period. However, over the long term, this sediment is expected to route downstream as it does now, such that a sediment equilibrium would be reached in the reservoir and mechanical removal would no longer be needed. Sediment is currently routing through Van Arsdale Reservoir in equilibrium without impacting diversion reliability. For these reasons, major modifications at Cape Horn Dam to allow flushing through weir or gate operations are not recommended or considered further.

Were Scott Dam to remain, modifications to Cape Horn Dam could address fish passage issues discussed in earlier sections of this technical memorandum but would not likely include changes to the water-diverting function of Cape Horn Dam.

Lastly, if Cape Horn Dam were removed and not replaced, an alternative diversion infrastructure would need to be developed, which is described in the following section.

3.4.3 Alternative Diversion Technologies

The following sections describe potential alternative diversion technologies for a scenario where Cape Horn Dam is removed. For all alternative diversion technologies discussed below to be considered for future more detailed analysis, it is assumed that the diversion must attempt to satisfy the following performance criteria: 1) be able to divert at least 300 cfs consistent with the assumptions in Water Supply Scenario 2 (dam(s) removed), 2) provide water supply reliability equal to or greater than the existing diversion infrastructure, and 3) be able to have operational capabilities to accurately meet downstream instream flow requirements. The performance and feasibility of these technologies are dependent upon site conditions, including depth of alluvium, channel stability, depth to bedrock, and final channel profile after removal of Scott Dam and Cape Horn Dam. These alternative diversion technologies have not been verified as being able to reliably divert and control flows and would need considerable additional analysis to verify viability.

3.4.3.1 Radial Collector Wells

Radial collector wells (or radial collectors) are large wells located either in or along the banks of alluvial rivers that typically include a large wet well caisson with several perforated or slotted laterals extending outward from the caisson into the native alluvium below the bed of the river (Figure 3-16). Radial collector wells rely heavily on the hyporheic zone below the riverbed and are therefore influenced more by the static level of surface water than by the piezometric groundwater head. Radial collector wells would need to be constructed a sufficient distance apart so as not to compete for the same water. For example, Sonoma Water's radial collector / riverbank filtration wells along the Russian River must be located at least 400 to 500 meters apart to avoid interference with each other. Radial collector wells do not require a check structure or low-head dam to divert, but as evidenced by the Sonoma Water's experience with riverbank filtration, one may be required to achieve or maintain the desired diversion capacity. The caissons for radial collectors can be constructed using a few standard methods, including secant pile or tangent pile walls. More commonly, sections of the caisson are constructed on top of a cutting shoe and the alluvium is removed from within the caisson section with a clam shell bucket. The caisson then sinks into the alluvium under its own weight until it nears ground surface. Then another section is formed and poured on top of the first section and the process repeated until the bottom of the caisson extends to the desired depth, typically bedrock. Once constructed, pipe jacking equipment can be lowered into the caisson to advance the laterals. A few examples of where radial collector wells are being used to divert water from rivers in Northern California can provide some limited insight into the applicability of this technology to the Project.

The first example is located on the Mad River, near Arcata in Humboldt County (see Figure 3-16). The Humboldt Bay Municipal Water District (HBMWD) owns and operates six radial collector wells, each with a caisson on the order of 13 feet inside diameter that range in depth from about 60 feet to 90 feet below ground surface. Based on communications with HBMWD, five of the six wells are used to withdraw about 14 million of gallons per day (MGD) (22 cfs) on average. However, the peak capacity of each well appears to range from about 6 to 10 MGD (9 to 16 cfs) each. Based on this upper limit, which cannot be maintained continuously, over 30 wells would be required to replace the diversion at Cape Horn Dam, all else being equal.

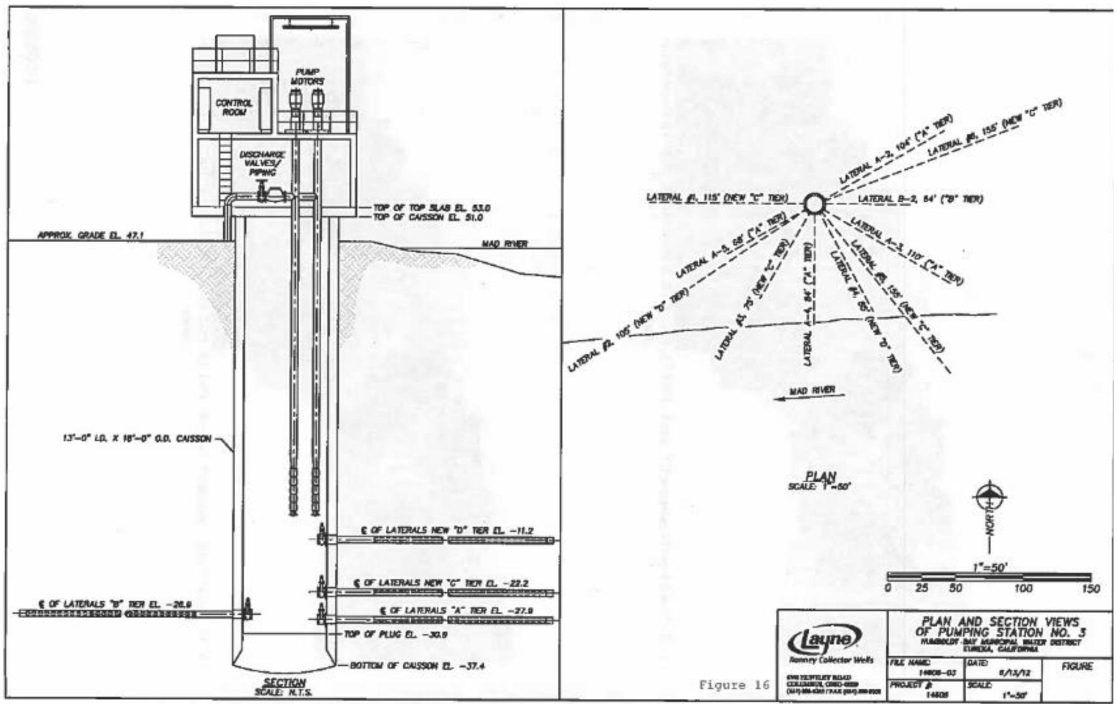

Figure 3-16. Example Ranney Well Elevation and Plan, Mad River.

Another example comes from Sonoma Water, which owns and operates six radial-collectors along the Russian River near Forestville. The collectors have 13- to 18-foot inside diameter steel reinforced concrete caissons. Based on data presented in D'Alessio et al. (2018), these collectors have total flow rates between about 10 to 34 MGD (22 to 46 cfs), depending on the number collectors in operations and whether an inflatable dam has been raised. These collectors contain 12 pumps that are powered by 1,100- to 2,000-horsepower motors. Assuming an average capacity of about 17 MGD (25 cfs) per collector, achieving 300 cfs of diversion would require 12 radial collectors with pumps along the Eel River sufficiently spaced apart to avoid interference (likely 400-500 meters apart), all else being equal. Again, potentially more may be required for a safety factor and to provide standby collectors during periods of maintenance.

Both of these example systems include pumping sub-systems. The use of a radial collector well system on the Eel River could require significant upgrades to bring high-voltage power services to this area. Alternatively, providing a gravity supply of water from each well could require a final, larger diameter lateral extending out from each well and eventually combining into a main trunk gravity supply line that connects up with the existing tunnel. It is expected that the tunnel portal invert elevation could be above the original bed of the river in the absence of Cape Horn Dam and, therefore, siting the Ranney well field would require that one of the following two conditions be met:

1. The tunnel connection would need to be made sufficiently airtight and provisions are introduced to create a reliable siphon; or
2. The radial collector wells are located far enough upstream that there is sufficient driving head to convey water to the tunnel without entraining air at the well or creating a vacuum at the tunnel connection.

Regarding the first condition, a siphon is not suitable for application at Project because siphons are prone to losing prime when air is entrained from either the upstream or downstream end, and the addition of a priming pump could not work at this site because making the Project system airtight is unlikely. Also, when the water pressure approaches the vapor pressure for a given water temperature, the water will effectively boil and rapidly release gas, which will lead to a collapse of the primed water column.

Regarding the second condition, there is significant uncertainty at this time regarding the quasi-steady state elevation of the Eel River invert, should Cape Horn Dam be removed. Furthermore, it is not clear whether the dam could be removed all the way to the toe, or whether removal could stop short of the toe and extend, for instance, to the abandoned low-level release elevation only. In either case, the connection of the main trunk line to the tunnel could need to extend sufficiently upstream such that the water level (minus friction losses) is above the crown of the tunnel. Depending on the extent of the removal, the length of the main trunk line would need to be between about 1,500 feet and 8,700 feet upstream of the existing tunnel portal. This assumes very minimal head losses. But if the main trunk line is, for example, the same size as the tunnel (i.e., 7-foot diameter) and is conveying a maximum diversion flow rate of 300 cfs, then the velocity in the main trunk line is 7.8 ft/s, which will lead to significant head losses through the system and require that the main trunk line is extended even further upstream. In addition, to allow for sufficient spacing of the collector wells to avoid interference with each other, a trunk line header would need to be constructed of several thousands of meters in length, significantly longer than even the main trunk line.

An alternative approach for the main trunk line may be to network the gravity discharge pipes for each of the wells together near the existing diversion and connect them with a new, larger and lower tunnel adit that extends into the hillside and connects with the existing tunnel. However, the existing tunnel extends into the hillside at a similar slope – 0.3% – such that an average adit length of about 5,100 feet may be required. This is nearly the entire length of the existing tunnel, which is likely impractical and cost prohibitive. Regardless of the main trunk line location (adjacent to the Eel River or as a lower tunnel adit), the several thousands of meters of trunk line header to allow for sufficient spacing of the 30+ collector wells are likely impractical and cost prohibitive.

Based on the level of investigation in this feasibility study, there are substantial uncertainties about the feasibility of this option due to channel movement and morphological changes after Scott Dam removal, the possibility of inadequate alluvium to drill wells, hydrogeologic conditions that may not allow subsurface capture of 300 cfs, and the high cost to construct approximately 30 radial collector wells spaced 400-500 meters apart with thousands of meters of trunk line header.

3.4.3.2 Infiltration Galley

Infiltration galleries typically consist of a series of shallow horizontal perforated collector pipes embedded within a gravel filter pack below or adjacent to a surface water source. Surface water percolates through the bed material and filter to the collector pipes (or well casings) and then drains to a wet well. Water is typically pumped from the wet well to a water treatment facility (for municipal systems) or irrigation system. However, for the Eel River system, the wet well could gravity feed to the 7-foot-diameter steel diversion line if placed far enough upstream to provide sufficient head with friction losses. Infiltration galleries do not require a check structure or low head dam to divert.

Infiltration galleries are a well proven technology that have been used on municipal water supply and irrigation systems throughout the United States. For example, an infiltration gallery was installed on the Tuolumne River in Stanislaus County California for the Turlock Irrigation District (TID). The Tuolumne River infiltration gallery has a tested intake capacity of 100 cfs and is used as a domestic water supply source by the Stanislaus Regional Water Authority (TID, 2018). Figure 3-17. shows the perforated collector pipes embedded in the gravel pack from TID's infiltration gallery during construction in 2000.

Figure 3-17. Lower Tuolumne River infiltration gallery (TID 2018).

The primary benefit to infiltration galleries is that the gravel pack pre-filters the water entering the supply system by removing organic material and suspended sediment. Where fish passage and habitat are a concern, properly designed infiltration galleries are typically considered to be fish friendly (i.e., low risk for impingement). However, NMFS has developed criteria and guidelines for the design and operation of infiltration galleries, as shown in Table 3-1.

Table 3-1. National Marine Fisheries Service (NMFS 2011) infiltration gallery design criteria/guidelines.

Description	NMFS Criteria
12.5.1.2 Minimum Depth and Velocity over Infiltration Gallery	Min Depth 0.5 ft Min Stream Velocity: 2 ft/s
12.5.1.3 Screen Material Opening	Gravel cover depth <24 in must meet juvenile fish screen criteria (See Table 2-2, 11.7.1.2)
12.5.1.6 Induced Vertical Approach Velocity at the Stream Bed	Maximum vertical interstitial velocity through the substrate must not exceed 0.05 ft/s.
12.5.1.8 Backwashing	All infiltration galleries must be designed to be capable of being backwashed.
12.5.1.9 Limitations/Cessation of Use	Infiltration galleries should not be constructed in areas where spawning may occur. If spawning occurs within 10 feet of a portion of an infiltration gallery, then use of those portions of the infiltration galleries within 10 feet of the redd should be discontinued for 90 days, or as directed by NMFS.

Figure A4-3-C104 (Appendix 2) presents a conceptual level layout of a 300 cfs capacity infiltration gallery. The system consists of three identical 100 cfs galleries that tie into the 7-foot-diameter pipeline via a steel manifold. Each gallery consists of three bays with four perforated stainless-steel well casings per bay. Assuming the site allows for equal spacing between gallery bays, the infiltration gallery could extend over 580 feet along the riverbed. Note that the infiltration gallery arrangement shown in Figure A4-3-C104 does not consider many of the site-specific design factors that may alter the pipe orientation, burial depth, gravel pack design, etc. The purpose of this representation is for order-of-magnitude cost estimates and to help the reader understand the primary system components and functionality. Alternatively, infiltration galleries may also be installed parallel to the riverbank where unconfined shallow aquifer conditions exist. This option was not considered as its feasibility is dependent upon knowledge of site-specific subsurface conditions.

While the infiltration gallery is a well proven technology, its application is limited to a narrow range of site conditions. Infiltration galleries are well suited for stable river channels with a consistent flow regime and low sediment load. The primary design concern with dynamic river systems and unstable geomorphology, such as the Eel River between Scott Dam and Cape Horn Dam, is that large flood events can remove the gravel pack and expose the collector pipes. In addition, large flood events can also potentially deposit material over the gravel bed and severely limit the flow to the collector pipes. Likewise, rivers with large sediment loads may clog the gravel pack and overwhelm the backwash system resulting in a low intake yield.

The Eel River is capable of extremely large flood events and has a naturally high sediment load. For example, Figure 3-18 shows the Cape Horn Dam fish ladder filled with sediment and cobbles as a result of the February 2019 flood events. As noted by Brown and Ritter (1986), “The Eel River has the highest recorded average annual suspended-sediment yield per square mile of drainage area of any river of its size or larger in the United States.” Under the Scott Dam removal scenario, even if all the sediment stored in Lake Pillsbury were excavated and stockpiled, the sediment load will increase by up to a factor of 5 above background levels based on the additional contribution from the upper watershed.

Figure 3-18. Cape Horn Dam Fish Ladder entrance showing accumulated sediment and debris.

Additionally, there is potential for the infiltration gallery to be partially shut down due to the presence of redds. As shown in Table 3-1, NMFS guidelines recommend that infiltration galleries be shut down for a period of three months if redds are located within 10 feet of the gallery. Due to the likelihood of channel altering flood events, high sediment load, and potential for temporary shutdowns due to the presence of redds, an infiltration gallery could have an even higher likelihood of failure than other subsurface diversion technologies. Based on the level of investigation in this feasibility study, there are remaining uncertainties about the feasibility of this option due to sediment and debris loading, as well as channel movement and morphological changes after Scott Dam removal.

3.4.3.3 Vertical Intake Screen Diversion

Vertical or inclined intake screens are commonly used on surface water diversions. Common intake configurations consist of single or multiple screened intake bays installed in-line with the riverbank. The primary benefits to vertical intake screens are that they are low impact to the river channel, have straightforward operation and maintenance requirements, and are operational over a wide range of flows.

Vertical intake screens may require a check structure of some kind to increase the depth at the diversion screen, that may or may not be channel spanning. Vertical intake screens have higher submergence requirements than cone screens. If diversion timing adjustments are allowed, diversion at the lowest flows may be avoided, reducing the need for a check structure.

The standard vertical screen could be equipped with a brush cleaning system. The advantages of this system are:

- The screen opening could be updated to meet NMFS criteria;
- The cleaning system (being a brush system) should be able to keep up with algae growth;
- The facility could have a good sweeping velocity;
- The Archimedes screw pump could be removed, simplifying operation and maintenance;
- The bypass pipe could be removed as fish would not be collected any longer; and
- The powerhouse could more reliably run with increased flow.

Intake screen configurations can be designed to meet NMFS criteria (Table 3-2) to minimize juvenile salmonid mortality rates. Static or "passive" screens are most commonly fabricated from stainless steel wedge wire manufactured by Hendrick Screen Company (Figure 3-19.). NMFS approach velocity criteria for passive screens is lower (0.2 ft/s) than active screens (0.4 ft/s) and therefore require a greater screen area. However, if space is not a limiting design factor for the intake structure, passive screen intake systems have significantly lower construction and maintenance costs than active screens due to the mechanical and electrical components required for passive screens. Passive screens should only be installed when debris accumulation is minimal and manual cleaning is a feasible option. This is not the case for an Eel River intake based on the high debris loads, particularly if Scott Dam is removed.

Table 3-2. National Marine Fisheries Service fish screen criteria (NMFS 2011).

Description	**NMFS Criteria**
11.6.1.1 Approach Velocity	< 0.4 ft/s (active screens) <0.2 ft/s (passive screens)
11.6.1.4 Flow Distribution	Screens must provide uniform flow distribution over the screen surface, thereby minimizing approach velocity over the entire screen.
11.6.1.5 Screens Longer Than Six Feet	Sweeping velocity across screen must be greater than the approach velocity.
11.6.1.6 Inclined Screen Face	An inclined screen face must be oriented less than 45 degrees vertically.
11.7.1.2 Slotted or Rectangular Screen Openings	Openings must not exceed 1.75 mm (approximately $1/16^{th}$ inch)

Figure 3-19. Inclined intake screen (passive cleaning).

The two most common types of active screen systems for vertical intakes are: (1) Mechanical brushes that sweep debris from the wedge wire screen or, (2) Horizontal or vertical rotating screens, as shown in Figure 3-20. Horizontal or vertical rotating screens consist of interlinked sections of engineered polymer screen. Vertical rotating screens can be beneficial when sweeping velocities are not available to carry the removed debris downstream of the screen as required for brush systems and horizontal traveling screens. Vertical screens utilize scraper bars or spray arm to remove debris which then falls into a collection trough. All active screen configurations are susceptible to fouling from heavy sediment or debris loads. However, active screen systems can also be fitted with airburst systems or sprayers to reduce risk of fouling.

Figure 3-20. Inclined intake rotating screen (active cleaning).

The benefit to an active screen is the cleaning system can automatically adjust to abrupt changes in sediment and debris load with the use of water level sensors and PLC systems. Where space is limited for the intake screen, an active screen system requires less submerged area due to the higher approach velocity criteria of 0.4 ft/s.

The primary design concern for a vertical intake screen system on the Eel River is the high sediment and debris load. Although both active screen types have the potential for clogging, horizontal or vertical rotating screens are usually more susceptible to breakdowns as sediment buildup prevents the screen from rotating. A recommended vertical intake alternative configuration would consist of a five-bay intake structure fitted with NMFS compliant wedge wire screen, mechanical brushes, trash rack, and hoist system.

In order to meet the NMFS 0.4 ft/s approach velocity criteria for a diversion rate of 300 cfs, the submerged screen area required is 750 square-feet. However, the final screen dimensions will depend on the anticipated river depth at the intake site. In addition, it is recommended that the screens be oversized to provide a factor of safety in anticipation of temporary or partial blockages. The screen dimensions for the five intake screens were assumed to be 20-foot-wide by 15-foot-tall with a minimum submergence of 7.5 feet. Note that bathymetric data for the Eel River was not available at the time of this study. Screen dimensions will vary depending upon actual site conditions.

The intake structure should be located on the outside of a stable bend (e.g., current diversion location) where higher channel velocities will prevent gravel bars from forming in front of the structure and sweeping velocities will effectively carry debris from the screen. A conceptual drawing of the vertical intake alternative is presented in Figure A4-3-C103 (Appendix 2).

Additional design features that should be considered in future design efforts are stoplogs, flow baffles, and a backwash system. When high flood events are anticipated (e.g., >7,000 cfs, the intake facility can be temporarily shut down and protected by installing stoplogs in front of the screens. If the screens are oversized, flow baffles may not be required. However, a hydraulic analysis should be conducted to determine if high velocity zones exist across the intake screen. If so, flow baffles can be used to evenly distribute flow across the intake and reduce risk of fish impingement. Lastly, a backwash system may be considered as it provides additional defense against blockage from impinged debris or sediment. Likewise, an airburst system may be considered if sediment buildup at the structure is anticipated.

The effectiveness of the vertical intake structure in the Eel River will largely depend upon site conditions at the proposed intake location. The main risk with this intake type is that a channel forming event could potentially leave the intake submerged in sediment or disconnected from the low flow channel. With proper site selection, these risks could be minimized with an active screen. Based on the level of investigation in this feasibility study, however, there are remaining uncertainties about the feasibility of this option due to channel movement and morphological changes after Scott Dam removal, and the wide range of river stage levels that diversion would need to reliably operate.

3.4.3.4 Cone Screen Diversion

Similar to vertical intake screens, cone screen intakes manufactured by Intake Screens, Inc. (ISI) are made of NMFS-compliant stainless-steel wedge wire steel screen and utilize mechanical brushes to remove debris and sediment from the screen. The primary difference is that due to the conical shape of the screen, the majority of screen area is located at the base of the screen. By placing the cone screen at or near channel bottom, diversion rates can be achieved in shallower water applications. This is a significant benefit for a diversion intake on the Eel River under the Scott Dam removal scenario where the flow is unregulated and highly variable. As shown in Figure 3-21., ISI cone screens were utilized by the Tehama-Colusa Canal Authority on the Sacramento River for the intake to a 500 cfs pumping plant. As seen in the figure, the cone screens are operating at full capacity with only a few feet of submergence.

Cone screens are a low-flow diversion and so may or may not need any type of check structure. Forty-two inches of depth is required to divert 50 cfs through each cone screen. Cone screens have lower submergence requirements than the vertical screens discussed in the section above. In addition, if diversion timing adjustments are allowed, diversion at the lowest flows may be avoided, removing any need for a check structure.

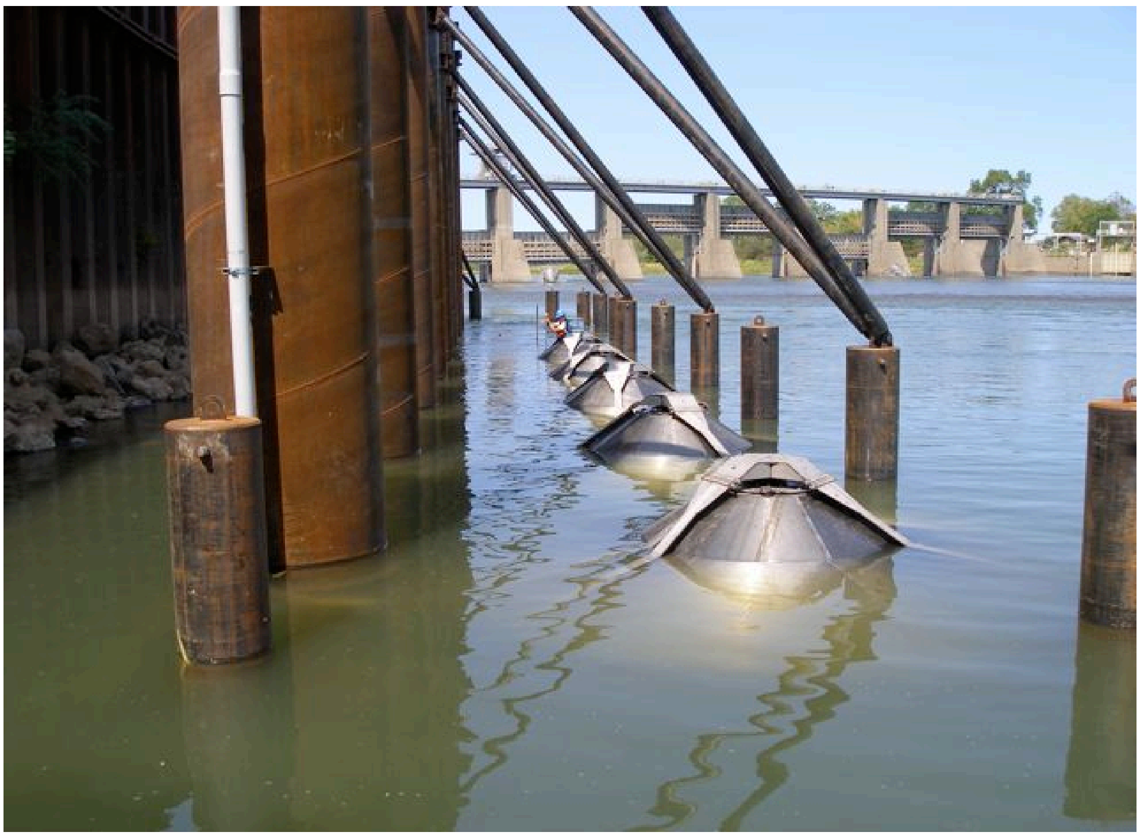

Figure 3-21. A 500 cubic feet per second (cfs) cone screen intake on the Sacramento River (photo courtesy of Intake Screens, Inc.).

Another benefit to the cone screen is that the shape is structurally sound and is more resilient to heavy sediment and debris loads as well as high velocity flows. In addition, due to the screen being base mounted, the elevation of the screen can easily be adjusted to accommodate changing riverbed levels by simply adding or removing risers or installing on an adjustable bulkhead as shown in Figure 3-22..


Figure 3-22. Cone screen on an adjustable bulkhead (photo courtesy of Intake Screens, Inc.).

One possible configuration for an alternative Eel River intake, shown in Appendix 2, Figure A4-3-C102, consists of six 14-foot diameter ISI cone screens installed in series and connected to the 84-inch diameter intake diversion pipe via a steel pipe manifold. Each 14-foot cone screen is rated at 60 cfs for a total intake capacity of 360 cfs. Although not shown in Figure A4-3-C102, it could be reasonable to install a seventh cone screen for system redundancy. Due to the high sediment load in the Eel River, each cone screen should be fitted with an air burst system to prevent accumulation of sediment over the screens. Similar to other active screens, the cone screen brush and air burst systems operation can be automated and remotely controlled with Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA) systems. Both systems could be recommended due to the responsiveness of the Eel River to storm events and remote site location. A control building for the intake site will be required to house the PLC and SCADA equipment and air compressor for the air burst system. A backup generator is also recommended to keep the system running in the event of a power outage. If site conditions allow, ISI cone screens can also be run off of solar power.

Based on the level of investigation in this feasibility study, there are remaining uncertainties about the feasibility of this option due to channel movement and morphological changes after Scott Dam removal.

3.5 Potter Valley Powerhouse

The following section discusses options for the Potter Valley Powerhouse, including current operations, Scenario 4B (dams remain) operations, Scenario 2 (dam(s) removed) operations, and decommissioning. Before discussing these options, however, an overview of the hydrologic model and Water Supply Scenarios is provided, along with a description of the hydropower model developed to simulate power production under the different options.

3.5.1 Overview of Hydrologic Model and Water Supply Scenarios

The hydrology output from the Jared Huffman Ad-Hoc Committee Water Supply Working Group was used for all analyses (Addley et al, 2019). HEC-ResSim was used to model the Russian River drainage (Russian River model) and the upper Eel River drainage (Potter Valley Project model) on a daily time step for the Water Year 1911-2017 time period (107 years). Each of the two drainages had a unique HEC-ResSim model, and the output of diversions from the Project model was an input variable for the Russian River Model. Historic unimpaired inflows and downstream tributary accretions were computed for both models, as were evaporation losses and assumed water use in Potter Valley and downstream of Lake Mendocino under current conditions.

The modeling effort assessed a range of water operations scenarios (Table 3-3), many of which did not meet water supply needs in the Russian River basin. Of the water operations analyzed, Scenario 4B (dams remain) and Scenario 2 (dam(s) removed) were selected for evaluation in this document because they both appear to meet Russian River water demands and represent the two strategies of the Feasibility Study (dams remain and dam(s) removed). Climate change scenarios were also analyzed by the Water Supply Working Group, but these were not used in the Feasibility Study analysis. Lastly, Scenario 4B and Scenario 2 reflect modifications to water operations, but both are fundamentally based on the existing Reasonable and Prudent Alternative (RPA) flows developed by NMFS (2002). Importantly, Current Operations and Scenario 4B assume a 170-cfs diversion capacity based on constrained diversion capacity and mass balance of the hydrology model (see Addley et al, 2019), while Scenario 2 assumes restoration of diversion capacity from 170 cfs to 300 cfs. While the actual current diversion capacity is 240 cfs, 170 cfs diversion capacity is used in the Hydropower Model to be consistent with the hydrology scenarios (Addley et al 2019). For example, the HEC-ResSim model for Scenario 2 assumes that diversions to the Potter Valley will cease once unimpaired inflows reach the minimum RPA flows plus a 30 cfs buffer. If the Planning Agreement Parties (Parties) proceed with licensing, these RPA flows will be re-evaluated, and another round of hydrologic modeling would need to be conducted to more accurately assess future hydrologic conditions (including climate change).

Table 3-3. Matrix of Water Supply Scenarios modified from the Ad Hoc Committee Water Supply Working Group (Addley et al. 2019).

Modeling Scenarios			Russian River & Lake Mendocino Alternatives		
			Current Operations	**Lake Mendocino FIRO (Hybrid) with Fish Flow Project Operations[1]**	**Raise Coyote Valley Dam**
Potter Valley Project Alternatives	Dams Remain	Current Operations[2]	Baseline: Existing Climate (n=1)		
			Baseline FC: Future Climate (n=4)		
		Revised Operations[3]	Scenario 4: Existing Climate (n=1)	Scenario 4B: Existing Climate (n=1)	
	Dam(s) Removed	Run-of-the-River[4]		Scenario 2: Existing Climate (n=1)	
				Scenario 2FC: Future Climate (n=4)	
		Decommission[5]	Scenario 1: Existing Climate (n=1)	Scenario 3: Existing Climate (n=1)	Scenario 5: Preliminary analysis, Existing Climate

Note: Red boxes are Scenarios analyzed by the Hydropower Model.

[1] Lake Mendocino Forecast Informed Reservoir Operations (FIRO) and Sonoma County Water Agency Fish Habitat Flows and Water Rights Project Draft Environmental Impact Report (State Clearinghouse No. 2010092087) (Fish Flow EIR) Assumptions: Maximum allowed reservoir elevation during November-March flood reserve space raised from 68,400 acre-feet (ac-ft) to 80,050 ac-ft. Reduces Lake Mendocino releases in all years except driest year by up to 80 cubic feet per second (cfs). Achieve unmet Potter Valley Irrigation District (PVID) demands (up to 15,320 ac-ft) via PVID pumpback from Lake Mendocino.

[2] Current operations: Scott Dam and Cape Horn Dam stay in place, streamflows and diversions based on 2002 Biological Opinion Reasonable and Prudent Alternative (RPA) flows, maximum diversion=170 cfs based on model calibration mass balance. Russian River flows based on 2008 Biological Opinion RPA and 1986 Decision 1610, existing flood control rule curve (no FIRO).

[3] Project Revised Operations Assumptions: 1) allow discretionary Project diversions when Scott Dam is spilling up to 170 cfs, 2) reduce Eel River minimum instream flow "floor" by up to 50 cfs in winter and spring, and 3) reduce minimum instream flow on the East Fork Russian River year-round by various amounts for different water year types.

[4] Run-of-the-River Assumptions: Remove Scott Dam; continue Van Arsdale diversions with a maximum Project diversion of 300 cfs resulting from capital projects that improve diversion reliability; achieve unmet PVID demands (up to 15,320 ac-ft) via in-valley storage, aquifer storage and recovery, pumpback from Lake Mendocino, or other means.

[5] Decommission Assumptions: Scott Dam, Cape Horn Dam, and Project Diversion would be completely removed, no water diversions from Eel River to Russian River, Eel River streamflows would be unimpaired.

3.5.2 Hydropower Model Development

A hydropower model was developed to analyze two cases presented for the future operation of the Potter Valley Powerhouse: 1) Scott Dam (and potentially Cape Horn Dam) removed and 2) Scott Dam and Cape Horn Dam remain. These two potential future operational scenarios are compared with modeled current operations (Table 3-3). Daily average tunnel flow regimes for each case identified were developed as described above. Powerhouse outflows in the model (E-5, E-7, and E-6, see Figure 2-6) were combined in the tailrace which was held at a constant water surface elevation of 1,014.8 feet (NGVD 1929 datum). The powerplant equipment was modeled as a two-unit system to match the penstock configuration. The two-unit model capacity of 11.3

MVA matches the documented combined capacity of Unit #1 (3.3 MVA), Unit #3 (2.5 MVA), and Unit #4 (5.5 MVA). While Unit #3 is currently out of service, the model capacity of 11.3 MVA was maintained to correspond to the capital improvement schedule and existing FERC license. A combined average plant efficiency of 84.9% was used in the model to represent conversion of waterpower to electrical power delivered to the substation high-side bus. Operation was modeled on a daily average basis with headwater level maintained at a constant level of 1,494.3 feet (NGVD 1929 datum). Penstock friction was modeled using the Darcy-Weisbach equation and the tunnel was modeled using the Hazen-Williams equation. Friction loss values from these methods were found to match other penstock and tunnel analysis work previously conducted by McMillen Jacobs. The power model also assumes that the plant is maintained at the existing hydraulic and electrical capacity (i.e., no major modifications to the turbines, generators, switchyard, etc.).

3.5.3 Hydropower Model Results

Annual energy generation results for Scenario 2 and Scenario 4B were compared with historical energy generation at the facility for the period 1985 through 2014 (calendar years). This comparison is presented graphically in Figure 3-23. From the figure, it is clear that the effect of the RPA flows is substantial when comparing historical generation with theoretical generation for the period prior to about 2005. After that point, when water diversions are better aligned with RPA flows, historical energy production begins to decrease below theoretical values. This is due to the new term in the amended license stating that discretionary diversions cannot be made when the reservoir is below the target storage curves, even when the reservoir is spilling. This may also be in part due to extended outages at the powerhouse for maintenance reasons, and the derating of the intake screens to a maximum flow rate of 240 cfs.

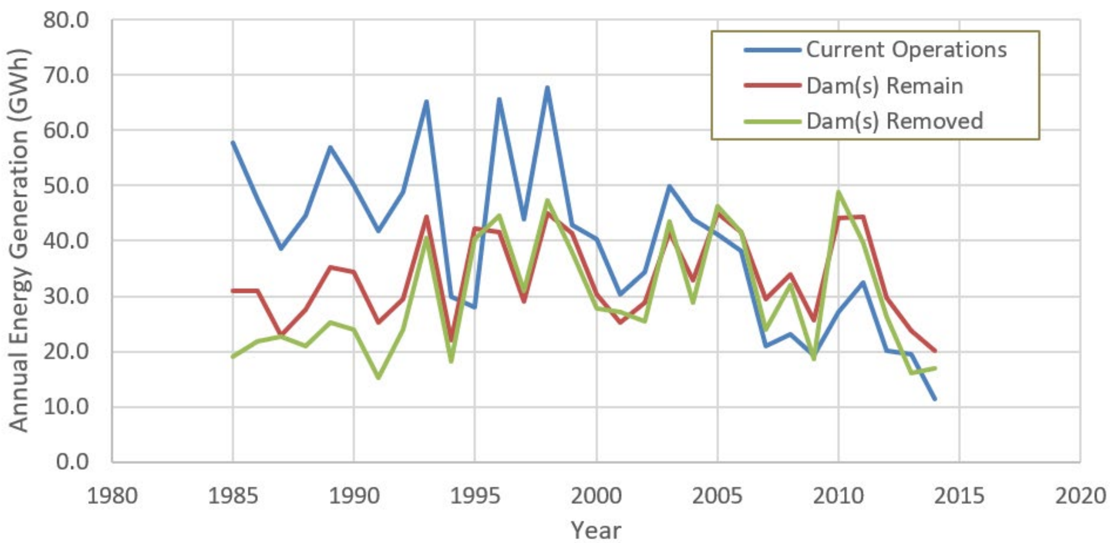

Figure 3-23. Annual energy generation for current operations (Baseline), dam(s) removed (Scenario 2), and dams remain (Scenario 4B), calendar year 1985 through 2014.

Another important observation from Figure 3-23 is that generation is nearly the same for both the dam[s] removed and the dam[s] remain scenarios. This is because the total annual tunnel flows are nearly the same, as evidenced by Figure 3-24, which presents an overlay of annual tunnel flow volumes for the period 1911 through 2017. However, it is important to note that diversion timing may have significant implications for the price earned for the electricity generated.

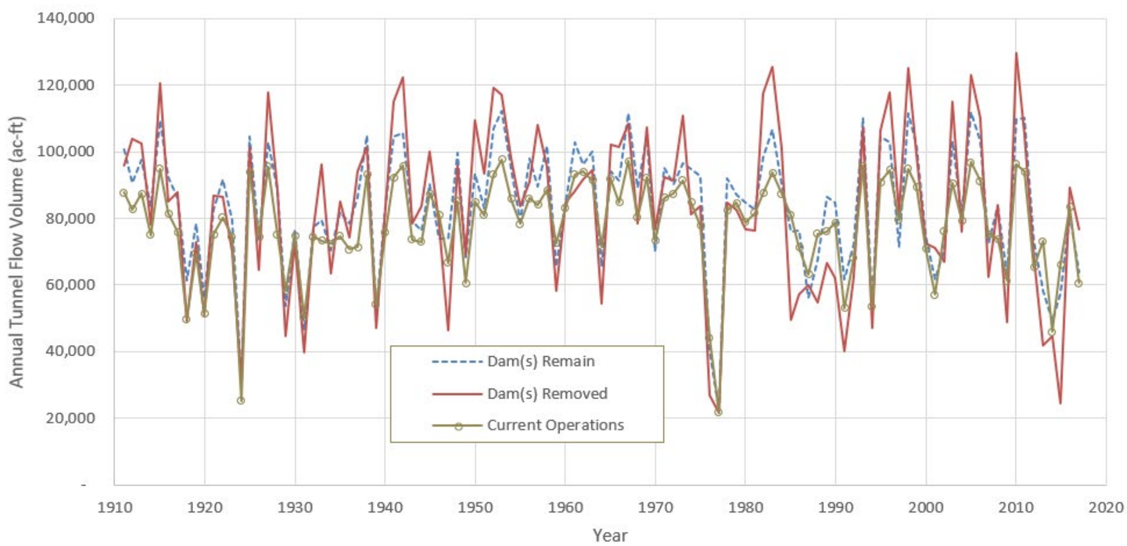

Figure 3-24. Annual tunnel flow volume for current operations (Baseline), dam(s) removed (Scenario 2), and dams remain (Scenario 4B), calendar year 1911 to 2017.

In the case of Scott Dam being removed, the Eel River between Scott Dam and Cape Horn Dam would once again experience an unregulated flow regime, with higher peak flows and much lower low flows on average. Although the total annual amount of water passing downstream (and being diverted to Potter Valley) would stay nearly unchanged, the timing of flows would change dramatically. Instead of diverting fairly predictable quantities of water year-round, the Project could divert larger amounts of water during the wet season when the water is available, storing that water in Lake Mendocino for release in the dry season when very little to no water is available in the river for diversion. Because of this shift in diversion timing and maximum diversion rate, the existing powerhouse is likely not optimally sized for diverting from an unregulated flow regime on the Eel River.

Additional model input parameters and model results for each of the two scenarios are presented in Table 3-4 and Table 3-5.

Table 3-4. Modeled diversions for various operations.

Statistics for RPA Tunnel Flows	Scenario 2 (Dam(s) Removed)	Scenario 4B (Dams Remain)
Assumed Peak Diversion Flow (cfs)	300	170
Average (annual total dsf [1])	41,700	42,200
Std Dev (annual total dsf)	12,600	9,400
One standard deviation range (annual total dsf)	29,100 –54,300	32,700 –51,600

[1] dsf = second-foot day = the volume of water represented by a flow of 1 cubic foot per second for 24 hours; equal to 86,400 cubic feet; useful when comparing to plant discharge.

Table 3-5. Modeled generation for various operations.

Model Generation	Unit	Average Hydrologic Year	Wet Year	Dry Year
Dam(s) Removed (Scenario 2)	MWh [1]	31,200	43,500	19,700
	aMW [1]	3.6	5.0	2.2
Dams Remain (Scenario 4B)	MWh	32,600	40,400	24,200
	aMW	3.7	4.6	2.8

1 MWh = megawatt hour; aMW = average megawatt (total energy divided by 8,760 hours/year)

3.5.4 Powerhouse Decommissioning

One of the options considered by the Feasibility Study is to decommission the Potter Valley Powerhouse which would avoid the FERC licensing process. This option would provide diversions without generation by following several major steps to install a free discharge valve (FDV). The list below assumes the new FDV(s) are located in the existing powerhouse.

- Existing penstock termination supports and anchors would require modification to accept new piping to connect to the FVD, the middle unit piping would be removed, and the penstocks modified to accept a reverse bifurcation; an alternative to the bifurcation is to install two FDVs, one per penstock.
- Powerhouse foundation changes after removal of the turbines would be required to anchor the FDV; these modifications would require a deeper or as-deep embedment than the existing turbines.
- Removal of the existing turbine draft tubes and reconfiguration of the downstream powerhouse wall would be required.
- Removal and disposal or salvage of turbines, generator, transformer, and auxiliary equipment.
- Installation of the valve, hydraulic power unit (HPU), and controls/communication equipment.
- Placement of the FDV may require a crane with capacity over that of the powerhouse crane, which may in turn require changes to the existing powerhouse roof.
- Tailrace modification to assure FDV discharge(s) can match existing canal flow requirements for the East, West, and Powerhouse Canals. Tailrace modification to assure FDV discharge(s) can match existing canal flow requirements for the East, West, and Powerhouse Canals.
- Dismantle the existing substation and modifications to the existing powerhouse electrical circuits tailored to the operation of the FDV.
- Any electrical distribution system changes made necessary by the removal of the generation source would have to be completed prior to construction. Any electrical distribution system changes made necessary by the removal of the generation source would have to be completed prior to construction.

An alternative to the list above is to reroute the penstocks to a new thrust block FDV base. This alternative would allow for a more flexible construction plan as maintaining diversions during construction would be easier. At this time potential land and space restrictions associated with an FDV located away from the existing powerhouse have not been vetted. There are additional regulatory and water rights implications of Potter Valley Powerhouse decommissioning that would make this option more challenging to pursue.

3.6 Dam Removal

Dam removal as part of the dam(s) removed alternatives has many components. How to remove the dams, the timing and phasing of dam removal, the timing, phasing, and volumes of sediment discharge associated with dam removal, the strategy and scale of revegetation under the reservoir inundation area, and consideration of downstream infrastructure, and ecological and environmental impacts. Each of these components is described in the following sections. The actual sequencing of dam removal, with considerations related to construction access, dewatering, erosion and sediment control, and other aspects of a large-scale demolition, are currently in development and are not presented here.

3.6.1 Scott Dam Removal Overview

In combination with a PVID water supply reliability project option, the process for removing Scott Dam could commence on the Russian River side of the basin divide, with implementation of water supply reliability infrastructure for Potter Valley to offset lost water supply reliability due to Scott Dam removal. This would need to be closely followed by infrastructure improvements to the Van Arsdale Diversion to ensure appropriate water supplies during the Scott Dam removal phase, as well as after removal. Scott Dam removal could then follow a phased approach (e.g., 4-5 years as illustrated in McBain Associates 2018) or a rapid approach over a single year. Further investigations into these removal options are ongoing. Sediment management within Lake Pillsbury would need to be tailored to the dam removal strategy selected and approved by FERC (phased release of sediment, no release of sediment, rapid release of sediment), substantially based on analysis of potential downstream impacts from sediment release (diversion structure reliability, ecological and environmental impacts). Evaluation of sediment evacuation and sediment management various Scott Dam removal options is also ongoing.

Were Scott Dam to be removed, the Project would transition to a run-of-river project that would maintain the trans-basin diversion and flow augmentation to the East Branch Russian River, generally diverting in the winter and spring when Eel River flows are high, then ceasing in the summer and early fall months when unimpaired flows are low. There are several examples of this type of run of-river-diversion configuration, although they are not all hydropower projects, including Robles Diversion Dam on the Ventura River, Alameda Creek Diversion Dam on Alameda Creek, and Granlees Dam on the lower Cosumnes River.

Removal of Scott Dam could rely on the existing low-level outlet and/or sluiceway to convey Eel River flows during decommissioning. Currently, the low-level outlet is outfitted with a needle valve with a very limited low head capacity, such that very little water could be conveyed through the valve with a low reservoir pool elevation. At some point during Scott Dam decommissioning, the needle valve would be removed, and the low-level outlet could be expanded so that Eel River flows can pass through the dam under open channel conditions. Alternatively, the sluiceway outlet, which has a lower invert elevation, could be re-opened to convey Eel River water in a similar manner. In both cases, underwater work could be required. Once complete, the reservoir could be nearly completely drawn down and the remainder of the decommissioning could take place.

In addition to Scott Dam removal, restoration activities along the Eel River and its tributaries are expected in the area formerly occupied by Lake Pillsbury. These activities could likely include site grading, sediment stabilization, erosion control measures, eradication of invasive or noxious weeds, live siltation baffles, restoration of emergent wetlands, seeding and planting of riparian shrubs and deciduous trees, irrigation, installation of wood structures and boulder clusters, and access improvements (see Sections 3.6.2 and 3.6.4). These activities are expected to last up to ten years after dam removal and could include monitoring activities related to water quality (e.g., temperature), biotic data (e.g., redd counts), and fluvial geomorphology (e.g., channel mapping). However, a comprehensive decommissioning plan informed by relevant studies will need to be completed prior to understanding the complete suite of site and river remediation that will be needed for dam removal.

Costs and anticipated sediment stabilization and excavation volumes for dam decommissioning are preliminary and are summarized in Appendix 3.

3.6.2 Lake Pillsbury Sediment Management

The Eel River has some of the highest sedimentation rates in the world, and the Eel River watershed upstream of Scott Dam is no exception. Historic and contemporary land use, combined with frequent and large wildfires, will continue to support very high sedimentation rates from the upper watershed. With Scott Dam removal, the unregulated drainage area upstream of the Van Arsdale Diversion would increase by a factor of five, and coarse sediment loads would increase substantially even if there were no additional sediment originating from the Lake Pillsbury sediment deposits. Therefore, estimating long-term sediment supply from the upper watershed based on measured changes to Lake Pillsbury storage, and estimating how much of the stored sediment could potentially be transported downstream with Scott Dam removal is important to assess the risk to downstream infrastructure, Van Arsdale Diversion reliability, and downstream ecological impacts.

To estimate how much sediment is stored within Lake Pillsbury, McBain Associates (2019) conducted an initial topographic differencing between a digitized copy of a 2015 PG&E bathymetric survey map and a 1921 USGS survey (pre-dam). As part of this Feasibility Study, PG&E provided a digital copy of the 2015 bathymetry Digital Terrain Model (DTM). In addition, we georeferenced a 1922 contour map prepared by PG&E (10-foot contours) using township lines and digitized the contours into AutoCAD Civil 3D. In addition, the 1921 USGS thalweg survey was added to the 1922 DTM to refine the pre-dam channel geometry.

Two methods were used to estimate total volume of sediment stored within Lake Pillsbury and a third method estimated the volume of sediment that could likely be evacuated from upstream of Scott Dam, were it to be removed. The first method differenced the 1922 DTM from the 2015 DTM applying a boundary (valley toe) to the volume surface that eliminated areas that overlapped valley walls. This method resulted in an estimated 22,000,000 cubic yards of sediment (Table 3-6).

The second method differenced an elevation of 1,828.3 feet (max water surface elevation, NGVD 1929 datum) from both the 1922 DTM and the 2015 DTM. This resulted in an estimated difference of 144,500,000 cubic yards and 124,000,000 cubic yards, respectively. Differencing these two results provides an estimate of 20,500,000 cubic yards of sediment stored within Lake Pillsbury. Of these two estimates, we recommend using the 20,500,000 yd^3 value as it reduces potential errors from the 1922 contour map. This mapping also does not capture sediment that is upstream of the 1922 and 2015 mapping boundaries (head of reservoir), so this 20,500,000 yd^3 estimate is likely a little low. Therefore, given the uncertainty in volumes from the mapping and upstream extent of surveys, we round up to 21 million yd^3 from here as our estimate of existing sediment under Lake Pillsbury.

Table 3-6. Summary of Lake Pillsbury sediment volumes based on two analytical approaches.

Analysis Approach	Volume (cubic yards [yd^3])
Volume Difference between Full Pool Elevation (1910.0 ft) Less 1922 DTM	144,500,000
Volume Difference between Full Pool Elevation (1910.0 ft) Less 2015 DTM	124,000,000
Difference	*20,500,000*
Bounded Volume Difference 2015 DTM Less 1922 DTM	22,000,000
Volume of sediment assumed to be stored in Lake Pillsbury (rounded from 20.5 million yd^3)	21,000,000

Next, the amount of sediment that could likely be scoured and transported downstream if Scott Dam were fully removed was estimated. In the absence of a sediment routing model, we used observations from other dam decommissioning studies and applied those observations to the unique conditions at Lake Pillsbury. For the mainstem Eel River upstream of the Rice Fork confluence, the valley is wide, and we anticipate that the river will migrate across the reservoir depositional layers as it downcuts through the reservoir sediments. As the river downcuts, it will leave higher terraces with steep faces at the angle of repose (assumed to be 1:1 at this time, to be refined in future analyses). Images from Lake Mills (Elwha River) and Lake Pillsbury (during 2014 drought) show this pattern on both rivers (Figure 3-25). Salmon Creek flows along the west side of Gravelly Valley and is low gradient with no confinement and should evolve in a similar way. However, the scale (width) of the migration belt will be much narrower because Salmon Creek is very small.

Figure 3-25. Channel migration and downcutting pattern on the Elwha River (left) immediately following dam removal, and similar migration and downcutting at the head of Lake Pillsbury during the 2014 drought (right).

In contrast, the valley confinement of the Rice Fork and other small, confined tributaries entering the reservoir does not allow space for lateral channel migration and terrace formation, and thus should result in nearly 100% of the sediment being scoured and transported downstream. See Figure 3-26 for a similar system at Condit Dam, which quickly evacuated the majority of the sediment at the dam site. Conceptual models of channel downcutting processes are shown in Figure 3-27.

Figure 3-26. Condit Dam on the White Salmon River (left) and after dam removal (right) illustrating the rapid channel downcutting and near 100% sediment scour/transport in a more confined valley similar to Rice Fork (photos courtesy of Steve Stampfli and Andy Maser).

The final method digitized the estimated active channel and associated benches from the 1922 contour map to create a planform boundary for sediments expected to mobilize downstream (Figure 3-27 and Figure 3-28). This planform boundary was sketched using a combination of professional judgement on how we expected the channels to move laterally at different locations, guided by 1921 and 1922 topography (when the migrating and downcutting channel would likely intersect pre-dam topography). This boundary was then daylighted to the 1921 and 1922 topography assuming 1:1 side slope and a trapezoidal channel (no pools or riffles), a new DTM was created of this potential “future” channel, and topographic differencing with the 2015 DTM was conducted. This method resulted in an estimated 12,000,000 yd^3 of sediment that could potentially mobilize downstream once Scott Dam was removed and no sediment removal was conducted.

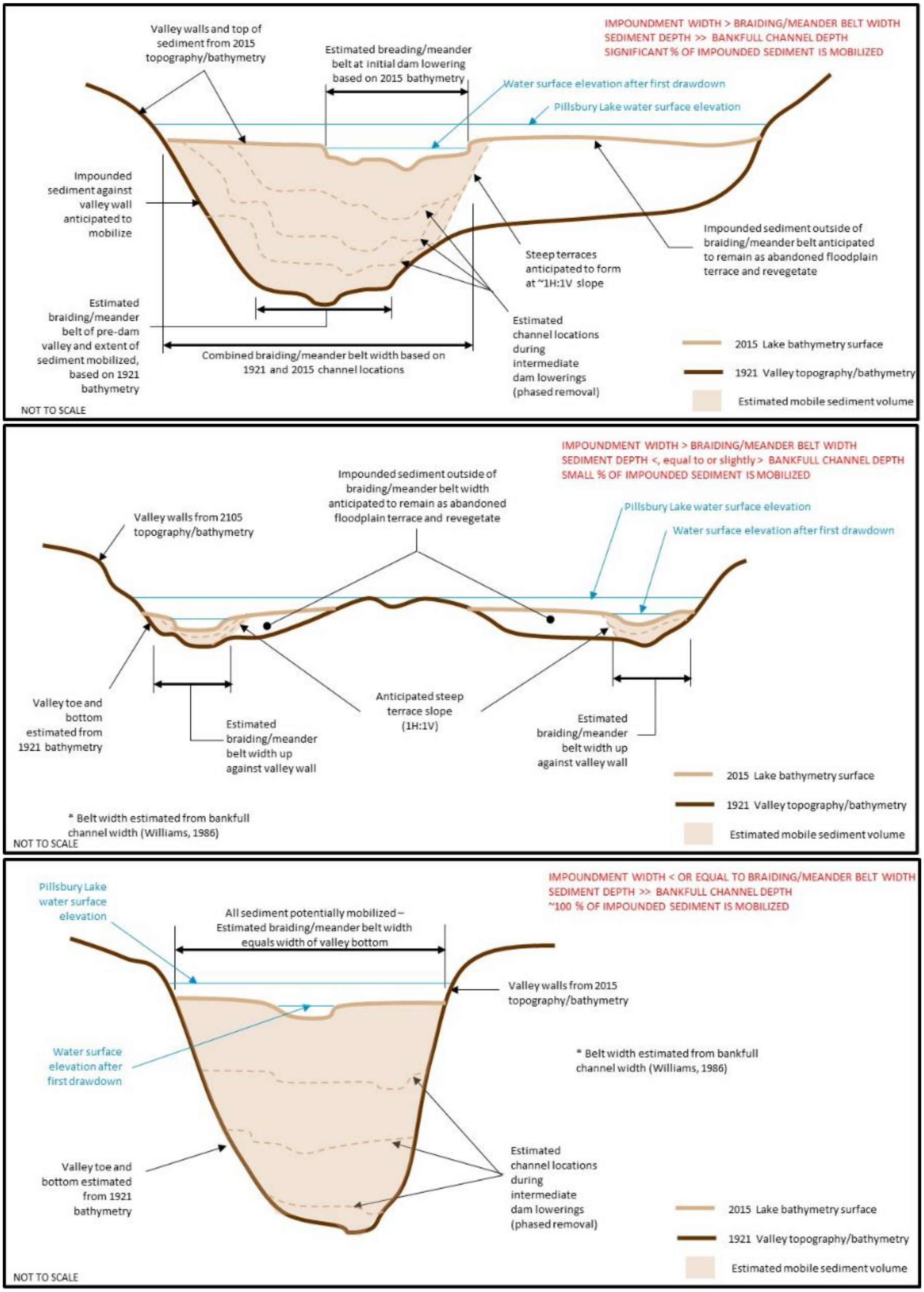

Figure 3-27. Anticipated channel downcutting processes on different stream branches in Lake Pillsbury (top-mainstem Eel River, middle-Salmon Creek, bottom-Rice Fork and tributaries).

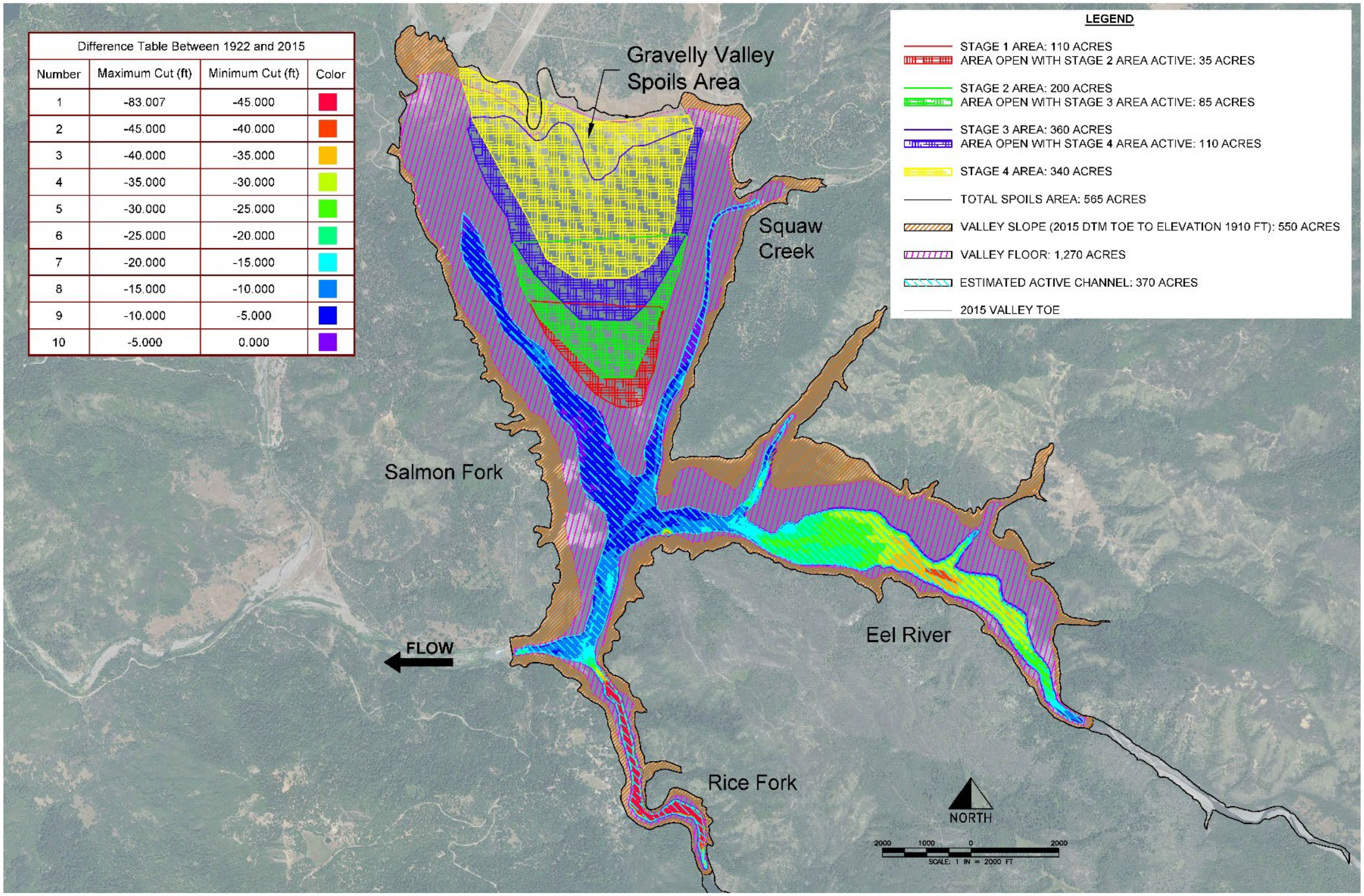

Figure 3-28. Anticipated channel downcutting zones on the different stream branches within Lake Pillsbury, and potential spoils area for 12 million yd^3 of sediment if the Scott Dam removal option is pursued. Colored areas in channels reflects expected depth of channel downcutting, colored areas in Gravelly Valley reflects computed depths of spoils. Computations reflect that all spoils would occur within the existing Lake Pillsbury inundation footprint.

As discussed above, the process for Scott Dam removal could occur as a short-term process to quickly release sediments stored in Lake Pillsbury (allow higher sediment concentrations and transport, but for shorter amount of time), or Scott Dam could be removed in phases to more gradually release the sediment over a number of years, or the notched dam could be used as a sediment trap where the incising river could transport sediment to the dam site for excavation or pumping to a storage area. For a phased dam removal process, four stages were assumed. The first stage would notch the dam 50 ft and followed by two phases at 20 ft, and a final phase at 22 ft (Figure 3-29).

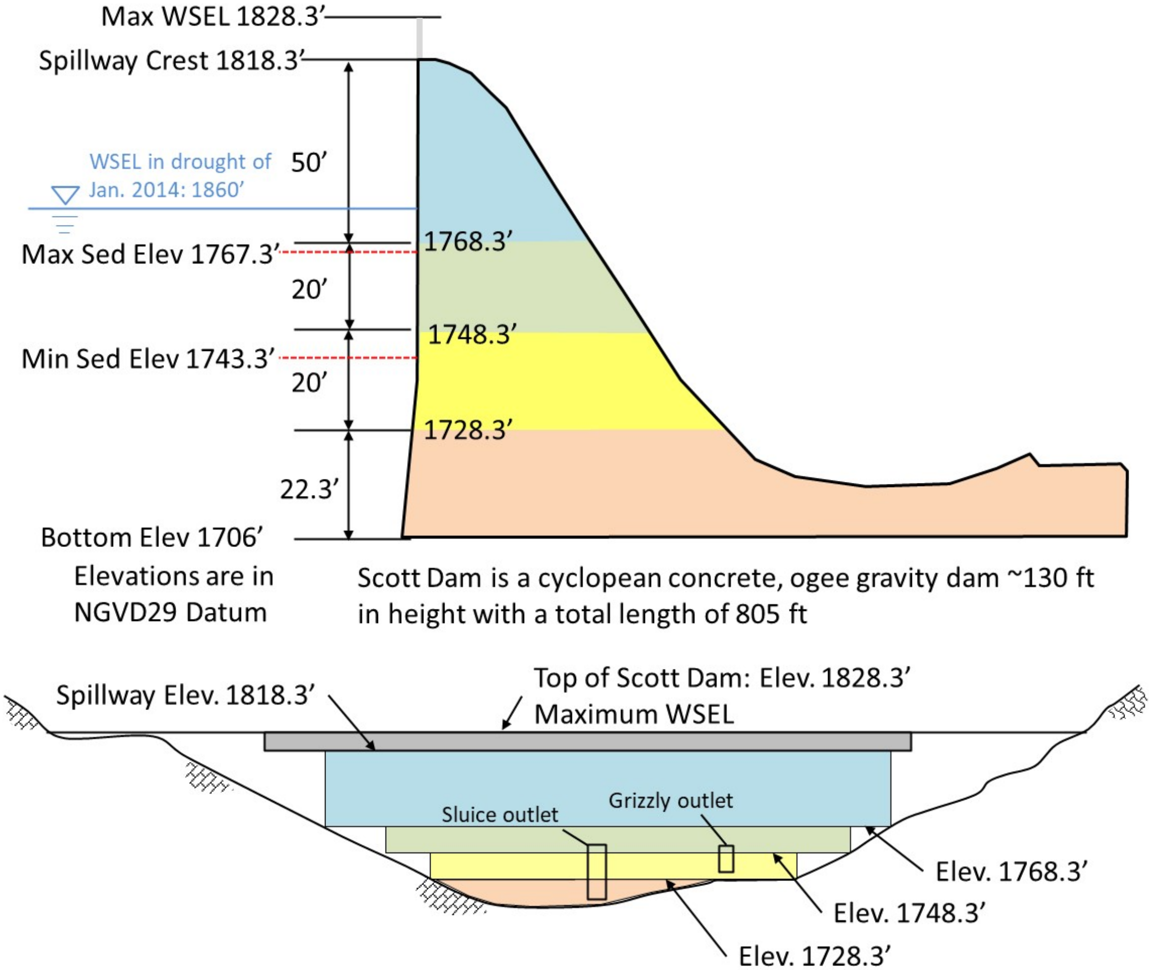

Figure 3-29. Potential Scott Dam phased removal strategy if the 12 million yd^3 of anticipated mobile sediment is removed and stockpiled at Gravelly Valley spoils area.

The feasibility of simply letting 12 million yd^3 of sediment route downstream is partially dependent on technical analysis of downstream impacts, regulatory constraints and liability risks. To help bookend the sediment management approaches, the cost and time to excavate and spoil the 12 million yd^3 to a location within the Lake Pillsbury inundation area was estimated. Even with this excavation and rebuilding a channel near the original pre-dam channel grade, the channel would likely remain dynamic, and could be subject to lateral and vertical adjustments as well as elevated sediment transport (in addition to the background sediment delivered from the upper watershed).

Two sediment management methods were evaluated to incrementally remove the estimated 12 million yd^3 of sediment that could be expected to mobilize once Scott Dam is removed: (1) Dredge and Haul method; and (2) Slurry Pump method. Both methods assume demolition of Scott Dam in stages (phased demolition over 4 years) to allow sediment to transport downstream to a location immediately upstream of Scott Dam where it can be removed and transported to a nearby spoils area. In other words, use the notched Scott Dam as a sedimentation basin, and let the river transport the sediment to a centralized excavation location rather than extensive road building and hauling in the reservoir area. The proposed spoils area is located in Gravelly Valley between Squaw Creek and Salmon Creek, south of the airport and at an elevation that is higher than the first stage of Scott Dam demolition elevation of 1,768 feet (NGVD 1929 datum). The entirety of this potential spoils area is within the Lake Pillsbury inundation footprint.

For each of the two sediment management methods, total cost, unit cost, and project life span were estimated. Costs include startup costs (equipment purchase and mobilization), annual operation costs (annual labor and equipment rental), and project wrap-up costs (demobilization). Prices were sourced from direct quotes from retailers or derived from past projects of similar scale. All cost estimates are in 2019 dollars and no inflation factor was applied. Project duration for each of the two methods was estimated by dividing the 12 million yd^3 total by the production rate of each method. Both methods assumed that the spoil material could be placed at Gravelly Valley in lifts, with each lift contained by a gravel/cobble berm, and deposited sediments allowed to drain prior to installing another lift of spoils.

Our analysis of the Dredge and Haul method found that 1) existing roads were too long, narrow, and circuitous to effectively conduct the project, and 2) even with shorter, wider, more direct roads within the lake footprint, it was very expensive (>$100 million) and could require a very long time period (decades). This method was therefore dismissed.

We then investigated a slurry pump method where four floating barges could be deployed upstream of Scott Dam, and dredges could pump sediment into a 2.3-mile pipeline up to the spoils area at Gravelly Valley. The resulting duration for the slurry pump alternative was approximately 3.3 years, assuming an 11-month productive work window, 5 days/week, 10 hrs/day. This productivity estimate could be further refined or optimized by increasing the number of dredges/slurry pumps, increasing the number of crew shifts, and other sources of implementation economy.

In November 2019, Geosyntec conducted sediment sampling in Lake Pillsbury and Van Arsdale Reservoir depositional areas, and these samples were tested for a wide range of metals and contaminants (Geosyntec, 2020). Given historic observation of bioaccumulated mercury in Lake Pillsbury fish tissue samples, a primary concern was the potential presence of elemental mercury and methyl mercury in the reservoir sediments. Mercury in the water column was not tested as part of this study. Results indicate that both elemental mercury and methyl mercury are found at very low concentrations in the lake sediments they were able to sample, and do not appear to pose any elevated downstream mercury contamination risk if some or all of those sediments are allowed to route downstream as part of a dam(s) removed alternative (Geosyntec, 2020). Because methyl mercury adheres to fine sediments, these sample results in the shallower, finer sediments indicates that perhaps mercury contamination risk is low; however, there is some remaining uncertainty about mercury stored in older, deeper, coarser sediments that could not be sampled by the methods used in the Geosyntec (2020) study. Therefore, additional deeper sampling may be needed to confirm that mercury contamination risk is low and better inform future coarse sediment transport modeling, which will also better inform Lake Pillsbury sediment management strategies and regulatory compliance requirements.

3.6.3 Sediment Management Considerations for Downstream Infrastructure and Habitat

In the absence of a detailed sediment routing model to assess downstream disposition of Lake Pillsbury sediments, a simplified conceptual exercise to place 12 million yd^3 of potentially mobile sediment into some context is included here. Much of the shallow sediment in the reservoir is fine enough to be transported in suspension (Porterfield 1964, Geosyntec 2019). This large sediment volume induces significant risk for downstream transport and deposition impacts to Van Arsdale Diversion, Cape Horn Dam fish passage, other domestic water intakes, channel morphology, and fish habitat. No one can predict the stream flows which might occur following dam removal. For example, a series of drought years could postpone significant response, while a large flood could evacuate all of the sediment, fine and coarse, in a short period of time. The Elwha Dam and Marmot Dam removals present different scenarios than those proposed for Scott Dam removal, yet still provide lessons applicable to potential Scott Dam removal on the Eel River.

The Elwha River project consisted of two simultaneous dam removals: Glines Canyon Dam and Elwha Dam. As with Scott Dam, the upstream dam (Glines Canyon) contained most of the sediment in the form of an upstream delta. Dam removals were initiated simultaneously in 2011. Elwha Dam came down quickly over the course of one year and Glines Canyon Dam was notched down over a three-year period. The combined volume of sediment stored behind both dams was approximately 27.5 million yd^3, more than twice the estimated volume stored in the Eel River reservoirs. Sixty-five percent of the total stored sediment (18 million yd^3) was transported downstream following dam removal. Of the sediment transported downstream, 90 percent was transported to the coast (13 miles downstream of Glines Canyon Dam and 4.9 miles downstream of Elwha Dam) over a five-year period (Ritchie 2018). The 10 percent of the 18 million yd^3 that remained in the river system created approximately 3 to 5 feet of widespread aggradation. Maximum aggradation was generally less than 10 feet, with the absolute maximum being approximately 16 feet in one location (Bountry et al, 2018). Since Glines Canyon Dam removal was phased over several years, and subsequent flood magnitudes for the first three years were modest (less than 2-year events), the river gradually adjusted to the increased sediment supply and efficiently moved the increased load through the system.

The former Marmot Dam is analogous to Cape Horn Dam both are 49 feet high, insofar as both are essentially full to the brim and store approximately 1 million yd^3 of sediment. Marmot Dam was demolished in a single event and the stored sediments were retained behind a soil cofferdam awaiting the first high flow in the fall. During the initial breaching event (a relatively small storm that quickly eroded the cofferdam), the channel immediately downstream of the dam aggraded approximately 15 feet. The sediment wedge tapered in the downstream direction for approximately one mile to where it merged with the original bed profile. This sediment wedge was steeper and finer grained than the pre-removal stream bed (which increased the sediment transport capacity), making the river highly efficient at transporting the dam sediments. Downstream of the leading edge of this sediment wedge (about one mile), the Marmot Dam removal signal on bed aggradation was difficult to detect. With the removals of both Marmot Dam and the Elwha River dams, the initial suspended sediment pulse was very large. On the Elwha River, suspended sediment concentrations did not peak until the second year of the phased removal. Numerous pools and side channels quickly filled with sand in both cases, though many eventually scoured back to their original depth after several years.

Numerous factors determine the channel response to dam removal, including grain size of liberated sediments, hardness and abrasion of the sediment in transport, local channel morphology, and hydrograph shape of subsequent flow events. Detailed predictions are beyond the scope of this descriptive document, but since infrastructure risk will inform liability, a discussion of the potential for damage or failure at the two downstream bridges (near Soda Creek confluence and above Van Arsdale Reservoir), and diversion infrastructure in Van Arsdale Reservoir follows.

For the bridges, 2018 LiDAR (elevation of deck versus elevation of water surface) was examined to provide a provisional estimate of clearance at both bridges. A 6 feet deck to chord height and a stream depth of two feet was assumed. At Soda Creek, the distance from the bottom of the bridge chord to the riverbed is 30 feet and at Van Arsdale Reservoir it is 38 feet. Since sediment wedges from dam releases tend to be deeper at their upstream end (Major et. al. 2012), the Soda Creek bridge is at greatest risk due to its lower height, valley expansion, and its proximity to the source (Lake Pillsbury). To provide additional context, the Marmot Dam example of a sediment wedge which extends a mile below the dam site was applied. Assuming 90 percent of the Lake Pillsbury sediment routes through in suspension and the remaining 10 percent is deposited over the course of a mile results in an average deposition depth of 31 feet (1.2 million yd^3 spread out 200 feet wide over a mile).

The Soda Creek confluence reach will likely show the greatest downstream geomorphic response to sediment deposition associated with Scott Dam removal, where the reservoir deposits will evolve rapidly when exposed to fluvial erosion and mass wasting processes. The unique valley geometry at the Soda Creek confluence (where the canyon walls widen from 200 feet to over a thousand feet) coupled with the valley constriction downstream of the Soda Creek confluence (which reduces transport capacity upstream due to backwater effect) suggests that this site will likely accumulate the largest volume of sediment of all reaches. Accumulation greater than 20 feet may be possible given the volume of sediment stored within Lake Pillsbury and based upon the other dam removals discussed above. Whether it aggrades 20 feet or more, the river is likely going to change in this location and some remedial action will likely be required at the Soda Creek Bridge:

- Replacement - possibly the costliest, but may be unavoidable;
- Bypass channel with seasonal ford – may be able to preserve existing bridge and allows access outside of high flow periods; or
- Seasonal dredging – combined with the bypass channel and seasonal ford, could reflect an adaptive approach that could save the bridge, and could be scaled to water year type until the channel returns to a near-equilibrium state.

The channel at the bridge upstream of Van Arsdale Reservoir is much wider, the bridge is higher, and the site is located farther downstream from the source, suggesting that this bridge could be at lower risk from Lake Pillsbury sediment accumulation than the bridge near Soda Creek. Under a Cape Horn Dam removal scenario and alternative Van Arsdale Diversion, flood damage risk for the Van Arsdale Bridge could be lowered because: (1) sediment transport capacity near the bridge would increase as a function of increased water surface slope with removal of Cape Horn Dam, and (2) channel capacity beneath the bridge would likely increase as the channel profile adjusts (erodes by headcutting or increased shear stress) in response to Cape Horn Dam removal. At a minimum, channel erosion mitigation would likely be required at the bridge upstream of Van Arsdale Reservoir due to the potential for channel incision and headcutting from Cape Horn Dam removal. Depending on the depth of piers and the extent of anchoring to native bedrock, pier or even bridge replacement may be required. In addition, the channel below Cape Horn Dam would likely respond like the Sandy River below Marmot with 10-15 feet of aggradation tapering over roughly a mile as the 1,200,000 yd^3 coarser sediment in Van Arsdale Reservoir is eroded.

The diversion structure at Cape Horn Dam could be impacted by Lake Pillsbury fine and coarse sediment deposition due to the backwater effect of the dam, which reduces sediment transport capacity at the site. Some or all of the contemporary coarse sediment supply is currently routing through the Van Arsdale Reservoir and over Cape Horn Dam, largely on the inside of the bend across the river from the diversion infrastructure. If this process continues at a similar scale (e.g., the bar doesn't aggrade all the way across and overwhelm the diversion intake), then coarse sediment may not be of great concern. However, large amounts of fine sediment could move through in large waves and deposit near the diversion intake, increasing the risk of the diversion being periodically out of service following high flow events during high flow years (see Section 3.4 for limited discussion of modifications to the diversion to address these potential issues). The surface water diversion intake on the Elwha River, even though located on the outside of a bend, was completely overwhelmed by fine sediment and rendered inoperable, at least for the first few years following dam removal.

Lastly, if all Lake Pillsbury sediment is allowed to route downstream (expected 12 million yd^3 out of the total 21 million yd^3), impacts from fine sediment deposition could be expected on the lower Eel River based on channel response to the Elwha Dam removals. First, fine sediment deposition could impair downstream municipal water intake infrastructure and require cleaning or replacement. Second, substantial changes to the Eel River estuary could occur due to large volumes of fine sediment deposition, which could negatively impact the off-channel rearing habitats, as well as the ongoing and planned restoration efforts in the Salt River and surrounding estuary lands. Large scale changes in the Elwha River estuary were documented by Bountry et al., (2018), but these changes were largely driven by coarse sediment deposition since the lowermost dam was only 4.9 miles upstream of the estuary (compared to 169 miles for Scott Dam). Most of the fine sediment from the Elwha Dam decommissioning was transported in suspension. Given the lower gradient of the Eel River estuary compared to the Elwha River estuary, there is uncertainty whether the fine sediment load from Scott Dam decommissioning would remain in suspension to the ocean, and how much would deposit in biologically important off-channel habitats in the estuary.

Given the uncertainty of downstream sediment impacts and the absence of a robust sediment transport analysis for different sediment management alternatives, no costs are included for alternatives or actions to remediate potential downstream impacts other than replacement of the Soda Creek bridge and Pioneer Bridge.

In summary, should Scott Dam decommissioning be pursued, it is recommended that a hydraulic and sediment transport assessment under post-dam conditions be carried out for the two bridges Van Arsdale Diversion infrastructure, and Cape Horn Dam fish passage facilities to better assess sediment deposition risk. In addition, depending on results of the sediment transport modeling, additional study may be needed to assess the risk of downstream fine sediment deposition causing impacts to municipal water intake systems on the lower Eel River.

3.6.4 Revegetation within Lake Pillsbury Inundation Area

In the event that Scott Dam is removed, there will most likely be a substantial revegetation effort conducted to reclaim the lands currently under Lake Pillsbury. Despite these lands being underwater for almost 100 years, there is likely a seed bank remaining, combined with natural seed rain after dam removal, that will allow substantial natural revegetation to occur. However, based on recent dam decommissioning efforts on the Elwha River, and planned decommissioning on the Klamath River, a substantial revegetation effort should be assumed.

The inundation area of Lake Pillsbury, and thus the potential revegetation area, is 2,390 acres, of which is 1,270 acres is valley floor, 550 acres is valley slope and hillsides, and 570 acres is the potential spoils area at Gravelly Valley. Actual revegetation or other restoration actions would need to be informed by studies and extensive consultation with stakeholders and resource agencies and will also depend on dam removal and sediment management techniques selected. There is uncertainty in the potential revegetation treatment due to uncertain land ownership and land uses of the Lake Pillsbury footprint after draining. Therefore, a wide range of potential costs has been developed. An upper bookend of potential revegetation cost assumes that the entirety of the Lake Pillsbury footprint would need to be treated, which is not expected to occur. A lower bookend of potential revegetation cost assumes reliance on passive revegetation via remnant seed banks in the soil and new seed drop after the reservoir is drained. Costs were also developed based on unit costs from the Elwha River revegetation and recent cost estimates for Klamath River revegetation. These costs are summarized in Section 4. Lastly, under a Cape Horn Dam removal scenario, we assume passive revegetation of the inundation area because 1) our expectation is that most of this sediment will be scoured and routed downstream, there is likely a large natural seed bank in any remaining sediments, and 3) most of the area underneath the Van Arsdale inundation area will revert back to a riverine morphology with riparian vegetation and exposed cobble/gravel bars. The channel margins should quickly revegetate naturally with riparian and coniferous vegetation, and thus no planting is assumed.

3.6.5 Cape Horn Dam Removal and Sediment Management

Cape Horn Dam currently impounds Van Arsdale Reservoir, which provides sufficient intake submergence and driving head to deliver water to Potter Valley by way of gravity. If Cape Horn Dam is to remain, or if it is to be removed, sediment management would likely be an additional critical consideration should Scott Dam be removed upstream and large amounts of sediment be allowed to flush downstream.

Similar to Scott Dam removal, removal of Cape Horn Dam could rely on re-establishing use of the old sluiceway outlet, which has a lower invert elevation, and which could be re-opened to convey Eel River low flows. Alternatively, flows could simply be allowed to pass over the face of the dam during dam removal, as was done on the Elwha River. Once complete, the reservoir could be nearly completely drawn down and the remainder of the decommissioning could take place. It is anticipated that the main portions of the dam could be removed during one summer low-flow period (3-4 months), such that only minor interruptions in fish passage would be realized during dam removal. Refer to Appendix 3 for further information, including costs associated with Cape Horn Dam removal.

The main coordination challenge associated with Cape Horn Dam removal is how to ensure continued diversion of water for hydroelectric power generation and water supply to the Russian River during the removal process, and to ensure high reliability of diversion and delivery after removal. As with the removal of Scott Dam, decommissioning Cape Horn Dam would require the prior completion of new water supply reliability infrastructure for Potter Valley. Once completed, an alternative diversion system would need to be constructed. Due to the possibility that this new diversion system would be located within the accumulated sediment of Van Arsdale Reservoir, a technology that is flexible and can be adjusted to accommodate the changing channel bottom elevation after dam removal would be key.

PG&E historically dredged Van Arsdale Reservoir to maintain storage capacity. However, the high costs of dredging and frequent sediment transport/deposition events forced PG&E to cease dredging operations, and now sediment routes through the reservoir into downstream reaches (and sometimes the fish ladder/hotel). Because the sediment is routed on the inside of the river bend and the diversion is on the outside of the bend, dredging to maintain the diversion infrastructure has not been needed. The original usable storage capacity of Van Arsdale Reservoir was 1,140 ac-ft, while the current (2006) usable storage capacity is less than 390 ac-ft (PG&E 2017). Therefore, the total current sediment accumulation is approximately 750 ac-ft, or 1.2 million yd^3. Given the small storage area and the fact that gravel is currently routing through the reservoir into downstream reaches, much of the sediment stored in the reservoir is coarse sediment, consisting of sands, pea gravels, larger gravels, and cobbles (Geosyntec 2020). While the 1.2 million yd^3 of sediment is a large amount, it is small compared to the volume of likely mobile sediment in Lake Pillsbury (12 million yd^3) and is mostly coarse sediment rather than fine sediment. In addition, contaminant testing by Geosyntec (2020) indicates no elevated mercury or other contaminants in Van Arsdale Reservoir sediments. The amount of sediment behind Cape Horn Dam is similar to that behind Marmot Dam on the Sandy River (1.0 million yd^3 versus 1.2 million yd^3). With rapid Marmot Dam removal, maximum aggradation was 15 feet immediately downstream of the dam site, with near zero aggradation a mile downstream. Over the next few years, the 15 feet of initial aggradation quickly transported downstream, and a natural channel grade was re-established. We expect the Eel River downstream of Cape Horn Dam to respond in a similar manner, with short term aggradation immediately below Cape Horn Dam downstream for a mile or two, and rapid transport of aggraded sediment in the following years to re-establish a natural grade through the dam site. Therefore, we recommend that there would be no sediment removal conducted if Cape Horn Dam is removed, and the sediment be allowed to naturally route downstream.

3.6.6 Recommended Additional Studies

If Scott Dam and/or Cape Horn Dam removal is further considered, then further study of dam removal and associated sediment management will be needed along with an assessment of the ability to maintain water diversions of suitable quantity and reliability both during construction and post-removal. One of the primary purposes of this task is to evaluate the geomorphic and ecological tradeoffs of different approaches for Scott Dam removal and associated management of sediment in Lake Pillsbury. For example, there is approximately 21 million yd^3 of sediment stored in Lake Pillsbury, of which approximately 12 million yd^3 is considered to be susceptible to mobilization and transport downstream if Scott Dam is removed. In addition, there is approximately 1.2 million yd^3 of sediment in Van Arsdale Reservoir (PG&E 2017). Management of this sediment will be a critical component of any dam(s) removed alternative and will have substantial cost implications. For example, if Scott Dam is removed, should the sediment at risk of downstream transport be removed and stockpiled at Gravelly Valley, or can it be allowed to route downstream? If allowed to route downstream, should the dam and associated sediment transport be conducted in phases to slowly meter out the sediment, or should the dam be rapidly removed, and sediment quickly evaluated during the first large winter storms after dam removal? What are the downstream geomorphic, ecological, and infrastructure implications?

Section 3.6.3 discusses these issues in a qualitative way, largely relying on observations of similar dam removal projects in the Pacific Northwest. However, to more quantitatively assess these tradeoffs, modeling tools will be needed. The following additional studies are recommended to address these important questions:

- Estimate suspended sediment concentrations for dam(s) removed alternative and perform sediment transport modeling
    - Evaluate suspended sediment concentrations expected in the Eel River resulting from removal of Scott Dam using methods described in Cui et al., (2017)

  - Evaluate the biological impacts of high suspended sediment concentrations resulting from removal of Scott Dam and compare with background suspended sediment concentrations
- Build upon sampling conducted by Geosyntec (2020) to conduct additional reservoir sediment samples at depth to characterize reservoir sediment grain size and stratigraphy
- Collect LiDAR and bathymetry to support Eel River sediment transport modeling
  - Conduct low flow terrestrial LiDAR flight and ground survey of cross sections (bathymetry) from Scott Dam downstream to the Middle Fork Eel River confluence for use in hydraulic and sediment transport modeling
- Conduct 1-dimensional (1-D) sediment transport modeling to evaluate fate of coarse sediment released from removing of Scott Dam
- Evaluate the potential geomorphic effects of downstream sediment transport and deposition of Lake Pillsbury sediments via 2-dimensional (2-D) morphodynamic model at select sites to better understand potential effects of sediment deposition on channel morphology, bank stability, flooding, and aquatic habitat conditions. Information from 1D model will provide input to 2D model
- Evaluate Lake Pillsbury Sediment Management options
  - Using sediment transport model results, work with resource agencies to develop a preferred approach for managing Lake Pillsbury sediment, and develop initial engineering designs for that preferred approach (slurry pump, hauling, combination)
  - Compute natural sediment supply rates for Lake Pillsbury to obtain both long-term and individual water year natural sediment supply rates, then compare to predicted sediment transport rates under different management options of Lake Pillsbury sediments
  - Compute natural sediment supply rates for reaches below Cape Horn Dam (Dos Rios, Fort Seward, and Scotia gages) to compare to future sediment supply rates with dam(s) removed
- Evaluate Scott Dam removal options
  - Refine evaluation of Scott Dam removal options based on suspended sediment assessment and sediment transport modeling.
  - Based on the additional modeling tools described above, develop a more refined dam decommissioning strategy, plan, and cost estimates.
  - Re-evaluate potential impacts of sediment management strategy on downstream infrastructure, including bridges, Van Arsdale Diversion infrastructure, residential water intakes, flood risk impacts, downstream municipal water supply infrastructure, and downstream aquatic habitats.
  - To better assess reservoir grain size distribution and spatial patterns, conduct a more detailed mechanical coring of sediments to determine grain size distribution, and lateral and vertical sorting through Lake Pillsbury.
- Evaluate Cape Horn Dam passage options
  - Complete a comprehensive analysis of Cape Horn Dam passage and fish protection options, in addition to the initial options that have already been

considered. Passage options must reliably meet NMFS and/or CDFW screening and passage criteria.
    - Perform supplemental analysis of Cape Horn Dam removal feasibility and/or alternate diversion infrastructure into diversion tunnels.
- Depending on (1) model predictions of suspended sediment concentrations for different dam decommissioning and sediment management options, (2) comparisons with background levels, and (3) discussions with resource agencies, evaluate the need for downstream biological mitigation measures during the dam removal and sediment evacuation process (off-stream rearing, creating refugia from high suspended sediment concentrations, temporary supplemental fish propagation).

3.7 Potter Valley Irrigation District Water Supply

Under a separate contract with Sonoma Water, a draft "Potter Valley Project Capital Modifications Supplemental Analysis Report" was prepared by McMillen Jacobs (2020) to supplement the "Potter Valley Project Capital Modifications Feasibility Study Report" in Appendix 3 (McMillen Jacobs Associates 2018). The primary objective of the 2020 Draft Supplemental Analysis Report was to evaluate water supply alternatives to Potter Valley, describe what the Project alternatives might include, provide feasibility-level cost estimates, and list the uncertainties and data gaps associated with each. The Draft Supplemental Report considered a wide range of potential alternatives, including:

- Reduced water storage at Lake Pillsbury, with partial removal of Scott Dam, but retention of sufficient storage to meet PVID needs. This alternative was screened out due to the shape of Lake Pillsbury and the need for a dam up to 93 feet tall to provide storage for PVID water only, which is only slightly smaller than the current Scott Dam.
- Potter Valley tributary water storage was considered by identifying potential dam locations within Potter Valley to store local runoff and diverted Eel River waters. These investigations are continuing as part of a separate, non-FERC-related study.
- Potter Valley water storage on the valley floor, which was dismissed due to the impractically large levee or berm system that would be required to impound the volume of water needed for PVID use.
- Potter Valley aquifer storage and recovery, which was not evaluated at length due to a dearth of useful subsurface information, and discussions with local water users indicating the alluvial depth (and potential water storage capacity) is low.
- Water pump-back and piping options from Lake Mendocino, which may be less desirable from a cost perspective for PVID in terms of annual operations and maintenance costs. However, investigations into this option are ongoing based on revisions to design criteria (specifically peak PVID water demand) as part of a separate, non-FERC-related study.
- Consideration of water delivery efficiencies within the PVID service area, which are also ongoing as part of a separate, non-FERC-related study.

More detailed analysis of these and other alternatives will need to be completed in future phases of study to identify and optimize the best alternative(s) for PVID supply.

3.8 Additional Water Supply Reliability Assessment

As described elsewhere in this document, additional analysis will be needed to further verify and validate the reliability of water supply for the Russian River, particularly for the dams removed alternatives and permutations. Water supply modeling conducted by the Ad Hoc Water Supply working group demonstrated that water supply quantities can be delivered to the Russian River side under ‘run-of-river' conditions, using a certain suite of water diversion timing and volume assumptions. Additional modelling of sensitivities around those assumptions should be completed, to verify reliability in the event of low probability or unforeseen future conditions. In addition, any modifications to diversion infrastructure will need to be assessed against operational reliability criteria (e.g., ability to operate in all flow, debris and sediment conditions) and operational control criteria (e.g., ability to divert water, release required minimum flows, and other operate to regulatory requirements), and finally for against capital and operational cost criteria.

4 COSTS AND RISKS SUMMARY

This section provides a broad overview of costs and risks of the various options considered in Section 3. These costs and risks will be evaluated by the planning agreement Parties and used to inform a selection of alternatives and a Project Plan.

4.1 Costs Summary

The American Association of Cost Engineering (AACE) provides guidelines for development of cost estimates for various levels of project definition (see Table 4-1; AACE 2019). For this project, Class 5 cost estimates have been prepared; these are also called concept screening level estimates, as defined by AACE International. This level of estimate is deemed appropriate for taking a first pass at project design, which corresponds to a range of 0% to 2% level of design development. Class 5 cost estimates are prepared for several purposes, such as strategic planning, business development, project screening, alternative scheme analysis, confirmation of economic or technical feasibility, and preliminary budget approval.

To support the initial cost estimate preparation, past project data were used to determine an order-of-magnitude level cost estimate for each option in 2018 dollars. Soft costs, including regulatory compliance, monitoring, reporting, management, and contingencies, were not included in Table 4-2. In addition, budgetary pricing was requested of various vendors for a variety of components. Costs for operations, maintenance, repair, replacement, and rehabilitation (OMRR&R) were estimated for relevant items. A summary cost table of all options is provided below in Table 4-2. Note that these estimates do not benefit from the anticipated studies that will take place as the Project advances, nor do they benefit from extensive stakeholder or resource agency input. Note also that the costs provided below are bounded by the high and low value estimates that are also provided in the table, underscoring the level of uncertainty in the estimates at this time.

Table 4-1. American Association of Cost Engineering Guidelines.

Class	Level of Project Definition (Expressed As % ff Complete Definition)	End Usage (Typical Purpose of Estimate)	Method (Typical Estimating Method)	Expected Accuracy Range (Typical Variation in Low and High Ranges [A])
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment or Analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study of Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%

Notes: The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the dost estimate after application of contingency (typically at a 50% level of confidence) for give scope. Source: AACE International Recommended Practice No. 17R-97

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Table 4-2. Summary of Capital and Operation and Maintenance (O&M) Class 5 cost estimates for Feasibility Study Options.

Option ID	Facility	Modification Option	Capital Cost ($)	Low Estimate Capital Cost (-50%) ($)	High Estimate Capital Cost (+100%) ($)	Annual O&M Cost ($)	Low O&M Cost (-50%) ($)	High O&M Cost (+100%) ($)
1	Scott Dam	Natural Fishway	$26,040,600	$13,020,300	$52,081,200	$310,000	$155,000	$620,000
2	Scott Dam	Modified Conventional Fishway	$100,640,000	$50,320,000	$201,280,000	$95,000	$47,500	$190,000
3	Scott Dam	Trap and Haul	$51,100,000	$25,550,000	$102,200,000	$400,000	$200,000	$800,000
4	Scott Dam	Hopper System	$81,881,000	$40,940,500	$163,762,000	$400,000	$200,000	$800,000
5	Scott Dam	Whooshh System	$13,268,200	$6,634,100	$26,536,400	$504,300	$252,150	$1,008,600
6	Scott Dam	Floating Surface Collector	$92,485,200	$46,242,600	$184,970,400	$2,350,000	$1,175,000	$4,700,000
7	Scott Dam	Variable Intake Surface Collector	$90,798,000	$45,399,000	$181,596,000	$2,205,000	$1,102,500	$4,410,000
8	Scott Dam	Through Spillway	$1,512,000	$756,000	$3,024,000	$0	$0	$0
9	Scott Dam	Tributary Collection	$65,120,000	$32,560,000	$130,240,000	$2,110,000	$1,055,000	$4,220,000
10	Scott Dam	Tributary Collection - Screw Trap	$592,000	$296,000	$1,184,000	$400,000	$200,000	$800,000
11	Scott Dam	Continued Operations [4]	$1,572,000	$786,000	$3,144,000	$1,404,713	$702,357	$2,809,426
12	Scott Dam	Phased Removal [1]	$54,378,000	$27,189,000	$108,756,000	$0	$0	$0
13	Scott Dam	Rapid Removal [1]	$48,210,000	$24,105,000	$96,420,000	$0	$0	$0
14	Cape Horn Dam	Upstream Fish Ladder Improvements	$1,035,140	$517,570	$2,070,280	$0	$0	$0
15	Cape Horn Dam	Fish Hotel Improvements	$627,800	$313,900	$1,255,600	$0	$0	$0
16	Cape Horn Dam	Trap and Haul	$4,440,000	$2,220,000	$8,880,000	$585,000	$292,500	$1,170,000
17	Cape Horn Dam	Continued Operations [4]	$3,480,000	$1,740,000	$6,960,000	$762,624	$381,312	$1,525,247
18	Cape Horn Dam	Removal [1]	$58,890,000	$29,445,000	$117,780,000	$0	$0	$0
19	Van Arsdale Diversion	Radial Well Field	$102,342,000	$51,171,000	$204,684,000	$910,000	$455,000	$1,820,000
20	Van Arsdale Diversion	Cone Screen Diversion	$41,300,000	$20,650,000	$82,600,000	$316,000	$158,000	$632,000
21	Van Arsdale Diversion	Modifications at Fish Screen	$9,306,471	$4,653,236	$18,612,942	$0	$0	$0
22	Van Arsdale Diversion	Modify Fish Bypass Pipe	$73,500	$36,750	$147,000	$0	$0	$0
23	Powerhouse	Continued Operations [2]	$9,312,000	$4,656,000	$18,624,000	$1,383,663	$691,832	$2,767,326
24	Powerhouse	No Scott Dam - Continued Operations [2]	$3,312,000	$1,656,000	$6,624,000	$1,951,000	$975,500	$3,902,000
25	Powerhouse	No Scott Dam - Powerhouse Rehab [2, 3]	$17,404,800	$8,702,400	$34,809,600	$1,951,000	$975,500	$3,902,000
26	Powerhouse	Replace with FCV	$2,220,000	$1,110,000	$4,440,000	$10,000	$5,000	$20,000
27	PVID Water Supply	Pump-Back to Head of Valley	$90,888,280	$45,444,140	$181,776,560	$1,547,000	$773,500	$3,094,000
28	PVID Water Supply	Pump-Back with Tributary Storage	$113,495,280	$56,747,640	$226,990,560	$1,417,000	$708,500	$2,834,000
29	PVID Water Supply	Pump-Back with Piped Canal Network	$103,150,080	$51,575,040	$206,300,160	$1,423,000	$711,500	$2,846,000
30	PVID Water Supply	Pump-Back with Water Dropoff	$105,179,160	$52,589,580	$210,358,320	$1,408,000	$704,000	$2,816,000
31	Lake Pillsbury	No Scott Dam - Extensive Sediment Management[1]	$86,030,580	$43,015,290	$172,061,160	$0	$0	$0
32	Lake Pillsbury	No Scott Dam - 1.5 million yd^3 pilot channel[1]	$39,411,000	$19,705,500	$78,822,000	$0	$0	$0
33	Lake Pillsbury	No Scott Dam -all sediment downstream, no Scott Dam[1]	$24,311,000	$12,155,500	$48,622,000	$0	$0	$0
34	Lake Pillsbury	No Scott Dam -all sediment downstream, no Scott & CHD	$11,476,000	$5,738,000	$22,952,000	$0	$0	$0
35	Lake Pillsbury	Revegetation Unit Costs Group 3 PV Labor w/seed & mulch[1]	$75,086,260	$37,543,130	$150,172,520	$0	$0	$0
36	Lake Pillsbury	Revegetation Unit Costs Group 7 PV Labor w/ seed & mulch[1]	$64,806,180	$32,403,090	$129,612,360	$0	$0	$0

Option ID	Facility	Modification Option	Capital Cost ($)	Low Estimate Capital Cost (-50%) ($)	High Estimate Capital Cost (+100%) ($)	Annual O&M Cost ($)	Low O&M Cost (-50%) ($)	High O&M Cost (+100%) ($)
37	Lake Pillsbury	Revegetation Scaled to Elwha revegetation[1]	$50,757,140	$25,378,570	$101,514,280	$0	$0	$0
38	Lake Pillsbury	Revegetation Scaled to another local decommission revegetation[1]	$93,465,980	$46,732,990	$186,931,960	$0	$0	$0
39	All	FERC Licensing and Studies - Dams Remain	$9,012,000	$4,506,000	$18,024,000	$703,000	$351,500	$1,406,000
40	All	FERC Licensing and Studies - Dam(s) Removed	$12,482,000	$6,241,000	$24,964,000	$703,000	$351,500	$1,406,000

Notes:

[1] Capital costs include O&M costs for the first 10 years. O&M costs thereafter are zero as the system is expected to maintain itself.

[2] Capital cost includes the cost for re-licensing the project with FERC. Annual O&M costs are restricted to costs associated with the powerhouse only and do not include costs of facilities upstream of the penstock bifurcation.

[3] Capital costs include new turbines, governors and other equipment required to generate under alternative operating conditions. O&M costs are assumed to be the same or similar to those under existing conditions.

[4] Continued operations include up-front costs for outstanding maintenance and rehabilitation projects and O&M costs associated with those activities carried out over the last 5-year period and divided by 5 years. This assumes that similar maintenance activities can be expected in the future at these aging facilities.

4.2 Risks Summary

In addition to those costs associated with constructing infrastructure modifications and operating and maintaining the facilities described above, each of the facilities investigated has unquantified risks associated with it. These risks are inherent to owning these facilities, and while most of these risks can be mitigated, they cannot be easily or inexpensively eliminated. Table 4-3. presents a summary of these risks. From the table, numerous risks are not associated with any construction activity per se. For example, simply owning Scott and Cape Horn dams means assuming a number of risks associated with dam safety. On the other hand, other risks are associated with particular options to modify existing infrastructure or introduce new infrastructure altogether. These risks are typically bound to the uncertainties underlying the engineering design and construction of those options and can be minimized through proper investigations and analyses in advance of construction. Importantly, the risk factors listed in Table 4-3 are not equal: some carry considerably more risk than others, such that an Option with three risk factors does not necessarily have less risk than an Option with 25 risk factors. Therefore, Table 4-3 is meant to provide an illustration of the types of risk for the various options, but as stated above, not a quantitative or comprehensive overall assessment of risk. A more comprehensive assessment of risk factors can be completed during a future phase of analysis and design, when there is less uncertainty around the specific components of project design.

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Table 4-3. Summary of risks associated with infrastructure modification options and transfer of ownership.

Option ID	Facility	Goal	Modification Option	Examples of Potential Risks and Tradeoffs
1	Scott Dam	Upstream Fish Passage	Natural Fishway	1) Geologic hazards (e.g., landslides) could compromise stability/integrity of channel 2) Would require extensive excavation and construction activities on the left abutment of the dam 3) Bridging aqueduct may be required across ravine 4) Dam height and resulting length of the fishway may limit fish passage for specific fish species or during warmer water periods 5) Field conditions may differ from anticipated 6) Loss of approximately 1 mile of potential habitat 7) Vulnerable to possible slope stability issue. 8) Risk of some fish rejecting the false weir (species dependent) 9) During extreme high reservoir elevation the natural fishway could be at risk of high flows. 10) Predation in the trap holding pool (located at the top of the natural fishway) and at the ramp to the reservoir. 11) Requires extensive mechanical systems at the fishway exit to accommodate the reservoir fluctuation OR the reservoir level has to be maintained within a set range to support operation 12) May not be fully effective during summer periods due to change in water temperature due to the surface draw of the fishway and lower-level release to the river
2	Scott Dam	Upstream Fish Passage	Modified Conventional Fishway	2) Location along left bank susceptible to geologic and flood hazard 3) The AWS supply pipe located in front of the flip bucket at risk of being damaged. 4) The number of exits is unconventional and may not work. 5) The large rock in the reservoir will require some explosive to decrease the size for removal. Risk of explosive use in the slide area and close to an active facility. 6) Fish rejecting the tunnel. 7) Penetration through the dam 8) Lower pools may flood. 9) Challenging to get sufficient attraction flow. 10) Mixing of cold water (from intake at depth) with warm water from the reservoir surface water, and fish rejecting the ladder due to temperature difference above the entrance pools (only surface warm water at this point). 11) Excavation and dewatering in the tailrace.
3	Scott Dam	Upstream Fish Passage	Trap and Haul	1) Risk of flooding 2) High mortality rate due to mechanical equipment and handling. 3) Access road difficulty in different environmental conditions. 4) Low dissolved oxygen and high carbon dioxide levels; poor water quality requiring additional water quality enhancement system. 5) Trapping system not accommodating Pacific lamprey. 6) Risk on lifting fish transport pods onto truck. 7) Agencies requiring sorting, increasing capital and O&M cost, as well as operation procedure complexity, and need for more staffing. 8) Excavation and dewatering in the tailrace.
4	Scott Dam	Upstream Fish Passage	Hopper System	1) High mortality rate due to mechanical equipment. 2) Seismic risk of having an independent tower for the hopper. 3) The attraction could use cold water; risk of mortality of fish when placing them in the reservoir or in the tributaries. 4) Risk associated with lifting the hopper. 5) Trapping system not accommodating Pacific Lamprey. 6) Excavation and dewatering in the tailrace.
5	Scott Dam	Upstream Fish Passage	Whooshh System	1) Experimental technology. 2) Risk related to high flow damaging barge system. 3) Risk working from a barge. 4) Power reliability.

Option ID	Facility	Goal	Modification Option	Examples of Potential Risks and Tradeoffs
6	Scott Dam	Downstream Fish Passage	Floating Surface Collector	1) Uncertainty in capital costs due to large variation in costs of example FSCs 2) Risk of predation in Lake Pillsbury. 3) Risk of copepodis infection of juvenile salmonids routing through Lake Pillsbury. 4) Risk of poor fish attraction. May not fully collect downstream migrants due to fish loss in Lake Pillsbury. 5) Risk related to netting operation – debris accumulation on the net will likely require extensive maintenance. 6) Risk related to tuning flow through the screen due to mechanical malfunction of screen cleaner and baffles. 7) Risk to the powerline vulnerability over the distance and therefore loss of power. 8) Inherent risk from working from a barge. 9) Power reliability.
7	Scott Dam	Downstream Fish Passage	Variable Intake Surface Collector	1) Experimental technology 2) Large excavation required 3)Seismic stability risk. 4) Adverse flow condition requiring physical and CFD modeling. 5) Risk of predation in Lake Pillsbury. 6) Risk of copepodis infection in Lake Pillsbury. 7) Risk of poor fish attraction in Lake Pillsbury. 8) Power reliability
8	Scott Dam	Downstream Fish Passage	Through Spillway	1) Uncertainty in mortality and injury rates. 2) Risk of predation in Lake Pillsbury and in the Eel River below the tailrace. 3) Juveniles out-migrating when the reservoir is not spilling will likely not survive passing through needle valve.
9	Scott Dam	Downstream Fish Passage	Tributary Collection	1) Power reliability. 2) Debris and sediment loading. 3) Limited access during variable environmental conditions in winter. 4) Does not capture 100% of the juvenile out-migrant if designed for 5% exceedance flows. 5) Excavation and water tightness of diversion structure due to ground conditions. Potentially multiple locations increase handling and transport stress
10	Scott Dam	Downstream Fish Passage	Tributary Collection - Screw Trap	1) Susceptible to damage during high flows. 2) Can only capture a smaller percentage of juvenile out-migrant due to picket sizing and size of screw trap. 3) Size limitation related to water depth. 4) Limited access during variable environmental conditions. Potentially multiple locations increase handling and transport stress Inherent inefficiencies of screw trap collection techniques
11	Scott Dam	Leave/Remove	Continued Operations	1) Increasing cost of maintenance through time of older structure 2) Unanticipated FERC/DSOD requirements. 3) Hydrologic, geotechnical or seismic event causing inability to access or control dam or spillway operations, leading to uncontrolled release of water 4) Hydrologic, geotechnical or seismic event causing damage to the dam, spillway or ancillary facilities, leading to uncontrolled release of water 5) Gallery/toe drains become clogged over time, causing the dam to slide, leading to erosion of the foundation and an uncontrolled release of water. 6) Logs block one or more of the gate bays, reducing the spillway area, causing overtopping of the dam parapet walls, allowing an uncontrolled release. 7) During a storm, the radial gates are not raised in a timely manner, causing overtopping of the dam parapet walls, leading to an uncontrolled release of reservoir water. 8) Mechanical failure of the gate hoist prevents the radial gates from being raised to regulate the reservoir, causing the reservoir to rise during a major storm event, leading to an uncontrolled release.

Option ID	Facility	Goal	Modification Option	Examples of Potential Risks and Tradeoffs
12	Scott Dam	Leave/Remove	Phased Removal	1) Unforeseen hazardous materials. 2) Potential Sacramento Pikeminnow expansion downstream. 3) Clogging of Van Arsdale Diversion with sediment. 4) Blocking tributary access for salmonids. 5) Inundating downstream water diversions. 6) Prolonged downstream ecological impacts. 7) Changed public recreational areas, activities. 8) Post-activity ecosystem monitoring, mitigation. 9) Reduced water supply reliability for downstream water users (irrigation, municipalities). 10) Increased flood magnitude below Scott Dam.
13	Scott Dam	Leave/Remove	Rapid Removal	1) Unforeseen hazardous materials. 2) Potential Sacramento Pikeminnow expansion downstream. 3) Clogging of Van Arsdale Diversion with sediment, potentially requiring a temporary diversion infrastructure. 4) Blocking tributary access for salmonids. 5) Inundating downstream water diversions.6) Prolonged downstream ecological impacts. 6) Changed public recreational areas, activities. 7)Post-activity ecosystem monitoring, mitigation. 8) Reduced water supply reliability for downstream water users (irrigation, municipalities). 9) Increased flood magnitude below Scott Dam.
14	Cape Horn Dam	Upstream Fish Passage	Upstream Fish Ladder Improvements	1) Does not require diversion modification. 2) Modifications are to existing facilities with minimal environmental impact during and/or post-construction. 3) Debris and sediment loading may continue to cause periodic closure of the ladder 2) Pacific Lamprey may reject the new modification. 3) Could Discover structural issues when dewatering the facility. 4) Fish could reject the upper ladder for other reasons than hydraulic reasons. 5) Assumption of pool depth could be incorrect and therefore not meet the energy dissipation factor. 6) The bedrock floor being more weathered or rough than expected, limiting Pacific Lamprey passage. 7) Risk of not meeting entrance velocity through the entrance, due to gate positions.
15	Cape Horn Dam	Upstream Fish Passage	Fish Hotel Improvements	1) Initial list of Improvements do not fix the debris and sediment loading issue at the Fish Hotel. Additional improvement concepts need to be developed in subsequent phases of analysis to more fully address sediment and debris issues. 2) Fish hotel and lower ladder pools is subject to high debris loading and complete submergence during high flows. 3) Reservoir and ladder will cause some fish migration delay and predation.
16	Cape Horn Dam	Upstream Fish Passage	Trap and Haul	1)There are several typical risks associated with the additional handling of fish required by trap –and-haul, such as Risk associated with lifting the hopper, stress associated with Crowder operation, handling and transport stress, thermal stress, etc.. 3) Drainage issue due to water-to-water transfer. 4) In general, non-volitional passage and handling increases pre-spawn mortality.
17	Cape Horn Dam	Leave/Remove	Continued Operations	1) Operation of a dam and fish ladder in high (or higher with Scott Dam removal) sediment conditions, leading to challenges with fish passage and diversion capacity/reliability 2) Unanticipated FERC/DSOD requirements.
18	Cape Horn Dam	Leave/Remove	Removal	1) Unforeseen hazardous materials in sediment 2) Requires an alternative diversion structure to provide reliable water supply
19	Van Arsdale Diversion	Leave/Remove	Ranney Well Field	1) Volitional passage through natural river corridor – avoids migration delay and increased predation at structures. 2) No risk of fish impingement or egg incubation impacts due to perforated pipes being deep in substrate 3) Can use existing diversion facility if water is pumped into tunnel 4) Local hydrogeologic conditions unamenable to Ranney wells; large factor of safety may be required, leading to more wells 5) Managing flows downstream of the diversion to meet minimum instream flow requirements and ramping rates. 6) Capital construction costs are very high. 7) Challenges with construction: construction in the wet, maintaining diversion capability during construction period. 8) Reliability is unproven in these conditions and at this scale 9) O&M costs may be much higher due to sedimentation/clogging

Option ID	Facility	Goal	Modification Option	Examples of Potential Risks and Tradeoffs
				10) Steady-state channel elevation after Scott Dam removal may lead to siphon, longer adit, or longer large diameter pipe runs 11) The depth to bedrock may not provide enough space or depth for the 12-20 wells required to divert 300 cfs. 12) For gravity feed, need to be located far enough upstream that there is sufficient driving head to convey water to the tunnel without entraining air or creating a vacuum, or drill new adit. 13) Likely would need to be located closer to existing diversion with deeper bedrock and more valley width, thus requiring pumping rather than gravity feed 14) Per NMFS, should not be installed in areas where spawning occurs.
20	Van Arsdale Diversion	Leave/Remove	Cone Screen Diversion	1) Volitional passage through natural river corridor – avoids migration delay and increased predation at structures. 2) Diversion rates can be achieved in shallow water applications 3) Debris impact may damage or destroys screen(s) 4) Conical shape is more resilient to heavy sediment and debris loads 5) Steady-state channel elevation after Scott Dam removal may require siphon or longer tunnel adit 6) Screen elevation can be adjusted using risers to accommodate changing riverbed levels. 7) If installed far enough upstream, or construction of an adit, can use existing diversion facility and gravity flow 8) Hydraulic conditions and target diversion flow rates may require many cone screens (estimated 6 cone screens at 50 cfs each), increasing susceptibility to maintenance issues 9) O&M costs may be higher due to active brush cleaning equipment, electrical loads, and sedimentation/clogging of screens (compared with existing) 10) Managing flows to meet minimum instream flow requirements and ramping rates. 11) Channel may migrate away from screens - channel armoring may be required to protect infrastructure from lateral channel migration 12) A control building would be required to house electrical controls for brush cleaning system.
21	Van Arsdale Diversion	Leave/Remove	Modifications at Fish Screen	1) Cleaning system not catching up with algae growth and continued derated operation. 2) Excavation and dewatering. 3) Depending on the new design, the trash rack, bulkhead, and/or other equipment may not be able to be re-used, thereby increasing construction cost. 4) If Scott Dam is removed, increased sediment and debris loading.
22	Van Arsdale Diversion	Leave/Remove	Modify Fish Bypass Pipe	1) NMFS or CDFW may not approve the fish bypass pipe release location.
23	Powerhouse	Leave/Remove	Continued Operations	1) Ownership of an aging powerhouse means equipment may fail unexpectedly, leading to high O&M costs 2) Continued loosening of tunnel wall and entrainment of material into penstocks 3) Unanticipated FERC/DSOD requirements
24	Powerhouse	Leave/Remove	No Scott Dam - Continued Operations	1) Ownership of an aging powerhouse means equipment may fail unexpectedly, leading to high O&M costs 2) Future climate and environmental conditions may further diminish diversions, reducing revenues 3) Continued loosening of tunnel wall and entrainment of material into penstocks
25	Powerhouse	Leave/Remove	No Scott Dam - Powerhouse Rehab	1) Future climate and environmental conditions may further diminish diversions, reducing revenues 2) Continued loosening of tunnel wall and entrainment of material into penstocks 3) Ownership of an aging powerhouse means equipment may fail unexpectedly, leading to high O&M costs
26	Powerhouse	Leave/Remove	Replace with Free Discharge Valve (FDV)	1) Unanticipated FERC/DSOD requirements (e.g., demolition of powerhouse) 2) Continued loosening of tunnel wall and entrainment of material into FDV 3) Reduced revenue making it more difficult to pay off capital and O&M costs 4) Regulatory and water right constraints
27	PVID Water Supply	Pump-Back	Pump-Back to Head of Valley	1) Rights-of-way and roadside geology increase capital costs of pipe alignment 2) Geology at Lake Mendocino increases cost of wet well installation 3) Lake Mendocino is not capable of storing diverted water in winter for subsequent summer use by PVID 4) Cost of pumping

Option ID	Facility	Goal	Modification Option	Examples of Potential Risks and Tradeoffs
28	PVID Water Supply	Pump-Back	Pump-Back with Tributary Storage	1) Uncontrolled release/partial or complete failure of new dam(s) 2) Rights-of-way and roadside geology increase capital costs of pipe alignment 3) Geology at Lake Mendocino increases cost of wet well installation 4) Lake Mendocino is not capable of storing diverted water in winter for subsequent summer use by PVID 5) Unforeseen geologic conditions at dam site increase capital costs 6) Hydrology of Busch Creek has overestimated annual supply of water 7) Unanticipated DSOD requirements 8) Cost of pumping
29	PVID Water Supply	Pump-Back	Pump-Back with Piped Canal Network	1) Losses from canal infiltration have been overestimated 2) Rights-of-way and roadside geology increase capital costs of pipe alignment 3) Geology at Lake Mendocino increases cost of wet well installation 4) Lake Mendocino is not capable of storing diverted water in winter for subsequent summer use by PVID 5) Cost of pumping
30	PVID Water Supply	Pump-Back	Pump-Back with Water Dropoff	1) Rights-of-way and roadside geology increase capital costs of pipe alignment 2) Geology at Lake Mendocino increases cost of wet well installation 3) Lake Mendocino is not capable of storing diverted water in winter for subsequent summer use by PVID 4) Cost of Pumping
31	Lake Pillsbury	Leave/Remove Sediment	No Scott Dam - Extensive Sediment Management	1) Erosional failure of spoils area lifts 2) Additional equipment along river for long periods of time will increase risk of fuel or hydraulic spills 3) Relatively high cost
32	Lake Pillsbury	Leave/Remove Sediment	No Scott Dam - 1.5 million yd^3 pilot channel	1) Erosional failure of spoils area 2) Fuel or hydraulic spills 3) Large volumes of sediment depositing downstream, impacting bridges, Van Arsdale Diversion, and water intake systems
33	Lake Pillsbury	Leave/Remove Sediment	No Scott Dam -all sediment downstream, no Scott Dam	1) Erosional failure of spoils area 2) Additional equipment along river for long periods of time will increase risk of fuel or hydraulic spills 3) Large volumes of sediment depositing downstream, impacting bridges, Van Arsdale Diversion, and water intake systems
34	Lake Pillsbury	Leave/Remove Sediment	No Scott Dam -all sediment downstream, no Scott Dam & no Cape Horn Dam	1) Large volumes of sediment depositing downstream, impacting bridges, Van Arsdale Diversion, and water intake systems 2) Scour of Eel River Road Bridge due to headcutting upstream from Cape Horn Dam removal 3) Additional 1.2 million yd^3 of Van Arsdale Reservoir sediments to route downstream
35	Lake Pillsbury	Revegetation	Revegetation Unit Costs Group 3 PV Labor w/seed & mulch	1) Revegetation effort to achieve desired success may be more expensive 2) Future fires may destroy planted vegetation 3) Invasive plants may take over newly exposed surfaces under Lake Pillsbury
36	Lake Pillsbury	Revegetation	Revegetation Unit Costs Group 7 PV Labor w/ seed & mulch	1) Revegetation effort to achieve desired success may be more expensive 2) Future fires may destroy planted vegetation 3) Invasive plants may take over newly exposed surfaces under Lake Pillsbury
37	Lake Pillsbury	Revegetation	Revegetation Scaled to Elwha revegetation	1) Revegetation effort to achieve desired success may be more expensive 2) Future fires may destroy planted vegetation 3) Invasive plants may take over newly exposed surfaces under Lake Pillsbury
38	Lake Pillsbury	Revegetation	Revegetation Scaled to another local decommission revegetation	1) Revegetation effort to achieve desired success may be more expensive 2) Future fires may destroy planted vegetation 3) Invasive plants may take over newly exposed surfaces under Lake Pillsbury

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APPENDIX 1
Calculations for Infrastructure Modification Options

Calculation Cover Sheet

Project: Potter Valley

Client: Sonoma County Water Agency **Proj. No.:** 19-103

Title: Cape Horn and Scott Dam Fish Passage Evaluation

Prepared By, Name: Vincent Autier, Jessica Wiegand

Prepared By, Signature: Jessica Wiegand **Date:** 2/6/2020

Peer Reviewed By, Name: Vincent Autier

Peer Reviewed, Signature: **Date:** 2/28/2020

SUBJECT: Sonoma County Water Agency
Potter Valley
Scott and Cape Horn Dam Fish Passage Calculations

BY: J. Wiegand **CHK'D BY:** V. Autier
DATE: 1/31/2020
PROJECT NO.: 19-103

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McMILLEN JACOBS ASSOCIATES

SUBJECT:	Sonoma County Water Agency	**BY:** J. Wiegand	**CHK'D BY:** V. Autier
	Potter Valley	**DATE:**	1/28/2020
	Cape Horn Downstream Fish Passage Evaluation	**PROJECT NO.:**	19-103

Purpose

The purpose of this calculation sheet is to evaluate the existing upstream fish passage at Cape Horn Dam.

Calculation

The following calculations have been provided:

1. Flow over Fish Ladder Weir
2. Height of Water in Pools 5 thru 28
3. Dimensions of Orifice
4. Velocity through Submerged Entrance
5. Energy Dissipation Factor
6. Diffuser Wall Velocity

1. Flow over Fish Ladder Weir

$$Q_w = C_w C_v L h^{3/2}$$

$$C_v = \left(1 - \left(\frac{h_d}{h}\right)^{3/2}\right)^{0.385}$$

Where:
- Qw = Weir Flow (cfs)
- Cw = Weir Discharge Coefficient
- Cv = Villemonte Coefficient for Submerged Weir Flow
- L = Length of Weir (ft)
- h = Head on Weir (ft)
- hd = Downstream Head on Weir (ft)

Weir Length, L =	4	ft	
Upstream Head on Weir, h =	1.00	ft	
Downstream Head on Weir, hd =	0.00	ft	
Weir Discharge Coef., Cw =	3.33		Assumed
Submerged Weir Coef., Cv =	1.00		The weir is not submerged
Weir Flow, Qw =	13.3	cfs	

Note: This is different than the 9-12 cfs that PG&E communicated. This head is probably less than 1-foot.

2. Height of Water in Pools 5 thru 28

$$Q_w = C_w C_v L h^{3/2}$$

$$C_v = \left(1 - \left(\frac{h_d}{h}\right)^{3/2}\right)^{0.385}$$

Where:
- Qw = Weir Flow (cfs)
- Cw = Weir Discharge Coefficient
- Cv = Villemonte Coefficient for Submerged Weir Flow
- L = Length of Weir (ft)
- h = Head on Weir (ft)
- hd = Downstream Head on Weir (ft)

Weir Flow, Qw =	15.3	cfs	Flow over fish ladder weir combined with flow from bypass pipe (2 cfs)
Weir Length, L =	4	ft	
Downstream Head on Weir, hd =	0.00	ft	
Weir Discharge Coef., Cw =	3.33		Assumed
Submerged Weir Coef., Cv =	1.00		The weir is not submerged
Upstream Head on Weir, h =	1.1	ft	

Note: h > 1.0 ft; therefore, it does not meet criteria.

3. Dimensions of Orifice

$$Q_o = C_o A_o \sqrt{2gh}$$

Where:
Qo = Orifice Discharge Flowrate (cfs)
Co = Orifice Discharge Coefficient
Ao = Orifice Area (ft²)
g = Gravitational Acceleration (ft/s²)
h = Head on Orifice (ft)

Orifice Discharge Flowrate, Qo =	13.3	cfs	
Orifice Discharge Coef., Co =	0.70		Assumed
Gravitational Accel., g =	32.2	ft/s²	
Head on Orifice, h =	1.00	ft	
Orifice Area, Ao =	2.37	ft²	
Orifice Height and Width =	**1.54**	**ft**	Assuming a square orifice

Note: Assuming that this is a square orifice, it is likely a 1.5' x 1.5' opening.
This opening meets NMFS crieteria.

4. Velocity through Submerged Entrance

$$v_o = Q_o / A_o$$

Where:
vo = Orifice Velocity (fps)
Qo = Orifice Discharge Flowrate (cfs)
Ao = Orifice Area (ft²)

Orifice Discharge Flowrate, Qo =	100.0	cfs	
Orifice Area, Ao =	15.00	ft²	The submerged entrance is 3-feet in width by 5-feet in height
Orifice Velocity =	**6.67**	**fps**	

Note: 6.0 fps is typically the maximum entrance velocity; therefore, the entrance velocity is high.

5. Energy Dissipation Factor

$$V = \frac{\gamma Q H}{EDF}$$

NMFS, Section 4.5.3.5

Unit Weight of Water, γ =	62.4	lbs/ft³	
Fish Ladder Flow, Q =	13.3	cfs	
Fish Ladder Flow (in lower pools), Q =	15.3	cfs	the lower pools have an additional 2 cfs of flow from the PVP bypass
Energy Head of Pool-to-Pool Flow =	1.0	ft	
Energy Dissipation Factor (EDF) <	4.0	ft-lbs/s/ft³	
Calculated Pool Volume =	207	ft³	

Pool Width (ft)	Pool Length (ft)	Pool Depth (ft)	Pool Volume (ft³)	Volume Check	EDF (ft-lbs/s/ft³)	EDF Check
6.5	9.33	5	303	> 0, OK	2.7	< , !
5.5	9	4.5	223	> 0, OK	3.7	< , !
5	9	4.25	191	> 0, OK	4.3	< , !
4.5	8.66	4	156	> 0, OK	0.3*	< , !

* The EDF for the pool with a width of 4.5' is calcualted using the higher flow of 15.3 cfs.

Note: The EDF criteria is met for some, but not all of the pools (about half of the pools will not meet the EDF criteria).

6. Diffuser Wall Velocity

WSEL in tailrace ≃	1452.17	ft	(variable)
WSEL in entrance pool	1453.17	ft	(variable)

$$Water\ Depth = WSEL\ in\ entrance\ pool\ - Bay\ Invert\ (ft)$$

Bay #	Bay Invert (ft)	Water Depth (ft)	Bay Width (ft)	Diffuser Wall Area (ft^2)
1	1444.0	9.2	5.25	48.1
2	1444.0	9.2	5.25	48.1
3	1444.0	9.2	5.25	48.1
4	1446.0	7.2	5.25	37.6
5	1447.0	6.2	5.25	32.4
6	1448.0	5.2	5.25	27.1
			∑ Area =	241.6 ft^2

$$Q = v\sum A$$

Where:

Q = Diffuser Wall Flow, (cfs)

v = Diffuser Wall Velocity, (fps) (solve for)

∑A = Diffuser Wall Area, (ft^2)

Diffuser Wall Flow, Q =	88	cfs	Provided by PG&E
Diffuser Wall Area, ∑A =	241.6	ft²	

Diffuser Wall Velocity =	0.36	fps	<1.0 fps for vertical diffusers per NMFS 4.3.2.1

Conclusion

1.The flow for the existing upstream fish ladder seems to vary between 13.3 and 15.3 cfs.
2. The height of the water in pools 5 thru 28 is 1.1 ft.
3. Orifice dimensions seem to meet NMFS criteria.
4. The velocity through the submerged entrance is high.
5. The energy dissipation factor criteria will not be met in approximately half of the pools.
6. The diffuser wall velocity seems to meet NMFS criteria.

McMILLEN JACOBS ASSOCIATES

SUBJECT:	Sonoma County Water Agency (SCWA)	**BY:** N.Cox	**CHK'D BY:** V.Autier
	Cape Horn Dam	**DATE:** 2/20/2020	
	Cape Horn Dam AWS Flows	**PROJECT NO.:** 19-103	

Purpose

The purpose of this calculation sheet is to estimate the AWS flows entering the Fish Hotel at Cape Horn Dam.

References

- *Tullis, J. Paul. (1989). Hydraulics of Pipelines, Pumps, Valves, Cavitation, Transients. New York: John Wiley & Sons.*
- *Hydraulic Design Criteria (HDC) (1973). Conical Transitions, Loss Coefficients. Sheet 228-4. Revised 7-73.*
- *Rennels, Donald D. & Hudson, Hobart M. (2012). Pipe Flow, A Practical and Comprehensive Guide. Hoboken, Jew Jersey: John Wiley & Sons.*
- Miller, D.S. (1990). Internal Flow Systems, Design and Performance Prediction, Second Edition. Houston, Texas: Gulf Publishing Company.

Layout

Information

Unit Weight of Water, γ =	62.4	lbs/ft³	
Kinematic Viscosity, v =	1.22E-05	ft²/s	Kinematic Viscosity at 60° F
Acceleration of Gravity, g =	32.2	ft/s²	
Pipe Roughness, e =	0.18	ft	Estimate for CMP Pipe
Entrance Loss, K_l =	0.5		Table 1.4 (Tullis, 1989)
Tee Loss, K_l =	0.9		Diagram 16.10 (Rennels, eta, 2012)
45° Miter Bend Loss, K_l =	0.3		Diagram 15.1 (Rennels, eta, 2012)
Estimate Reducer Loss, K_l =	0.10		HDC 228-4
Exit Loss, K_l =	1.0		
Crest AWS Overflow =	1458.92	ft	
Weir Discharge Coefficient, C =	2.85		Broad Crested Weir
Crest / Screen Length, L =	20	ft	
Screen Width, W =	5.15	ft	
Number of Drop Inlets =	4	each	
Drop Inlet Diameter =	2	ft	CMP Drop Inlets
Length, L =	6	ft	
Header Diameter =	4	ft	CMP
Header Length, L =	20	ft	Approximately
Exit Gate Width =	3	ft	
Exit Gate Height =	3	ft	
Normal Forebay Elevation =	1459.75	ft	
Normal Tailwater Elevation =	1449.50	ft	

Calculation - Pipe Full Equations with Downstream Control

Forebay Elevation =	1460.26	ft	
Total Flow =	154	cfs	

Screens

Flow, Q =	154	ft^3/s	Assumption: flow is uniform in the drop inlets
Screen Area, A =	102.92	ft^2	
Velocity, V =	1.49	ft/s	
Velocity Head =	0.03	ft	Velocity Head, $V^2/2g$
Screen Porosity =	40%	percent	Assumed
Angle to Flow =	90	degrees	
Angle Multiplier =	1.00		(Figure 48, USBR, "Fish Protection at Water Diversion", April 2006)
k =	5.00		(Figure 47, USBR, "Fish Protection at Water Diversion", April 2006)
Adjusted k =	10.00		
Minor Loss, K_l =	10.00		Includes: Fish Screen
Minor Losses, h_l =	0.35	ft	Minor Losses, K_l ($V^2/2g$)
Total Losses, h_L =	0.35	ft	
EGL =	1459.91	ft	Energy Grade Line at Drop Inlets
HGL =	1459.87	ft	Hydraulic Grade Line at Drop Inlets

Drop Inlets

Number of Drop Inlets =	4		
Flow, Q =	38	ft^3/s	Assumption: flow is uniform in the drop inlets
Diameter, D =	2.0	ft	
Area, A =	3.14	ft^2	
Length, L =	6	ft	
Velocity, V =	12.24	ft/s	
Velocity Head =	2.33	ft	Velocity Head, $V^2/2g$
Roughness, e =	0.18	ft	
friction factor, f =	0.0958		Colebrook-White Equation
friction Losses, h_f =	0.67	ft	Friction Losses, fL/D ($V^2/2g$)
Minor Loss, K_l =	1.40		Includes: Entrance, Tee
Minor Losses, h_l =	3.26	ft	Minor Losses, K_l ($V^2/2g$)
Total Losses, h_L =	3.93	ft	
EGL =	1455.98	ft	Energy Grade Line at 48" CMP
HGL =	1453.65	ft	Hydraulic Grade Line at 48" CMP

48" CMP

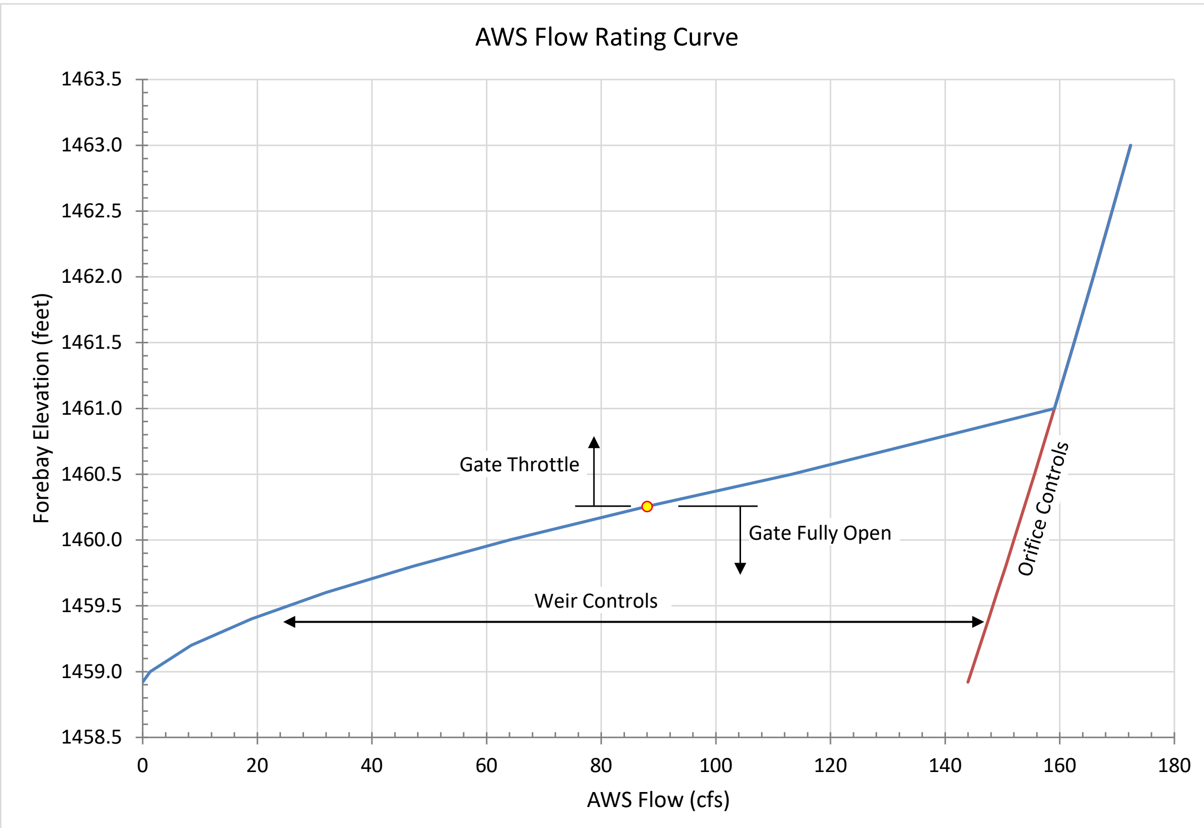
Flow, Q =	154	ft^3/s	
Diameter, D =	4.0	ft	
Area, A =	12.57	ft^2	
Length, L =	20	ft	
Velocity, V =	12.24	ft/s	
Velocity Head =	2.33	ft	Velocity Head, $V^2/2g$
Roughness, e =	0.18	ft	
friction factor, f =	0.0681		Colebrook-White Equation
friction Losses, h_f =	0.79	ft	Friction Losses, fL/D ($V^2/2g$)
Minor Loss, K_l =	0.30		Includes: Bend
Minor Losses, h_l =	0.70	ft	Minor Losses, K_l ($V^2/2g$)
Total Losses, h_L =	1.49	ft	
EGL =	1454.49	ft	Energy Grade Line at Gate
HGL =	1452.16	ft	Hydraulic Grade Line at Gate

Gate

Flow, Q =	154	ft^3/s	
Exit Gate Width =	3	ft	
Exit Gate Height =	3	ft	
Area, A =	9.00	ft^2	
Velocity, V =	17.09	ft/s	
Velocity Head =	4.54	ft	Velocity Head, $V^2/2g$
Minor Loss, K_l =	1.10		Includes: Reducer, Exit
Minor Losses, h_l =	4.99	ft	Minor Losses, K_l ($V^2/2g$)
Total Losses, h_L =	4.99	ft	
EGL =	1449.50	ft	Energy Grade Line at Exit (TW)
Difference =	0.00		

Results

Forebay Elevation (ft)	AWS Flow (cfs)	Head on Weir (ft)	Weir Flow (cfs)	Pipe Full Headloss (ft)	Pipe Full Flow (cfs)
1458.92	0	0.0	0	9.4	144
1459.00	1	0.1	1	9.5	145
1459.20	8	0.3	8	9.7	146
1459.40	19	0.5	19	9.9	148
1459.60	32	0.7	32	10.1	149
1459.80	47	0.9	47	10.3	151
1460.00	64	1.1	64	10.5	152
1460.26	88	1.3	88	10.8	154
1460.50	113	1.6	113	11.0	156
1461.00	159	2.1	171	11.5	159
1461.50	163	2.6	236	12.0	163
1462.00	166	3.1	308	12.5	166
1462.50	169	3.6	386	13.0	169
1463.00	172	4.1	470	13.5	172



SUBJECT: Sonoma County Water Agency
Potter Valley
Cape Horn Downstream Fish Passage Evaluation

BY: V. Autier **CHK'D BY:** J. Wiegand
DATE: 2/11/2020
PROJECT NO.: 19-103

Purpose

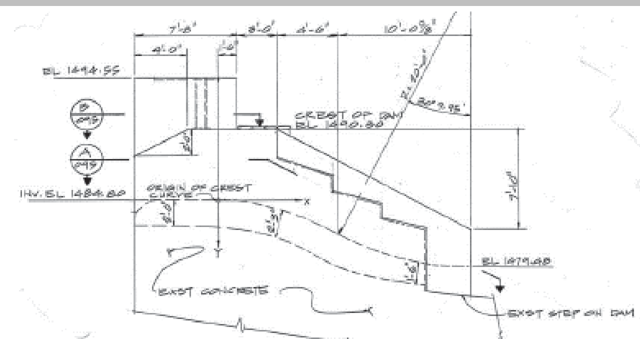
The purpose of this calculation sheet is to evaluate the dowsntream fish passage at Cape Horn Dam.

Criteria

Criteria	Value	Units	Comments
Fish Return			
Bypass Velocity	6 < x < 12	feet/sec	NMFS 2011, Section 11.9.3.8
Maximum Impact Velocity	25	feet/sec	NMFS 2011, Section 11.9.4.2

Input

Starting Elevation of Fish Water Release =	1484.8	ft
Invert of flume Elevation =	1479.48	ft
Van Arsdale normal water surface elevation =	1490.3	ft
Outlets =	2	EA
Outlet Width =	2	ft
Outlet Height =	4	ft
Flume Length =	19	ft
Normal water level above the fish barrier =	1459.7	ft
Maximum Drop =	19.78	ft
Maximum Flow =	124	cfs



Section through exit flume - Source: STID 2015 - Cape Horn

Flume Velocity:

$Q = V \times A$ and

$V = \frac{k}{n} R^{2/3} S^{1/2}$ and

$R = \frac{A}{P}$ and

$A = b \times y$

Where:
Q = Discharge (cfs)
V = Flume Velocity (fps)
A = Cross Sectional Area of Flow (ft²)
k = Unit Conversion Factor
n = Roughness Coefficient
S = Channel Slope (ft/ft)
R = Hydraulic Radius of the Flow Cross-Section (ft)
P = Wetted Perimeter (ft)
b = Water Depth (ft)
y = Flume Width (ft)

Assuming a water depth of 1.04 feet

A =	2.09	sf
P =	6.09	ft
R =	0.34	ft
S =	0.28	ft/ft
n =	0.013	for concrete
k =	1.49	
V =	29.71	fps
Q =	124.00	cfs

Flow (cfs)	Water Depth (ft)	Water Depth (in)	Velocity (fps)	Jet Impact Velocity (ft/s)
0	0.00	0.00	0	0
1	0.05	0.59	5.07	36
5	0.13	1.58	9.48	36.9
10	0.20	2.43	12.35	37.8
124	1.04	12.52	29.71	46.4

Notes: Assumes both gates opened the same amount.

Determine Jet Impact Velocity:

The Kinematic Equation for final velocity

$$V_f^2 = V_i^2 + 2ad$$

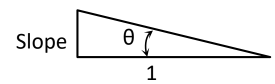
$$V^2 = V_x^2 + V_y^2$$

Where:

V_f =	Final Velocity (ft/s)
V_i =	Initial Velocity (ft/s)
a =	Acceleration, gravitational acceleration (ft/s²)
d =	Displacement of the object (ft)
V =	Total Velocity (ft/s)
V_x =	Horizontal Component of Velocity (ft/s)
V_y =	Vertical Component of Velocity (ft/s)

Initial Horizontal and Vertical Velocity Components

Slope Angle, θ =	0.27	radians	15.6	degrees
Horizontal Velocity Component, V_x =	28.61	ft/s	Based on the cosine of the angle	
Vertical Velocity Component, V_y =	8.01	ft/s	Based on the sine of the angle	



Final Vertical Velocity Component

gravitational acceleration, g =	32.2	ft/s²	
Final Vertical Velocity, V_{fy} =	36.58	ft/s	Based on the fall height of 19.8 ft

Jet Impact Velocity, V_j =	46.4	ft/s	NO!	< 25 ft/s

Conclusion

The impact velocity is always exceeded.
The flume velocity is nearly always exceeded.

SUBJECT: Sonoma County Water Agency
Potter Valley
Cape Horn Upstream Fish Passage Evaluation

BY: V. Autier **CHK'D BY:** J. Wiegand
DATE: 2/10/2020
PROJECT NO.: 19-103

Purpose

The purpose of this calculation sheet is to size the holding pool for a potential trap and haul facility at Cape Horn.

References

- *NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.*
- *USFWS Fish and Aquatic Conservation*
- *Potter Valley Project Monitoring Program, Progress Report for 1987 thru 1998. Prepared for PG&E from Steiner Environmental Consulting.*

Criteria

Criteria	Value	Units	Comments
Density			
Trap Holding Pool	0.25	ft³/lb	NMFS 2011, Section 6.5.1.2; Water temp < 50°F; 6 < DO < 7 ppm; fish held < 24 hours
Long-Term Holding Density	0.75	ft³/lb	NMFS 2011, Section 6.5.1.2; Water temp < 50°F; 6 < DO < 7 ppm; fish held < 24 hours
Hopper and Fish Truck Density	0.15	ft³/lb	Per NMFS 2011, Section 6.7.2.1
Flow			
Short-term Holding Flow	1	gpm/fish	minimum 0.67 gpm/fish (NMFS 6.5.1.3)
Fish Weight			
Chinook Salmon	40	lb	USFWS
Steelhead	11	lb	USFWS
Conservation			
Chinook Salmon	Endangered		
Steelhead	Threatened		CalFish.org

Note: If water temperatures are greater than 50°F, the poundage of fish held should be reduced by 5 percent for each degree over 50°F (NMFS 6.5.1.2)

Input

Year	Chinook Salmon		Steelhead		Comment
	Trapped	Passed	Trapped	Passed	
1944-45			9528		Steelhead returns to Van Ardsale Fisheries Station between 1933 and 1962 were
1947-48	994				typically over 2,000 fish.
1964-65					
1975-76					
1979-80	84	79	87	69	
1980-81	0	0	1966	1930	
1981-82	175	174	646	544	
1982-83	9	9	369	357	
1983-84	26	9	1534	1473	
1984-85	153	152	1980	1919	
1985-86	955	672	1199	1199	In 1985-86, Chinook migration Nov-26 - Jan-14; Steelhead Nov-30 - Feb-14
1986-87	1754	1624	1952	1910	
1987-88	1080	552	2168	2081	Fish hotel was built in 1987.
1988-89	328	168	331	273	50-percent of Chinook observed to reject the upper ladder.
1989-90	6	4	691	628	
1990-91	0	0	31	31	
1991-92	5	3	60	60	
1992-93	4	0	823	777	
1993-94	1	1	34	34	
1994-95	21	6	434	407	
1995-96	525	325	1743	1597	
Min	**0**	**0**	**31**	**31**	
Max	**1754**	**1624**	**2168**	**2081**	
Mean	**302**	**222**	**944**	**899**	
Peak Day	1961	Based on Max			Did not account for the 1944-45 year; which was exceptional.
	623	Based on Mean			
	1292	Average			

Calculation

1. Determine the Minimum Daily Required Volume of the Trap Holding Pool

Chinook =	302	EA	
Steelhead =	944	EA	
Minimum Volume =	5611	ft^3	at Water temp < 50°F

Can hold less fish during warmer water temperature. Note that Chinook and Steelhead migrate from end of November to say mid-February.

2. Determine the Minimum Required Flow

Required Flow Rate =	2.78	cfs	< 13.3 cfs	OK

The required flow is less than the existing upper ladder flow.
Flow is not a limiting factor.
The ladder flow will need to be diffused in the holding pool through a wall diffuser.

3. Determine the Wall Diffuser Size

Diffuser wall height =	4	ft	(assumed per site visit)
Ladder flow =	13.3	cfs	(variable)
Maximum approach velocity =	1	fps	for vertical diffusers per NMFS 4.3.2.1
Design approach velocity =	0.9	fps	
Diffuser wall length =	(solve for)	ft	

$$Q = VA$$

Where:
Q = Diffuser Wall Flow, (cfs)
v = Diffuser Wall Velocity, (fps)
A = Diffuser Wall Area, (ft^2) (solve for)

Diffuser Wall Area, A =	14.8	ft^2
Diffuser wall length >	3.69	ft

This can be accomodated within the pool width.

4. Trap Holding Pool Available Volume

Volume depth =	4	ft	(assumed per site visit)
Pool Width =	9.5	ft	(assumed per site visit)
Pool Length =	90	ft	(assumed per site visit)
Volume =	3420	ft^3	

The holding pool will need to be managed a couple of times per day during a peak day.

Conclusion

1. The trap holding pool can be accomodated on site in place of pools 30 and 31.
2. The ladder flow is sufficient to meet the minimum required flow.
3. The trap holding pool would need to be managed twice a day during peak days.

McMILLEN JACOBS ASSOCIATES

SUBJECT:	Sonoma County Water Agency	**BY:** J. Wiegand	**CHK'D BY:** V. Autier
	Potter Valley	**DATE:** 1/29/2020	
	Cape Horn Downstream Fish Passage Evaluation	**PROJECT NO.:** 19-103	

Purpose

The purpose of this calculation sheet is to evaluate the existing PVP bypass at Cape Horn Dam.

References

- *RAJARATNAM N., KATOPODIS C., 1991. Hydraulics of Steeppass Fishways. Can. Soc. Civ. Eng., 18:6.*

Criteria

Criteria	Value	Units	Comments
Fish Return			
Bypass Velocity	6 < x < 12	feet/sec	NMFS 2011, Section 11.9.3.8
Maximum Impact Velocity	25	feet/sec	NMFS 2011, Section 11.9.4.2

Input

Maximum Drop =	9	ft	
Maximum Flow =	2	cfs	
Flume Slope =	0.107	ft/ft	assumed
Flume width =	1	ft	assumed

Bypass Velocity:

1. Find the depth of water in the flume

$$Q = 0.36(Sg)^{0.5}h^{1.55}$$

(RAJARATNAM and KATOPODIS, 1991)

Where:

Q = fishway flow (m^3/s)
h = depth above the floor baffles (m)
S = fishway slope (ft/ft)
g = acceleration due to gravity (9.81 m/s^2)

Q = 2 cfs
Q = 0.057 m^3/s
S = 0.107 m/m assumed
g = 9.81 m/s^2

h = 0.3 m
h = 1.0 ft matches visual observation

2. Calculate the area of water flowing through the flume

$$A = h * w$$

Where:
A = Area of flume normal to direction of flow (ft^2)
h = depth above the floor baffles (ft)
w = flume width (ft)

w = 1.0 ft assumed

A = 1.0 ft^2

3. Calculate bypass velocity

$$Q = v * A$$

Where:
Q = fishway flow (cfs)
v_{bypass} = bypass velocity (fps)
A = Area of flume normal to direction of flow (ft^2)

v_{bypass} = 2.0 fps

Note: The bypass velocity does not meet the requirements of being between 6 and 12 fps in the baffle flume.

Determine Jet Impact Velocity:

The Kinematic Equation for final velocity

$$V_f^2 = V_i^2 + 2ad$$

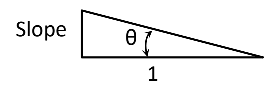
$$V^2 = V_x^2 + V_y^2$$

Where:

V_f = Final Velocity (ft/s)
V_i = Initial Velocity (ft/s)
a = Acceleration, gravitational acceleration (ft/s²)
d = Displacement of the object (ft)
V = Total Velocity (ft/s)
V_x = Horizontal Component of Velocity (ft/s)
V_y = Vertical Component of Velocity (ft/s)

Initial Horizontal and Vertical Velocity Components

Slope Angle, θ =	0.11	radians	6.1	degrees
Horizontal Velocity Component, V_x =	2.03	ft/s	Based on the cosine of the angle	
Vertical Velocity Component, V_y =	0.22	ft/s	Based on the sine of the angle	



Final Vertical Velocity Component

gravitational acceleration, g =	32.2	ft/s²	
Final Vertical Velocity, V_{fy} =	24.08	ft/s	Based on the fall height of 9 ft
Jet Impact Velocity, V_j =	**24.2**	**ft/s**	OK < 25 ft/s

Conclusion

The bypass velocity in the baffle flume seems to be 2.0 fps, which is less than the requirement of 6 to 12 fps.
The jet impact velocity is 24.2 fps, which meets the requirement of being less than 25 fps.

McMILLEN JACOBS ASSOCIATES

SUBJECT:	Sonoma County Water Agency	**BY:** V. Autier	**CHK'D BY:** J. Wiegand
	Potter Valley	**DATE:** 1/20/2020	
	Scott Dam Conventional Weir and Orifice Fishway	**PROJECT NO.:** 19-103	

Purpose

The purpose of this calculation sheet is to size a conventional weir and orifice fish ladder determining the flow, and pool dimensions, so that the fish ladder is passable to the target fish.

References

- *NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.*
- *USACE (US Army Corps of Engineers, Portland District). 2007. Willamette River Temperature Control Project, Fish Collection Facility. Cougar Reservoir, Willamette River Basin, South Fork Mckenzie River, Oregon. Design Documentation Report No. 22. January 2007.*
- *northwest hydraulic consultants (nhc). 2000. Fish Ladder Pit Tag Detector Antenna Weir, Hydraulic Model Study Final Report. Contract DACW57-98-D-0007 T05 for US Army Corps of engineers, Portland District. September 2000.*

Fish Ladder Design Criteria

Criteria	Value		Comments
Design TW Range: High TW	1805	ft	
Design TW Range: Low TW	1801	ft	
Hydraulic Drop	1	ft	NMFS, Section 4.5.3.1
Minimum Pool Dimensions			NMFS, Section 4.5.3.3
Length	8	ft	
Width	6	ft	
Depth	5.5	ft	
Energy Dissipation Factor (EDF)	4	ft-lbs/s/ft³	NMFS, Section 4.5.3.5
Orifice Velocity	6	ft/s or less	Assumed
Minimum Orifice Dimensions			
Width	12	inch	
Height	15	inch	
Minimum Transport Velocity	1.5	ft/s	NMFS, Section 4.4.2.1
Maximum Transport Velocity	4	ft/s	NMFS, Section 4.4.2.1

Note: 2.5 ft/s selected for steelhead prolonged speed

Step 1 - Inputs

Per Mead & Hunt:

Orifice Width =	12	inch
Orifice Height =	15	inch
Weir Length =	2	ft
Weir Height =	5.5	ft
Upstream Pool Depth =	5.50	ft
Downstream Pool Depth =	6.50	ft
Hydraulic Drop =	12	inch
Pool Width =	6	ft
Outside Pool Length =	8.5	ft
Wall Thickness =	6	inch
Inside Pool Length =	8.00	ft
Average Water Depth =	6.00	ft
Slope =	1V:9H	

Turning Pool Width =	6	ft
Minimum Turning Pool Length =	12.75	ft
Wall Thickness =	6	inch
Turning Inside Pool Length =	12.25	ft
Turning Average Water Depth =	6.00	ft
Turning Pool Slope =	1V:13H	

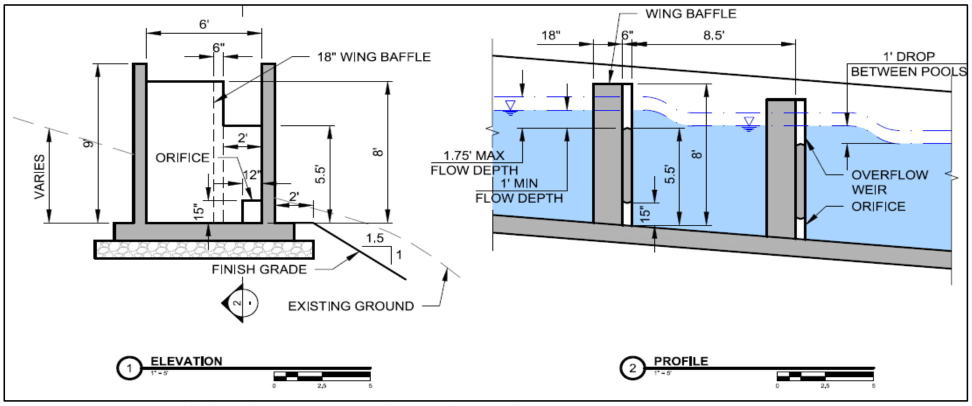


Figure 1 - Weir and Orifice Standard Pool (Mead & Hunt)

Step 2 - Determine Ladder Flow

Fish Ladder Orifice:

$$Q_o = C_o A_o \sqrt{2gh}$$

Where:

Q_o = Orifice Flow (cfs)
C_o = Orifice Discharge Coefficient
A_o = Orifice Area (ft²)
g = Gravitational Acceleration (ft/s²)
h = Head on Orifice (ft)

Orifice Discharge Coef., C_o =	0.70	
Gravitational Accel., g =	32.2	ft/s²
Head on Orifice, h =	1.00	ft
Upstream of Weir Water Depth =	6.50	ft
Downstream of Weir Water Depth =	5.50	ft
Orifice Area, A_o =	1.3	ft²
Orifice Flow, Q_o =	**7.0**	**cfs**

Check Orifice Velocity:

Orifice Velocity, V_o =	5.6	ft/s	< 6	OK

Fish Ladder Weir:

$$Q_w = C_w C_v L h^{3/2}$$

$$C_v = \left(1 - \left(\frac{h_d}{h}\right)^{3/2}\right)^{0.385}$$

Where:

Q_w = Weir Flow (cfs)
C_w = Weir Discharge Coefficient
C_v = Villemonte Coefficient for Submerged Weir Flow
L = Length of Weir (ft)
g = Gravitational Acceleration (ft/s²)
h = Head on Weir (ft)
h_d = Downstream Head on Weir (ft)

Weir Length, L =	2	ft	
Weir Height, Y =	5.5	ft	
Upstream of Weir Water Depth =	6.50	ft	
Downstream of Weir Water Depth =	5.50	ft	
Upstream Head on Weir, h =	1.00	ft	
Downstream Head on Weir, h_d =	0.00	ft	
Weir Discharge Coef., C_w =	3.8		Assumed, See Sensitivity Analysis
Submerged Weir Coef., C_v =	1.00		The weir is not submerged
Weir Flow, Q_w =	**7.6**	**cfs**	

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Fish Ladder Flow:

Total Ladder Flow, Q =	14.6	cfs

Discharge Coefficient Sensitivity Analysis

Standard Method: Francis Weir Equation with Rehbock Weir Coefficient Equation:

Francis Weir Equation:

$$Q_w = \frac{2}{3} C_1 C_v L \sqrt{2g} h^{3/2}$$

Rehbock Weir Coefficient Equation:

$$C_1 = \left(0.6035 + 0.0813\frac{h}{Y} + \frac{0.000295}{Y}\right)\left(1 + \frac{0.00361}{h}\right)^{3/2}$$

Where:

Q_w = Weir Discharge Flowrate (cfs)
C_1 = Weir Discharge Coefficient
C_v = Villemonte Coefficient for Submerged Weir Flow
L = Length of Weir (ft)
g = Gravitational Acceleration (ft/s²)
h = Upstream Head on Weir (ft)
Y = Height of Weir (ft)

Standard Weir Coefficients

Gravitational Accel., g = 32.2 ft/s²
Weir Discharge Coef., C_1 = 0.622
Weir Discharge Coef., C_{w1} = 3.326 $C_{w1} = \frac{2}{3} C_1 \sqrt{2g}$
Weir Flow, Q_{w1} = 6.7 cfs

Standard Orifice Coefficients

Gravitational Accel., g = 32.2 ft/s²
Orifice Discharge Coef., C_{o1} = 0.82
Orifice Flow, Q_{o1} = 8.2 cfs

Cougar Dam Fish Collection Weir Coefficients

Weir Discharge Coef., C_{w2} = 5.070 (USACE, 2007) & (nhc, 2000)
Weir Flow, Q_{w2} = 10.1 cfs

Cougar Dam Fish Collection Orifice Coefficients

Orifice Discharge Coef., C_{o2} = 0.66 (USACE, 2007) & (nhc, 2000)
Orifice Flow, Q_o = 6.6 cfs

Source	Weir Coef. C_w	Orifice Coef. C_o	Weir Flow Q_w	Orifice Flow Q_o	Total Flow Q_{total}	
Standard	3.33	0.82	6.7	8.2	14.9	
Cougar	5.07	0.66	10.1	6.6	16.8	←
Scott Dam	3.80	0.70	7.6	7.0	14.6	

For sizing purposes, the highest flow is selected.

Step 3 - Check Pool Volume

$$V = \frac{\gamma Q H}{EDF}$$

NMFS, Section 4.5.3.5

Unit Weight of Water, γ =	62.4	lbs/ft³
Fish Ladder Flow, Q =	14.6	cfs
Energy Head of Pool-to-Pool Flow =	1	ft
Energy Dissipation Factor (EDF) =	4	ft-lbs/s/ft³
Calculated Pool Volume =	228	ft³

Check Pond Volume:

Pool Width =	6	ft
Pool Length =	8.00	ft
Minimum Pool Depth =	5.50	ft

Pond Volume =	264	ft³	> 228	OK
Energy Dissipation Factor (EDF) =	3.5	ft-lbs/s/ft³	< 4	OK

Energy Dissipation Factor criteria is met.

Source	Calc Pond Volume (ft³)	Calc EDF (ft-lbs/s/ft³)		
Standard	232	3.52	< 4	OK
Cougar	261	3.96	< 4	OK
Scott Dam	228	3.46	< 4	OK

PROJECT:	Sonoma County Water Agency	**BY:** V. Autier	**CHK'D BY:** J. Wiegand
SUBJECT:	Potter Valley	**DATE:**	1/20/2020
	Scott Dam Vertical Slot Fishway	**PROJECT NO.:**	19-103

Purpose

The purpose of this calculation sheet is to size a fish ladder using vertical slot.

Criteria

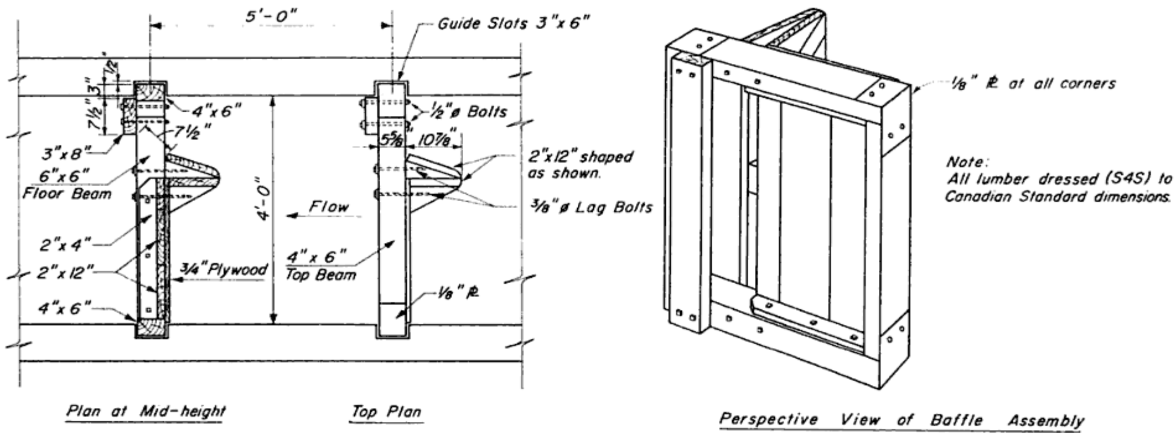


Figure 2.4 Baffle plan of small fishway for trout using a single vertical slot. This design uses a timber baffle and concrete fishway walls.

Reference:

References

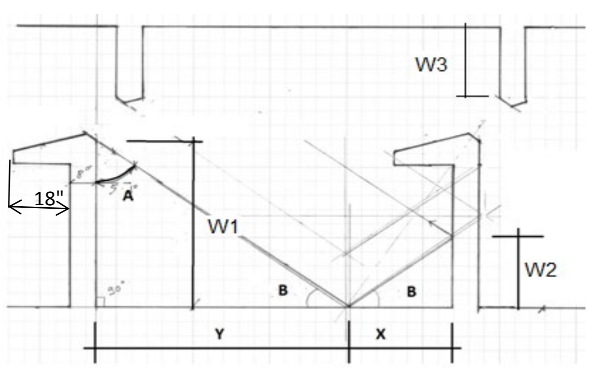
- *NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.*
- *Clay. 1961. Design of Fishways and Other Fish Facilities*
- *Bell. 1973. USACE Fisheries Handbook of Engineering Requirements and Biological Criteria*

Step 1 - Inputs

Orifice Width =	9	inch	Pool Width =	8	ft
Pool Depth =	54	inch	Pool Length (X+Y) =	10	ft
Orifice Sill =	0	inch	Wall Thickness =	8	inch
Head per Baffle =	12	inch	Average Water Depth =	5.00	ft

Step 2 - Determine Basic Geometry

Determine Angle A and W1



						Angle A		Angle B					
Pool Width	Length*	Pool Length (X+Y) (ft)	W1 (ft)	W2 (ft)	W3 (ft)	Degree	Rad	Degree	Rad	Y (ft)	X (ft)	Calculated (X+Y) (ft)	Difference (ft)
8.00	10.67	10.00	5	2.25	2.56	54.0	0.94	36	0.63	6.88	3.10	9.98	0.02

(*) Length is equal to X plus Y plus the wall width.
Note, the dog leg is typically 18-inch long and 4-inch wide at its minimum width.

Step 3 - Calculate Ladder Flow

$$Qo = Co \cdot Ao \cdot \sqrt{2gh}$$

Co = orifice discharge coefficient 0.75 Per Bell Fisheries Handbook Chapter 34.14, for 6 to 12-inch head per baffle.
Ao = orifice area 4.13 sf
Orifice width = 9 inch
h1 = 66 inch = Pool Depth + Head per Baffle = 54 + 12
Orifice Sill = 0 inch
g = gravitational acceleration 32.2 ft^2/sec
h = head 1.0 ft
Qo = design orifice flow through the slot (cfs)
Qo = 0.75*4.13*(2*32.2*1)^0.5
Qo = **24.8 cfs**

Step 4 - Check Pool Volume

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

Where,
V= Pool volume in cf (solve for) cf
γ = Unit weight of water 62.4 lb/ft3
Q = Fish ladder flow 24.8 cfs
H = Energy head of pool to pool 1.0 ft
Turbulence Factor 4 ft.lbs/ft^3 (maximum)

$V_{Minimum}$ = 387.3 cf

Pool Width = 8 ft
Average Water Depth = 5.00 ft
Pool Length (X+Y) = 10 ft (Clear space)

V_{Actual} = **396.3 cf** TRUE

Verify the Turbulence Factor
Turbulence Factor = 3.91 < 4 ft.lbs/ft^3 TRUE

SUBJECT:	Sonoma County Water Agency	**BY:** V. Autier	**CHK'D BY:** J. Wiegand
	Potter Valley	**DATE:** 1/17/2020	
	Scott Dam Floating Surface Collector	**PROJECT NO.:** 19-103	

Purpose

The purpose of this calculation sheet is to size the floating surface collector at Scott Dam.

References

• *NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.*

Criteria

Criteria	Value	Units	Comments
Fish Return			
Bypass Velocity	6 < x < 12	feet/sec	NMFS 2011, Section 11.9.3.8
Maximum Impact Velocity	25	feet/sec	NMFS 2011, Section 11.9.4.2
Approach Velocity	<0.4	feet/sec	NMFS 2011, Section 11.6.1.1
Sweeping Velocity	0.8 < x < 3		NMFS 2011, Section 11.6.1.5
Screen opening	1.75	mm	NMFS 2011, Section 11.7.1.2
Screen Material	SS		
Screen Open Area	27	%	NMFS 2011, Section 11.7.1.6

Input

High Forebay level	1910	feet
Low Forebay level	1869	feet
Vertical Variation	41	feet

This spreadsheet uses the following assumptions:

100% stage exceedance

Maximum intake flow =	1000	cfs
Primary screen flow =	85.6	%
Top of screen =	1911	feet
Throat =	24	inches
Opening =	17.65	feet
Wall slope =	0.1957	rad
	11.21	Degree

See profile

Note: Did not account for 0.5' of head loss.

Critical Depth (ft), Dc

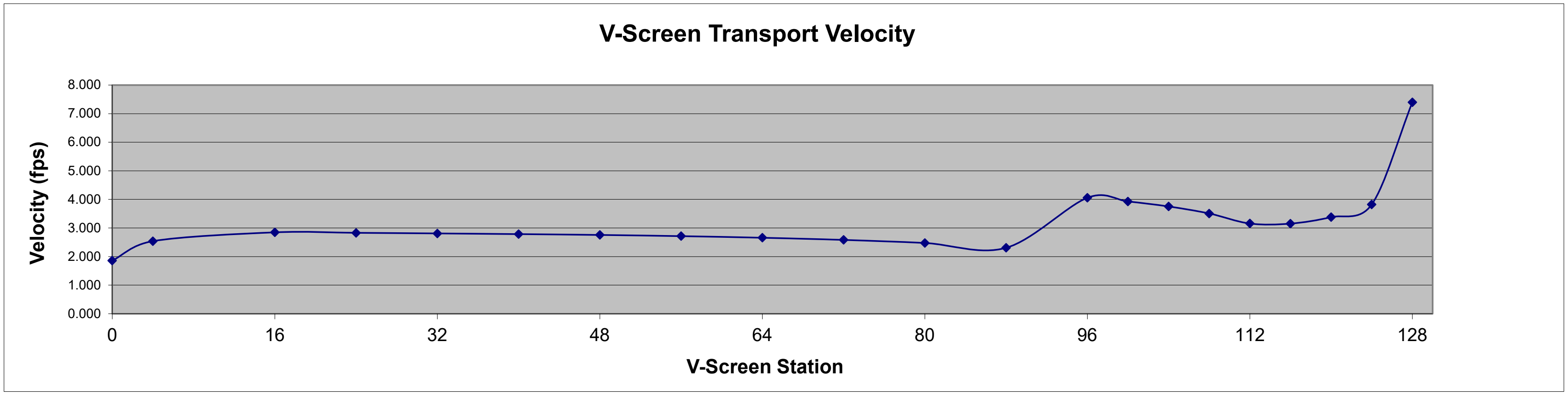
Dc = 1.69

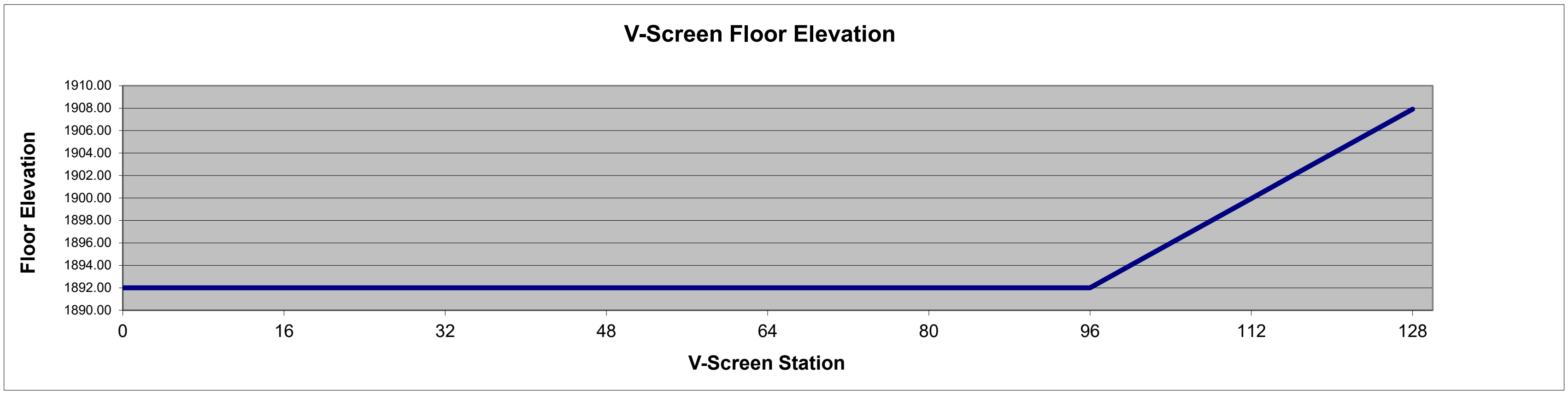
Check

H = Water Surface - Floor Elev.

H = 1.69

ZONE	STA	WATER SURFACE	HGL	FLOOR ELEV	WIDTH	FLOW AREA	Q	TRANS V	Delta Q	Screen Area	Vn	% open	Screen Depth	Wall Height	
Fish Collector Entrance	0	1909.95	1909.95	1892.00	30.00	539	1000.0	1.857	0.0	0.0				17.95	**ENTRANCE**
Fish Collector Entrance	4	1909.90	1909.90	1892.00	22.00	394	1000.0	2.539	0.0	0.0				17.90	
Fish Collector Entrance	16	1909.87	1909.87	1892.00	**19.65**	351	1000.0	**2.848**	0.0	0.0				17.87	**START OF SCREENS**
Primary Screen	24	1909.87	1909.88	1892.00	18.09	323	915.0	2.831	85.0	260.2	0.327	0.95	17.1	17.87	
Primary Screen	32	1909.88	1909.88	1892.00	16.52	295	830.0	2.810	85.0	260.4	0.326	0.95	17.1	17.88	
Primary Screen	40	1909.88	1909.88	1892.00	14.96	267	745.0	2.786	85.0	260.4	0.326	0.95	17.1	17.88	
Primary Screen	48	1909.88	1909.88	1892.00	13.39	239	660.0	2.756	85.0	260.4	0.326	0.95	17.1	17.88	
Primary Screen	56	1909.88	1909.89	1892.00	11.83	211	574.0	2.715	86.0	260.4	0.330	0.95	17.1	17.88	
Primary Screen	64	1909.89	1909.89	1892.00	10.26	184	488.0	2.658	86.0	260.5	0.330	0.95	17.1	17.89	
Primary Screen	72	1909.90	1909.90	1892.00	8.70	156	402.0	2.583	86.0	260.7	0.330	0.95	17.2	17.90	
Primary Screen	80	1909.90	1909.90	1892.00	7.13	128	316.0	2.476	86.0	260.7	0.330	0.95	17.2	17.90	
Primary Screen	88	1909.92	1909.92	1892.00	5.57	100	230.0	2.306	86.0	261.0	0.330	0.95	17.2	17.92	
Primary Screen	**96**	1909.75	1909.74	1892.00	**2.00**	**36**	**144.0**	**4.056**	**86.0**	261.4	**0.329**	**0.95**	**17.2**	**17.75**	**THROAT**
Secondary Screen	100	1909.76	1909.76	1893.99	2.00	32	123.9	3.928	20.1	60.8	0.331	0.95	8.0	15.77	
Secondary Screen	104	1909.78	1909.78	1895.98	2.00	28	103.6	3.753	20.3	60.8	0.334	0.95	8.0	13.80	
Secondary Screen	108	1909.81	1909.81	1897.97	2.00	24	83.1	3.508	20.5	60.8	0.337	0.95	8.0	11.84	
Secondary Screen	112	1909.84	1909.85	1899.96	2.00	20	62.4	3.156	20.7	60.8	0.340	0.95	8.0	9.88	
Secondary Screen	116	1909.84	1909.85	1901.94	2.00	16	49.8	3.153	12.6	36.1	0.349	0.95	4.8	7.90	
Secondary Screen	120	1909.82	1909.82	1903.93	2.00	12	39.8	3.380	10.0	28.5	0.351	0.95	3.8	5.89	
Secondary Screen	124	1909.78	1909.77	1905.92	2.00	8	29.5	3.822	10.3	28.5	0.361	0.95	3.8	3.86	
Secondary Screen	128	1909.60	1909.15	1907.91	2.00	3	25.0	7.396	4.5	15.2	0.296	0.95	2.0	1.69	WEIR


V-Screen Transport Velocity
Velocity (fps)
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
0
16
32
48
64
80
96
112
128
V-Screen Station


V-Screen Floor Elevation
Floor Elevation
1910.00
1908.00
1906.00
1904.00
1902.00
1900.00
1898.00
1896.00
1894.00
1892.00
1890.00
0
16
32
48
64
80
96
112
128
V-Screen Station

SUBJECT: Sonoma County Water Agency
Potter Valley
Scott Dam - Bypass pipe

BY: V. Autier **CHK'D BY:** J. Wiegand
DATE: 1/20/2020
PROJECT NO.: 19-103

Purpose

The purpose of this calculation sheet is to size the bypass pipe for the Scott Dam floating surface collector.

References

- *NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.*
- *Chow, V.T. Open-Channel Hydraulics. New York, McGraw-Hill. 1959.*

Criteria

Criteria	Value	Units	Comments
Pipe Size, Minimum	28-30	inch	NMFS 2011, Section 11.9.3.6 Diameter/Geometry Table 11-1
Minimum Bypass Velocity	6	feet/sec	NMFS 2011, Section 11.9.3.8
Maximum Bypass Velocity	12	feet/sec	NMFS 2011, Section 11.9.3.8
Flow	20-25	cfs	bypass flow from FSC
Depth	40	%	NMFS 2011, Section 11.9.3.9
Maximum Impact Velocity	25	feet/sec	NMFS 2011, Section 11.9.4.2
Materials	HDPE	-	All smooth interior and fittings

Calculation

Starting Elevation of Pipe =	1909.6	ft	
Ending Elevation of Pipe =	1806	ft	This is the Maximum WSEL in Scott Dam Forebay, plus 1 foot.
Design WSEL =	1805	ft	
Maximum Drop =	1	ft	

Fish Transfer Pipe:

Length of Transfer Pipe =	5300	ft	Estimated Pipe Length
Diameter of Transfer Pipe =	28.043	inches	30-inch nominal DIA of HDPE Pipe DR32.5
Pipe Slope =	0.020		Based on pipe length and starting and ending pipe elevation
Manning's n Coefficient =	0.011		Assume Smooth HDPE Pipe (Chow, 1959)
Flow Depth =	11.22	inches	40% pipe diameter = 11.22 inches

Mannings Equation

$$Q = \frac{1.4861}{n}\frac{A^{5/3}}{P^{2/3}}\sqrt{S_o}$$

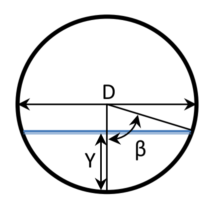
$$\beta = \cos^{-1}\left(1 - \frac{2Y}{D}\right)$$

$$A = \frac{D^2}{4}(\beta - \cos\beta\sin\beta)$$

$$P = \beta D$$

Where:

- Q = Discharge (cfs)
- n = Roughness Coefficient
- A = Cross Sectional Area of Flow (ft²)
- P = Wetted Perimeter (ft)
- S_o = Channel Slope (ft/ft)
- Y = Normal Depth (ft)
- D = Pipe Diameter (ft)
- β = Angle between the vertical and radial line (radians)



D =	2.34	ft		
Y =	0.94	ft		
β =	1.37	radians	78.5	degrees
A =	1.60	ft²		
P =	3.20	ft		
S_o =	0.0195			
n =	0.0110			

Bypass Pipe Flow Rate, Q =	19.09	cfs		
Transfer Pipe Velocity, V =	11.91	ft/s	OK	6 ft/s < V < 12 ft/s

The Kinematic Equation for final velocity

$$V_f^2 = V_i^2 + 2ad$$

$$V^2 = V_x^2 + V_y^2$$

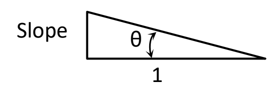
Where:

- V_f = Final Velocity (ft/s)
- V_i = Initial Velocity (ft/s)
- a = Acceleration, gravitational acceleration (ft/s²)
- d = Displacement of the object (ft)
- V = Total Velocity (ft/s)
- V_x = Horizontal Component of Velocity (ft/s)
- V_y = Vertical Component of Velocity (ft/s)

Determine Jet Impact Velocity:

Initial Horizontal and Vertical Velocity Components

Slope Angle, θ =	0.02	radians	1.1	degrees
Horizontal Velocity Component, V_x =	11.91	ft/s	Based on the cosine of the angle	
Vertical Velocity Component, V_y =	0.23	ft/s	Based on the sine of the angle	



Final Vertical Velocity Component

gravitational acceleration, g =	32.2	ft/s²	
Final Vertical Velocity, V_{fy} =	8.03	ft/s	Based on the fall height of 1 ft

Jet Impact Velocity, V_j =	14.4	ft/s	OK	< 25 ft/s

Table Showing Jet Impact Velocities vs. Forebay Elevation

Tailwater Elevation (ft)	Drop Height (ft)	Final Vertical Velocity (ft/s)	Jet Impact Velocity (ft/s)
1805.0	1.0	8.0	14.4
1801.0	5.0	17.9	21.5

Conclusion

- The slope will be 2%
- The transfer pipe velocity would be 11.91 ft/s
- The transfer pipe flow is 19.09 cfs.
- The pipe length would be 5300 ft

SUBJECT: Sonoma County Water Agency
Potter Valley
Scott Dam Penetration

BY: J. Wiegand **CHK'D BY:** V. Autier
DATE: 1/30/2020
PROJECT NO.: 19-103

Purpose

The purpose of this calculation sheet is to evaluate the potential size of a penetration for a transport channel through Scott Dam.

References

• *NMFS (National Marine Fisheries Service). 2011. Anadromous Salmonid Passage Facility Design. NMFS, Northwest Region, Portland, Oregon.*

Criteria

Criteria in the Transport Channel	Value	Units	Comments
Velocity range	1.5 - 4	fps	NMFS 4.4.2.1
Note: 2.5 ft/s selected as maximum transport velocity for steelhead prolonged speed			
Depth	5	ft	NMFS 4.4.2.2
Width	2-4	ft	NMFS 4.4.2.2
Lighting	N/A	N/A	Ambient natural light preferred or acceptable artificial lighting

Calculations

The following calculations are to determine:
1. Velocity in circular transport channel
2. Velocity in rectangular transport channel
3. Headloss in circular transport channel
4. Headloss in rectangular transport channel

1. Velocity in circular transport channel

Length of Transport Channel =	46	ft	Estimated Pipe Length
Diameter of Transport Channel =	48	inches	Per Mead & Hunt
Transport Channel Slope =	0.002		Based on pipe length and starting and ending pipe elevation
Manning's n Coefficient =	0.012		Assume HDPE Pipe
Flow Depth =	15.71	inches	Mead & Hunt assumed a flow depth of 1 foot. Note that 1 foot of water depth does not seem to pass the ladder flow.

Mannings Equation

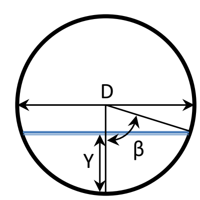
$$Q = \frac{1.4861}{n}\frac{A^{5/3}}{P^{2/3}}\sqrt{S_o}$$

$$\beta = \cos^{-1}\left(1 - \frac{2Y}{D}\right)$$

$$A = \frac{D^2}{4}(\beta - \cos\beta\sin\beta)$$

$$P = \beta D$$

Where:
Q = Discharge (cfs)
n = Roughness Coefficient
A = Cross Sectional Area of Flow (ft²)
P = Wetted Perimeter (ft)
S_o = Channel Slope (ft/ft)
Y = Water Depth (ft)
D = Pipe Diameter (ft)
β = Angle between the vertical and radial line (radians)



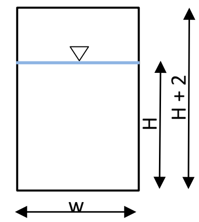
D =	4.00	ft		
Y =	1.31	ft		
β =	1.22	radians	69.8	degrees
A =	3.58	ft²		
P =	4.87	ft		
S_o =	0.0022			
n =	0.0120			

Transport Channel Flow Rate, Q =	16.80	cfs	16.8 < Q < 20.3	
Transport Channel Velocity, V =	4.70	ft/s	NO!	1.5 ft/s < V < 2.5 ft/s

The transport channel velocity is greater than the maximum transport velocity authorized by NMFS.
The Mead & Hunt circular transport channel would act as a fish barrier.

2. Velocity in rectangular transport channel

Length of Transport Channel =	46	ft	Estimated Pipe Length
Width of Transport Channel, w =	30	inches	Assumed (less than NMFS recommended width)
Transport Channel Slope =	0.0002		Assumed
Manning's n Coefficient =	0.012		Assume HDPE Pipe
Flow Depth, H =	60	inches	Assumed (meets NMFS recommendation)



Mannings Equation

$$Q = \frac{1.4861}{n}\frac{A^{5/3}}{P^{2/3}}\sqrt{S_o}$$

$$A = H * w$$

$$P = 2H + w$$

Where:

- Q = Discharge (cfs)
- n = Roughness Coefficient
- A = Cross Sectional Area of Flow (ft²)
- P = Wetted Perimeter (ft)
- S_o = Channel Slope (ft/ft)
- H = Water Depth (ft)
- w = Channel width (ft)

w =	2.50	ft
H =	5.00	ft
A =	12.50	ft²
P =	12.50	ft
S_o =	0.0002	
n =	0.0120	

Transport Channel Flow Rate, Q =	22.82	cfs	16.8 < Q < 24.8
Transport Channel Flow Rate, Q =	10,244	gpm	
Transport Channel Velocity, V =	1.83	ft/s	OK 1.5 ft/s < V < 2.5 ft/s

3. Headloss in circular Transport Channel

$$h_f = \frac{Ln^2v^2}{2.208R^{4/3}}$$

$$R = A/P$$

Where:

- hf = friction losses (ft)
- L = length of channel (ft)
- n = Roughness Coefficient
- v = transport channel velocity (fps)
- R = hydraulic radius (ft)
- A = Cross Sectional Area of Flow (ft²)
- P = Wetted Perimeter (ft)

L =	46	ft
n =	0.012	
v =	4.70	ft/s
R =	0.73	ft

Friction Losses in Transport Channel, h_f =	0.10	ft

4. Headloss in rectangular Transport Channel

$$h_f = \frac{Ln^2v^2}{2.208R^{4/3}}$$

$$R = A/P$$

Where:

hf =	friction losses (ft)
L =	length of channel (ft)
n =	Roughness Coefficient
v =	transport channel velocity (fps)
R =	hydraulic radius (ft)
A =	Cross Sectional Area of Flow (ft^2)
P =	Wetted Perimeter (ft)

L =	46	ft
n =	0.012	
v =	1.83	ft/s
R =	1.00	ft

Friction Losses in Transport Channel, h_f =	0.01	ft

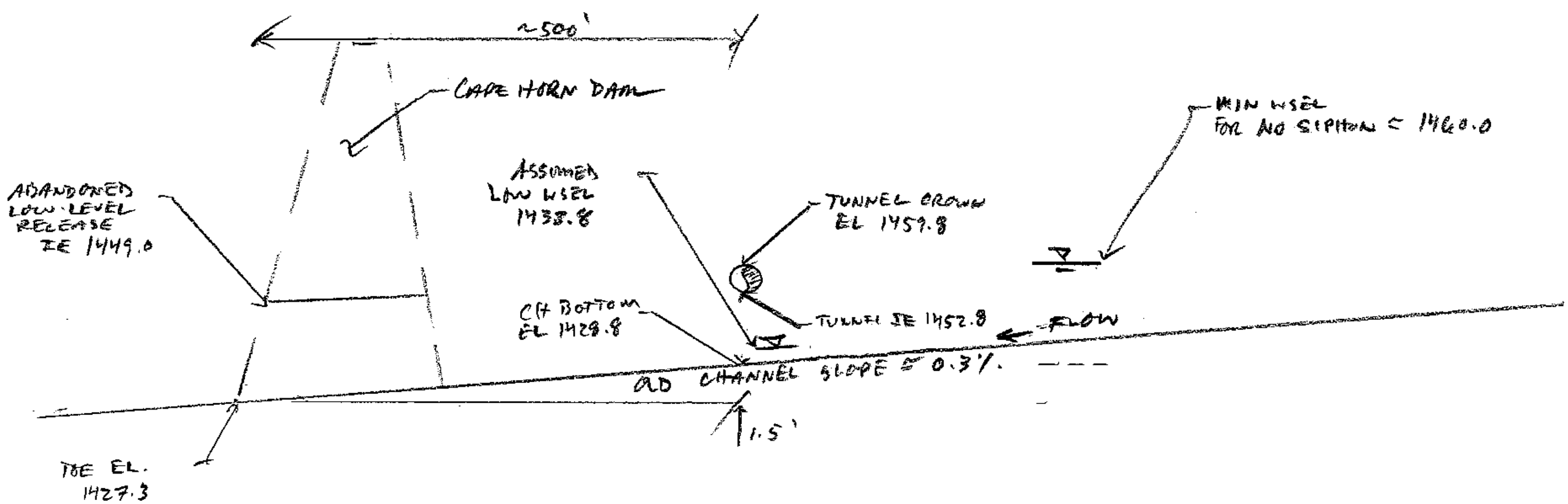
Conclusion

The Mead & Hunt circular transport channel does not meet velocity criteria and has 0.1 ft of frictional head loss over the length of the transport channel.
The rectangular transport channel does meet velocity criteria and has 0.01 ft of frictional head loss over the length of the transport channel.

PROJECT: POTTER VALLEY PROJECT FEASIBILITY STUDY | SHEET: 1 OF 1

SUBJECT: RANNEY WELL FIELD, LOCATION UPSTREAM | DATE: 2/12/20

BY: KRJ | CHECKED: | PROJECT NO.:



MIN. DIST. UPSTREAM TO RANNEY WELL FIELD = $L_1 = \frac{\Delta H_1}{S_1} = \left(\frac{1460.0 - 1433.8}{0.003}\right) = 8733$ ft

+0

$L_2 = \frac{\Delta H_2}{S_2} = \frac{(1460.0 - 1455.5)}{0.003} = 1500$ ft

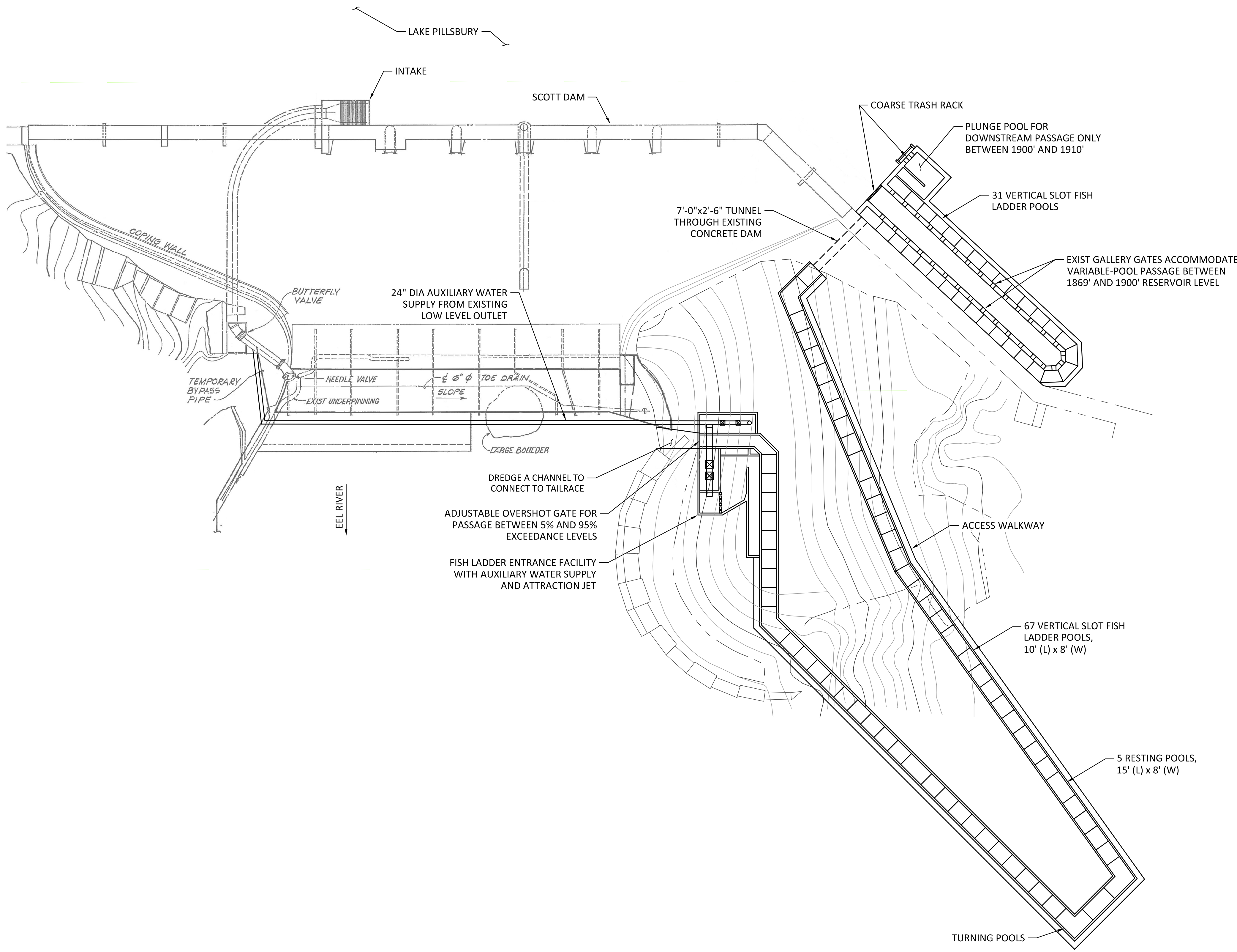
Power Model Macro

```
Sub macro1()

' Macro1 Macro
'
Dim sht1, sht2, sht3, sht4, sht5, sht6, sht7, sht8 As String
Dim Qeela(366), Qtuna(366), P(366), Qpa(366), Qia(366) As Single


sht1 = "Input": sht2 = "Storage":
sht3 = "Inflow": sht4 = "hf"
sht6 = "Output"

'input of constants and initial forebay water levels
HW = Worksheets(sht1).Cells(4, 2): 'initial water surface Cape Horn
TW = Worksheets(sht1).Cells(14, 5): 'Fixed Tailwater level at Potter Valley PH

Qtunmax = Worksheets(sht1).Cells(4, 4): 'Maximum Tunnel Discharge
Qumax = Worksheets(sht1).Cells(14, 2): ' max unit 3 flow
Qumin = Worksheets(sht1).Cells(14, 1): 'Min small turbine flow

c1 = Worksheets(sht2).Cells(4, 2): ' ac-ft to dsf

C2 = Worksheets(sht4).Cells(2, 13): 'x^2 coeff for Tunnel 1&2
c3 = Worksheets(sht4).Cells(2, 14): 'x coeff for Tunnel 1&2
C4 = Worksheets(sht4).Cells(22, 13): 'x^2 coeff for penstk
c5 = Worksheets(sht4).Cells(22, 14): 'x coeff for penstock
gam = Worksheets("hf-Tunnel1").Cells(5, 2)
nt = Worksheets(sht1).Cells(14, 3)
ng = Worksheets(sht1).Cells(14, 4)


Sheets(sht6).Select
  Range("C5:H400").Select
  Selection.ClearContents
 Sheets(sht1).Select

' build input inflow from inflow table
If Worksheets(sht1).Cells(9, 1) = "dry" Then
colinflow = 15
ElseIf Worksheets(sht1).Cells(9, 1) = "1979" Then
colinflow = 149
ElseIf Worksheets(sht1).Cells(9, 1) = "1973" Then
```

```
colinflow = 159
ElseIf Worksheets(sht1).Cells(9, 1) = "wet" Then
colinflow = 14
Else
colinflow = 13

End If
inflowadj = Worksheets(sht1).Cells(9, 3)
For rowin = 1 To 365
Worksheets(sht3).Cells(rowin + 6, 2) = Worksheets(sht3).Cells(rowin + 6, colinflow) * inflowadj
Next rowin

ito = 6: 'Inflow table row offset

Application.Calculation = xlManual
'
'Main loop
 For xday = 1 To 365

  Qi = Worksheets(sht3).Cells(xday + ito, 2)
  Qlocal = Worksheets(sht3).Cells(xday + ito, 3)
  Qeelmin = Worksheets(sht3).Cells(xday + ito, 4)

 ' determine Tunnel Discharge based on Cape Horn elevation

  Qtun = Qi + Qlocal - Qeelmin: 'Tunnel inflow estimate cfs

    If Qtun > Qtunmax Then
     Qtun = Qtunmax

    ElseIf Qtun < 0 Then
     Qtun = 0

    Else
    End If

     If Qtun < Qumin Then
      Qu = 0
      N = 0
      Qtun = 0
      ElseIf Qtun >= Qumin And Qtun <= Qumax Then
       Qu = Qtun
       N = 1
       ElseIf Qtun >= Qumax And Qtun <= 2 * Qumax Then
```

```
        Qu = Qtun / 2
        N = 2
      ElseIf Qtun > 2 * Qumax Then
        Qu = Qumax
        N = 2
        Qtun = N * Qu
     Else: End If

  Qeel = Qi + Qlocal - N * Qu

  Hfp = C4 * (Qu) ^ 2 + c5 * Qu
  Hft = C2 * (Qtun) ^ 2 + c3 * Qtun
  Hn = HW - TW - Hfp - Hft

  P(xday) = N * gam * Qu * Hn * nt * ng * 0.7457 / 550 / 1000
  Qia(xday) = Qi
  Qeela(xday) = Qeel
  Qtuna(xday) = Qtun
  Qpa(xday) = Qu * N

Next xday


For pday = 1 To 365
Worksheets(sht6).Cells(pday + 4, 3) = Qia(pday)
Worksheets(sht6).Cells(pday + 4, 4) = Qeela(pday)
Worksheets(sht6).Cells(pday + 4, 5) = Qtuna(pday)
Worksheets(sht6).Cells(pday + 4, 6) = Qpa(pday)
Worksheets(sht6).Cells(pday + 4, 7) = P(pday)

Next pday

Application.Calculation = xlAutomatic


End Sub
```

APPENDIX 2
Conceptual Drawings of Infrastructure Modification Options



PLAN

SCALE: NTS

REV	DATE	BY	DESCRIPTION
B	02/28/20	KJ	CONCEPTUAL DESIGN
A	07/24/19	KJ	CONCEPTUAL DESIGN

PRELIMINARY
NOT FOR CONSTRUCTION

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

Sonoma Water

SONOMA COUNTY WATER AGENCY
POTTER VALLEY PROJECT

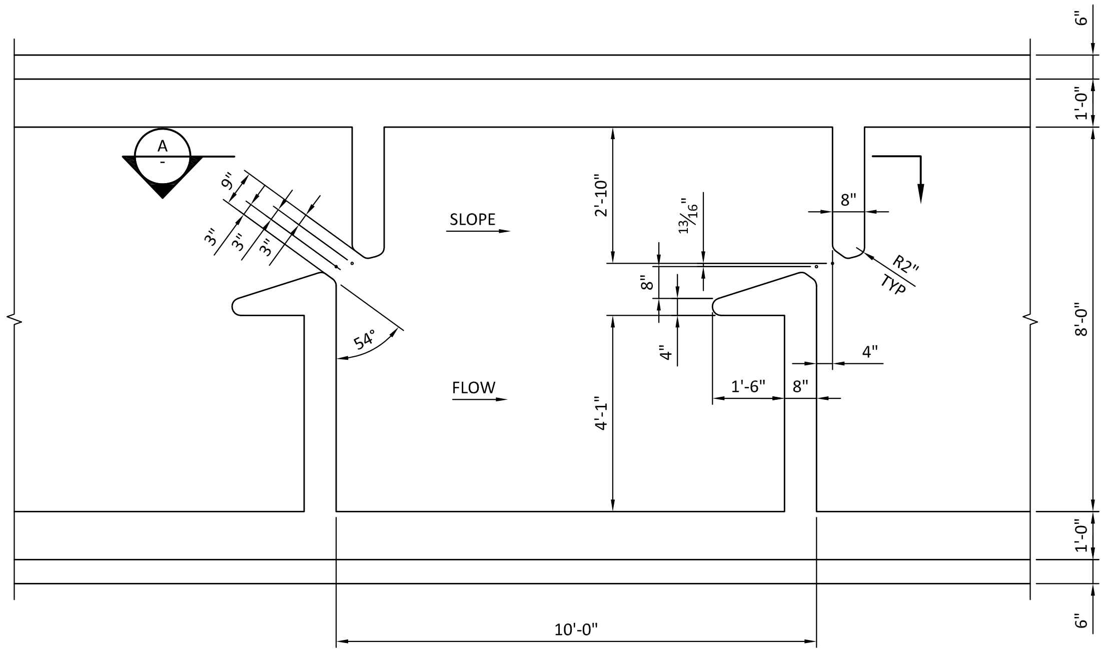
SCOTT DAM UPSTREAM FISH PASSAGE
PLAN

DESIGNED V. AUTIER
DRAWN J. LAHMON
CHECKED
PROJECT DATE 02/28/20

DRAWING
A4-1-C100

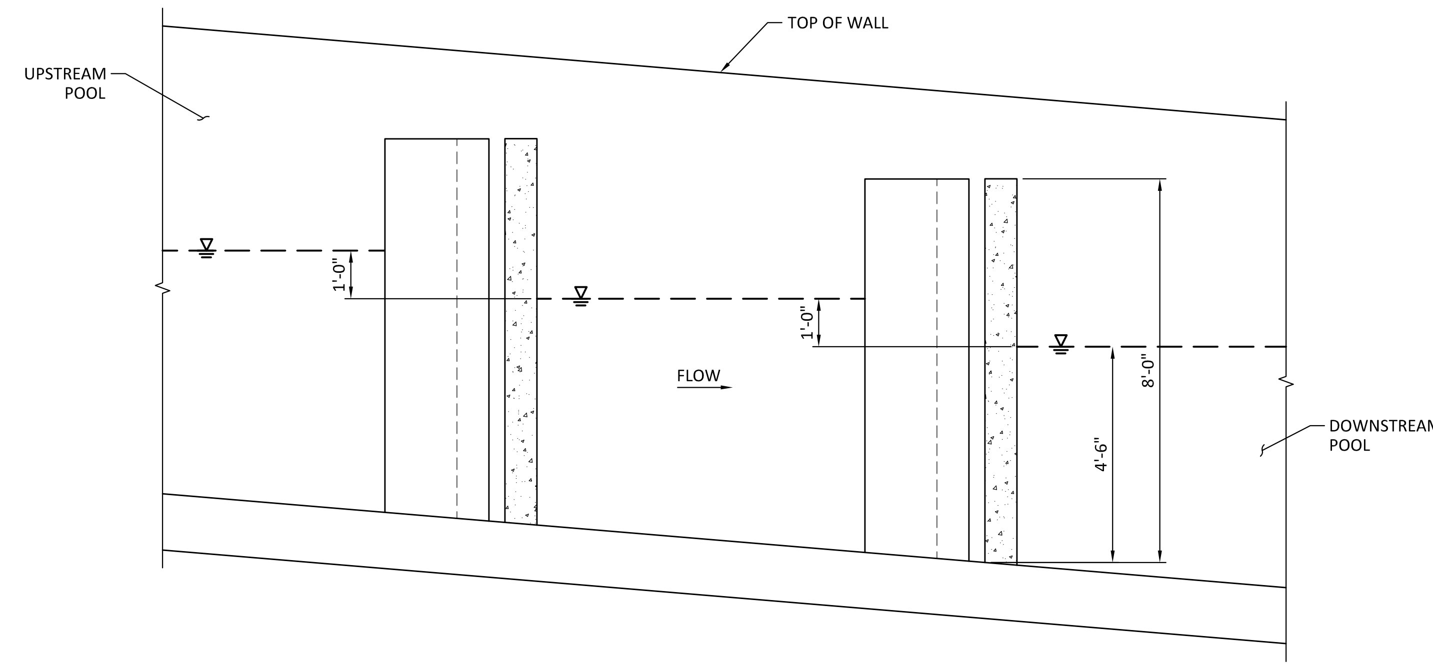
JOB NO: 000000

Path: C:\Users\Djohnston\Box\Projects\Sonoma County Water Agency (SCWA)\PVP Supplemental Analysis\6.0 Plans and Specs\6.3 CAD\A4-1-C100.dwg Plot date: Feb 28, 2020 01:22pm, CAD User: Djohnston



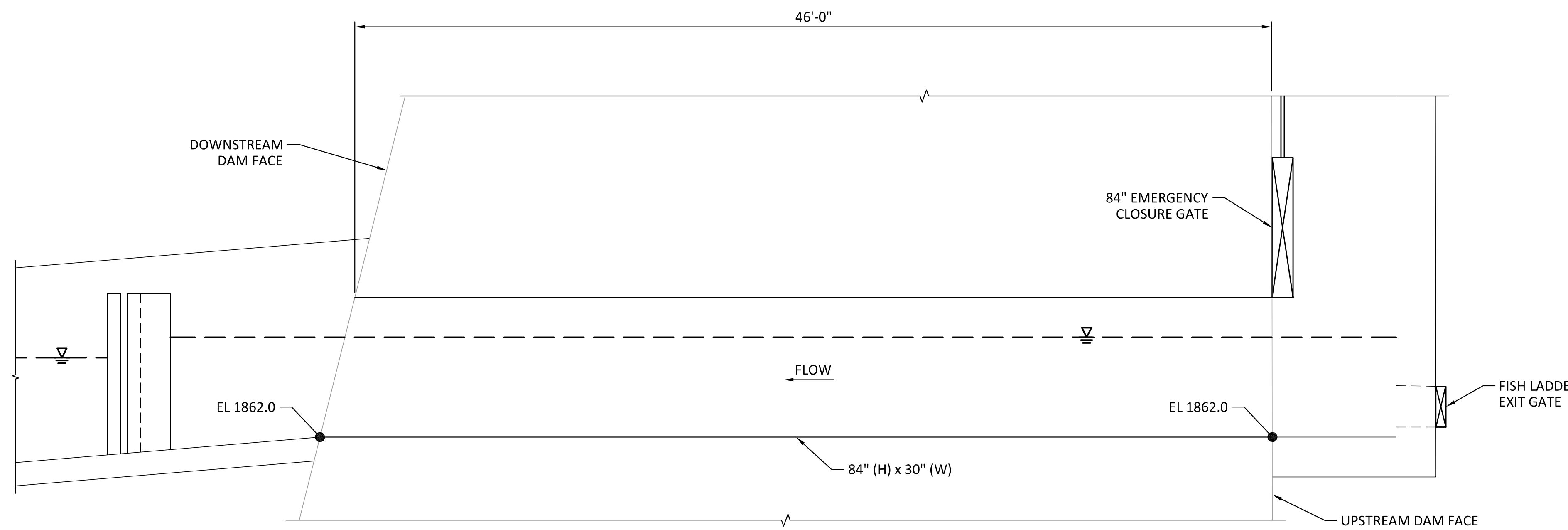
PLAN

SCALE: 1/2"= 1'-0"



SECTION

SCALE: 1/2"= 1'-0"



TUNNEL PROFILE

SCALE: 1/4"= 1'-0"

REV	DATE	BY	DESCRIPTION
B	02/28/20	KJ	CONCEPTUAL DESIGN
A	07/24/19	KJ	CONCEPTUAL DESIGN

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SONOMA COUNTY WATER AGENCY

POTTER VALLEY PROJECT

SCOTT DAM UPSTREAM FISH PASSAGE
PLAN AND SECTIONS

DESIGNED V. AUTIER

DRAWN J. LAHMON

CHECKED

PROJECT DATE 02/28/20

DRAWING

A4-1-C101

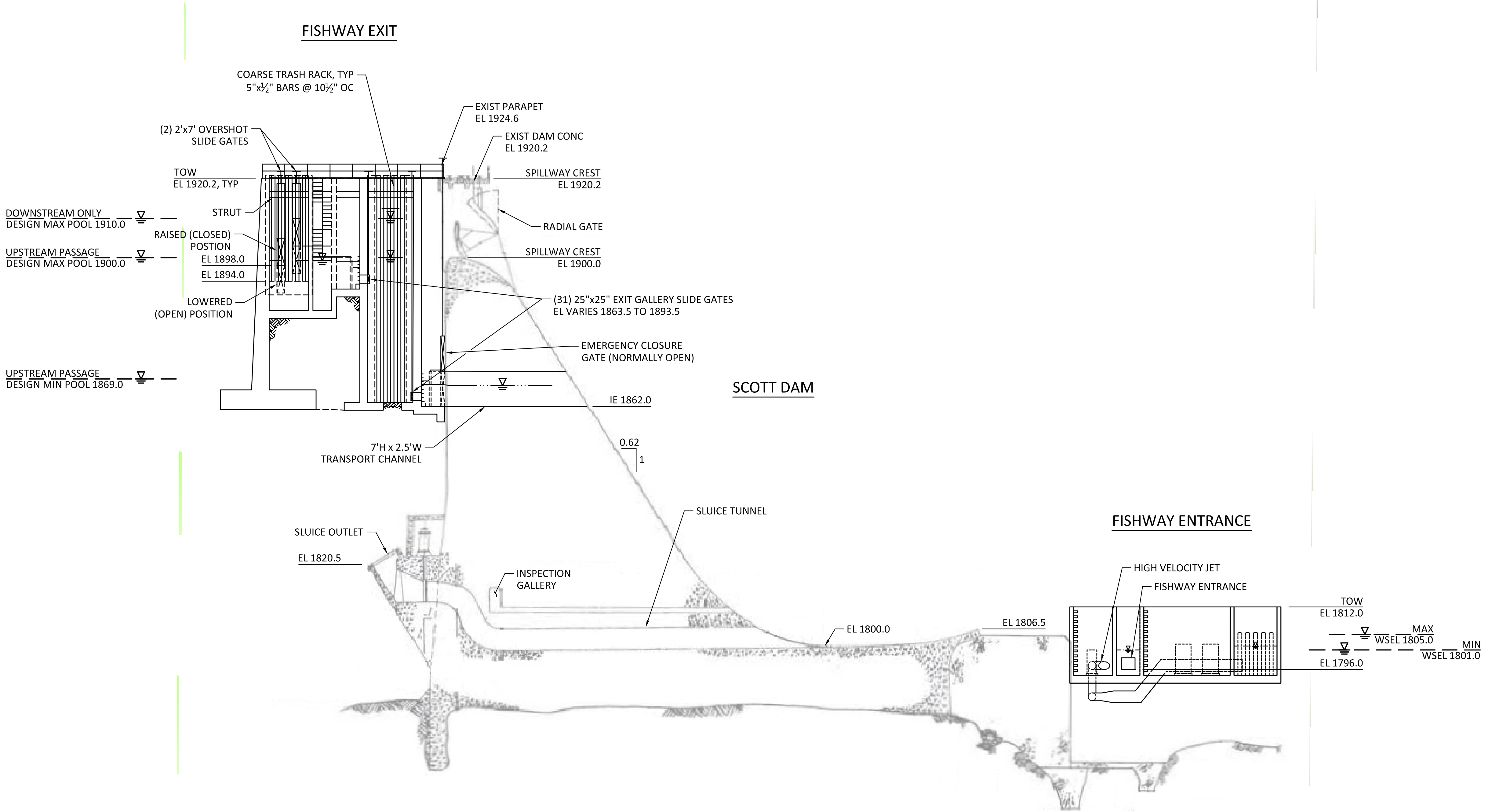
JOB NO: 000000

SHEET NOTES:

1. FISH LADDER IN NOT SHOWN ON THE HYDRAULIC PROFILE.

DESIGN CRITERIA:

HYDRAULIC HEAD PER POOL:	12 INCHES
FLOW:	20.3 CFS
ENERGY DISSIPATION FACTOR:	<4 FT-LB/SEC
AWS:	22.4 CFS
HIGH VELOCITY ATTRACTION FLOW JET:	10 CFS
TURNING POOLS TO BE TWICE THE LENGTH OF STANDARD POOLS	
MINIMUM FREEBOARD:	3 FT
VERTICAL RADIUS WHERE THERE IS CHANGE IN FLOW DIRECTION:	2 FT
DESIGN LOW FLOW:	21 CFS
DESIGN HIGH FLOW:	4,514 CFS
FISHWAY ENTRANCE HYDRAULIC DROP:	0.5 - 2.0 FT
TRANSPORT VELOCITY:	1.5 - 4 FPS



HYDRAULIC PROFILE

SCALE: NTS

Path: C:\Users\Djohnston\Box\Projects\Sonoma County Water Agency (SCWA)\PVP Supplemental Analysis\6.0 Plans and Specs\6.3 CAD\A4-1-G100.dwg Plot date: Feb 28, 2020 01:20pm, CAD User: Djohnston

REV	DATE	BY	DESCRIPTION
B	02/28/20	KJ	CONCEPTUAL DESIGN
A	07/24/19	KJ	CONCEPTUAL DESIGN

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SONOMA COUNTY WATER AGENCY

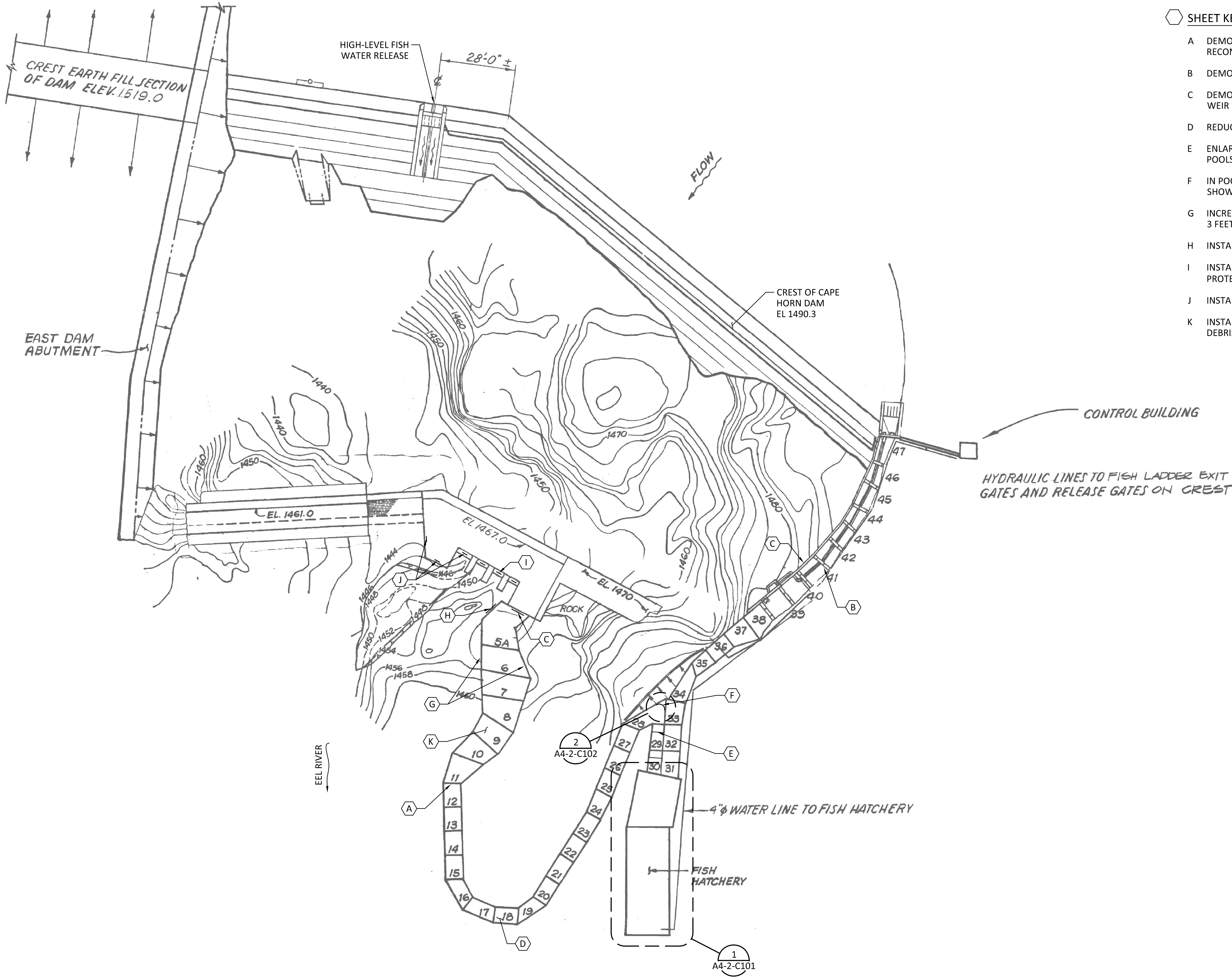
POTTER VALLEY PROJECT

SCOTT DAM UPSTREAM FISH PASSAGE
HYDRAULIC PROFILE AND DESIGN CRITERIA

DESIGNED V. AUTIER
DRAWN J. LAHMON
CHECKED
PROJECT DATE 02/28/20

DRAWING
A4-1-G100

JOB NO: 000000



PLAN

SCALE: NTS

SHEET KEY NOTES:

A DEMOLISH EACH FISH LADDER WEIRS FROM POOL 5 TO POOL 38 AND RECONSTRUCT NEW CONCRETE WEIRS INCLUDING LAMPREY ORIFICES.

B DEMOLISH EACH ORIFICE WALL FROM POOL 38 TO THE EXIT POOL 47.

C DEMOLISH LAMPREY SYSTEM; REPLACE WITH LAMPREY ORIFICES, 2 PER WEIR WALL.

D REDUCE LADDER FLOW TO MEET ENERGY DISSIPATION FACTOR.

E ENLARGE POOL 28 BY MOVING UPSTREAM THE WEIR WALLS BETWEEN POOLS 28, 29 AND 30.

F IN POOL 28, INSTALL A 2 FOOT VERTICAL RADIUS CURVATURE WHERE SHOWN.

G INCREASE EXTERIOR WALL HEIGHT TO HAVE A MINIMUM FREEBOARD OF 3 FEET BETWEEN POOLS 5 AND 15.

H INSTALL A MANUAL SLUICE WAYGATE.

I INSTALL THE MEAD & HUNT FISH HOTEL SEDIMENT AND DEBRIS PROTECTION SYSTEM (SEE APPENDIX).

J INSTALL LEVEL SENSORS AND AUTOMATED GATE POSITION CONTROLS.

K INSTALL REMOVABLE GRATING OVER POOLS 5 THRU 20 TO MINIMIZE DEBRIS INTRUSION INTO THE FISH LADDER DURING FLOOD EVENTS.

Path: C:\Users\Djohnston\Box\Projects\Sonoma County Water Agency (SCWA)\PVP Supplemental Analysis\6.0 Plans and Specs\6.3 CAD\A4-2-C100.dwg Plot date: Feb 28, 2020 08:15am, CAD User: Djohnston

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A	07/24/19	KJ	CONCEPTUAL DESIGN

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WARNING
0 1/2 1
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SONOMA COUNTY WATER AGENCY

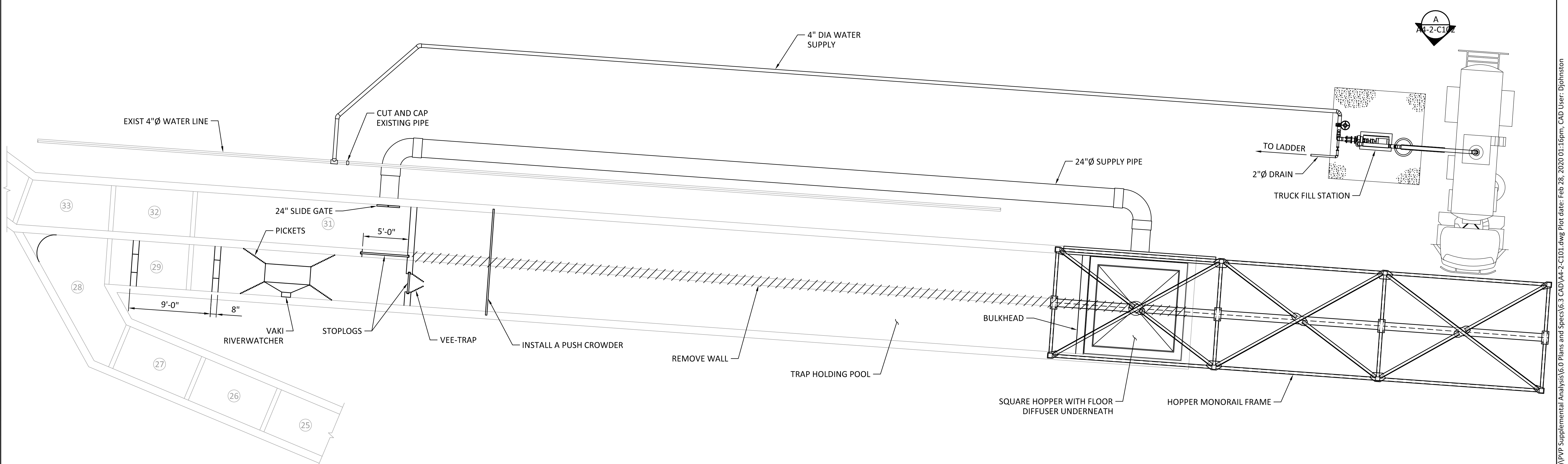
POTTER VALLEY PROJECT

CAPE HORN UPSTREAM FISH PASSAGE FACILITY
PLAN

DESIGNED V. AUTIER
DRAWN J. LAHMON
CHECKED
PROJECT DATE 02/28/20

DRAWING A4-2-C100

JOB NO: 000000



ENLARGED PLAN 1/C100

SCALE: NTS

Path: C:\Users\Djohnston\Box\Projects\Sonoma County Water Agency (SCWA)\PVP Supplemental Analysis\6.0 Plans and Specs\6.3 CAD\A4-2-C101.dwg Plot date: Feb 28, 2020 01:16pm, CAD User: Djohnston

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A	07/24/19	KJ	CONCEPTUAL DESIGN

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WARNING
0 1/2 1
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McMILLEN JACOBS ASSOCIATES

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SONOMA COUNTY WATER AGENCY
POTTER VALLEY PROJECT
CAPE HORN UPSTREAM FISH PASSAGE FACILITY
ENLARGED PLAN

DESIGNED V. AUTIER
DRAWN J. LAHMON
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PROJECT DATE 02/28/20

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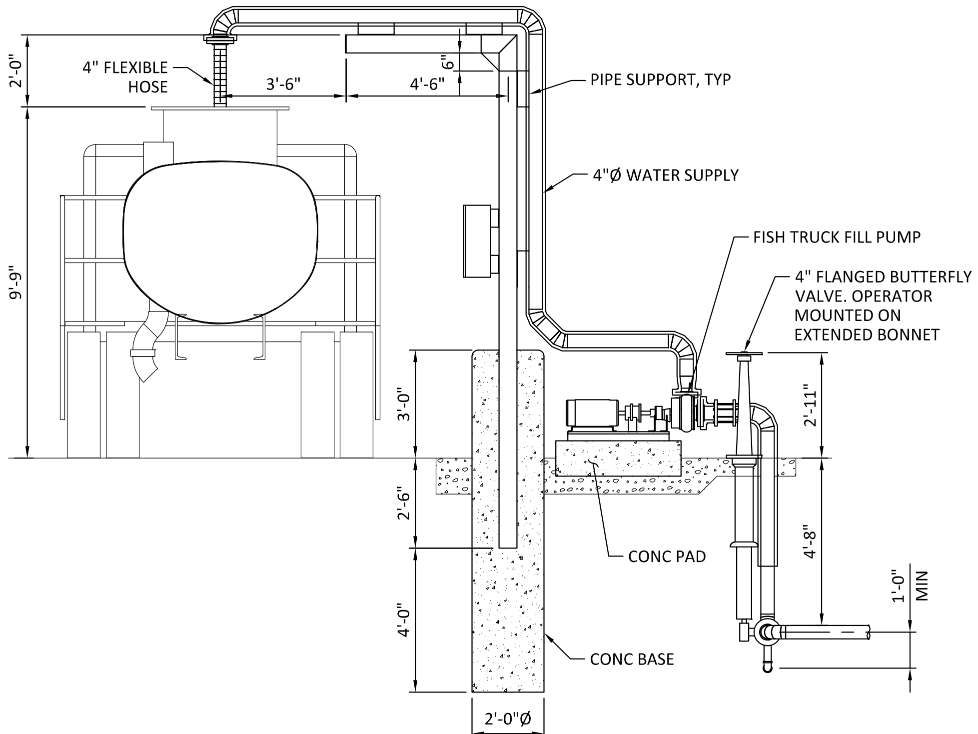
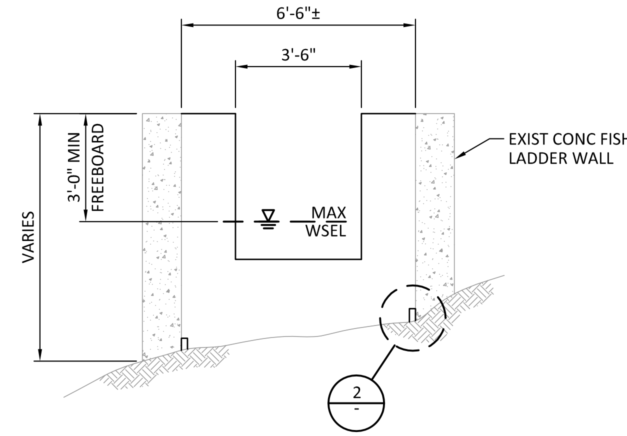
A4-2-C101

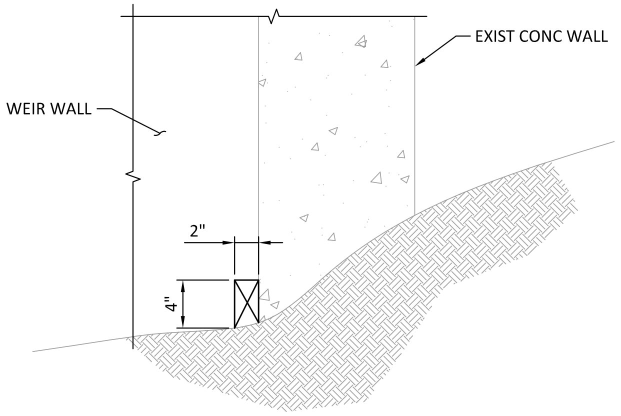
JOB NO: 000000



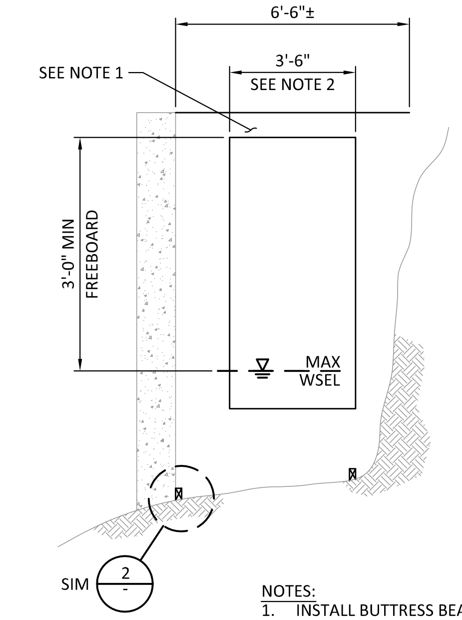
TRUCK FILL STATION VIEW
SCALE: NTS
A
A4-2-C101



TYPICAL FISH LADDER POOL DETAIL
SCALE: 3/8"= 1'-0"
1
-

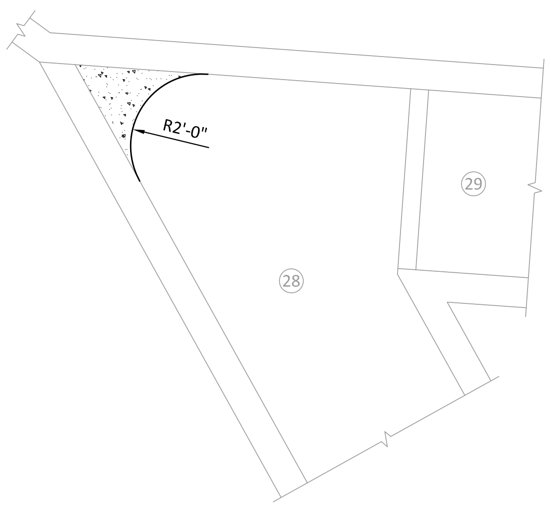


DETAIL
SCALE: 1 1/2"= 1'-0"
2
-

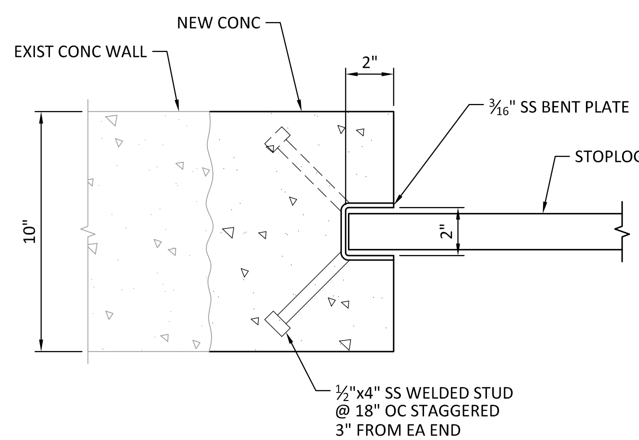


NOTES:
1. INSTALL BUTTRESS BEAM AS REQD PER STRUCTURAL NEED.
2. THIS ASSUMES THAT PVP TUNNEL BYPASS IS NOT DISCHARGED INTO FISH LADDER.

TYP SECTION THRU FISH LADDER POOLS 28 THRU EXIT POOL 47 DETAIL
SCALE: 3/8"= 1'-0"
3
-



DETAIL
SCALE: 3/8"= 1'-0"
4
C100



DETAIL
SCALE: 3/8"= 1'-0"
5
C101

REV	DATE	BY	DESCRIPTION
B	02/28/20	KJ	CONCEPTUAL DESIGN
A	07/24/19	KJ	CONCEPTUAL DESIGN

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Sonoma Water

SONOMA COUNTY WATER AGENCY
POTTER VALLEY PROJECT
CAPE HORN UPSTREAM FISH PASSAGE FACILITY
SECTIONS AND DETAILS

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DRAWN J. LAHMON
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PROJECT DATE 02/28/20

DRAWING
A4-2-C102

JOB NO: 000000

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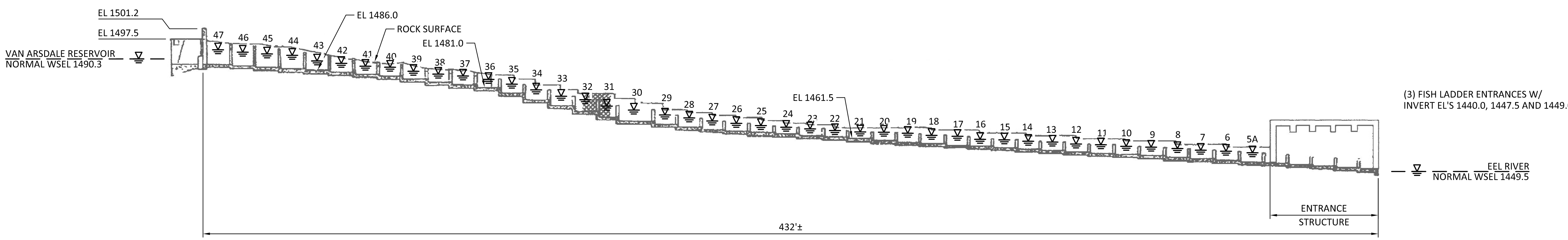


PROFILE OF FISH LADDER

SCALE: NTS

DESIGN CRITERIA:

HYDRAULIC HEAD PER POOL:	12 INCHES
FLOW:	11.7 CFS
ENERGY DISSIPATION FACTOR:	<4 FT-LB/SEC
AWS:	88 CFS
TURNING POOLS TO BE TWICE THE LENGTH OF STANDARD POOLS	
MINIMUM FREEBOARD:	3 FT
VERTICAL RADIUS WHERE THERE IS CHANGE IN FLOW DIRECTION:	2 FT
DESIGN LOW FLOW:	26 - 53 CFS
DESIGN HIGH FLOW:	1,695 - 4,514 CFS
FISHWAY ENTRANCE HYDRAULIC DROP:	0.5 - 2.0 FT
TRANSPORT VELOCITY:	1.5 - 4 FPS
NORMAL TAILWATER SURFACE ELEVATION:	1449.5
NORMAL FOREBAY WATER SURFACE ELEVATION:	1490.3

REV	DATE	BY	DESCRIPTION
B	02/28/20	KJ	CONCEPTUAL DESIGN
A	07/24/19	KJ	CONCEPTUAL DESIGN

PRELIMINARY
NOT FOR CONSTRUCTION

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

Sonoma Water

SONOMA COUNTY WATER AGENCY

POTTER VALLEY PROJECT

CAPE HORN UPSTREAM FISH PASSAGE FACILITY
HYDRAULIC PROFILE AND DESIGN CRITERIA

DESIGNED V. AUTIER
DRAWN J. LAHMON
CHECKED
PROJECT DATE 02/28/20

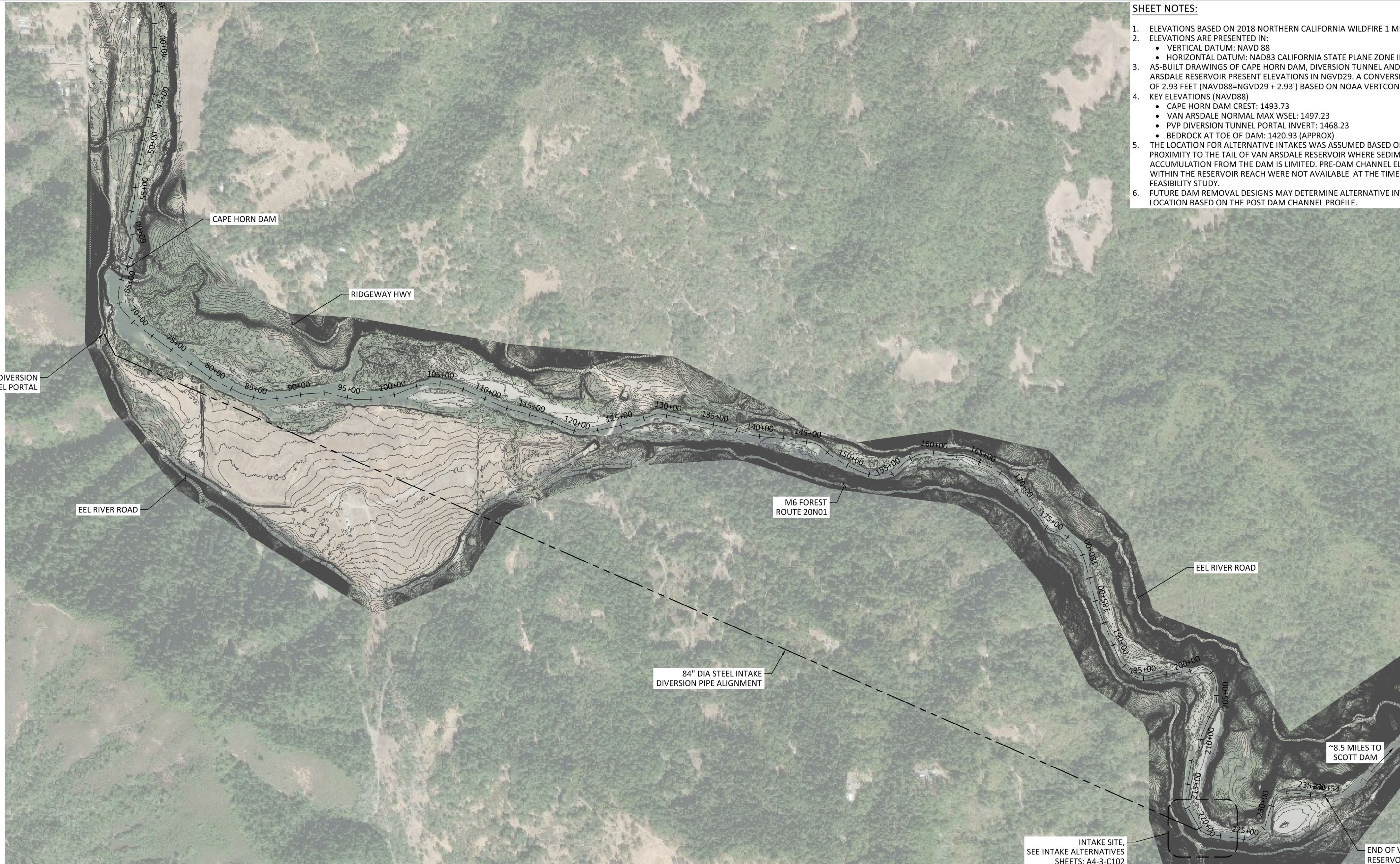
DRAWING
A4-2-G100

JOB NO: 000000

Path: C:\Users\Djohnston\Box\Projects\Sonoma County Water Agency (SCWA)\PVP Supplemental Analysis\6.0 Plans and Specs\6.3 CAD\A4-2-G100.dwg Plot date: Feb 28, 2020 08:16am, CAD User: Djohnston

SHEET NOTES:

1. ELEVATIONS BASED ON 2018 NORTHERN CALIFORNIA WILDFIRE 1 METER LIDAR.
2. ELEVATIONS ARE PRESENTED IN:
   - VERTICAL DATUM: NAVD 88
   - HORIZONTAL DATUM: NAD83 CALIFORNIA STATE PLANE ZONE II
3. AS-BUILT DRAWINGS OF CAPE HORN DAM, DIVERSION TUNNEL AND VAN ARSDALE RESERVOIR PRESENT ELEVATIONS IN NGVD29. A CONVERSION FACTOR OF 2.93 FEET (NAVD88=NGVD29 + 2.93') BASED ON NOAA VERTCON SOFTWARE.
4. KEY ELEVATIONS (NAVD88)
   - CAPE HORN DAM CREST: 1493.73
   - VAN ARSDALE NORMAL MAX WSEL: 1497.23
   - PVP DIVERSION TUNNEL PORTAL INVERT: 1468.23
   - BEDROCK AT TOE OF DAM: 1420.93 (APPROX)
5. THE LOCATION FOR ALTERNATIVE INTAKES WAS ASSUMED BASED ON PROXIMITY TO THE TAIL OF VAN ARSDALE RESERVOIR WHERE SEDIMENT ACCUMULATION FROM THE DAM IS LIMITED. PRE-DAM CHANNEL ELEVATIONS WITHIN THE RESERVOIR REACH WERE NOT AVAILABLE AT THE TIME OF THIS FEASIBILITY STUDY.
6. FUTURE DAM REMOVAL DESIGNS MAY DETERMINE ALTERNATIVE INTAKE LOCATION BASED ON THE POST DAM CHANNEL PROFILE.



EEL RIVER ALTERNATIVE DIVERSION INTAKE PLAN

SCALE: 1"= 500'

0' 500' 1000'

REV	DATE	BY	DESCRIPTION
B	02/28/20	KJ	CONCEPTUAL DESIGN
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PRELIMINARY
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WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

Sonoma Water

SONOMA COUNTY WATER AGENCY

POTTER VALLEY PROJECT

INTAKE ALTERNATIVES
DIVERSION PIPELINE ALIGNMENT PLAN

DESIGNED J. WOODBURY

DRAWN J. WOODBURY

CHECKED

PROJECT DATE 02/28/20

DRAWING

A4-3-C100

JOB NO: 000000

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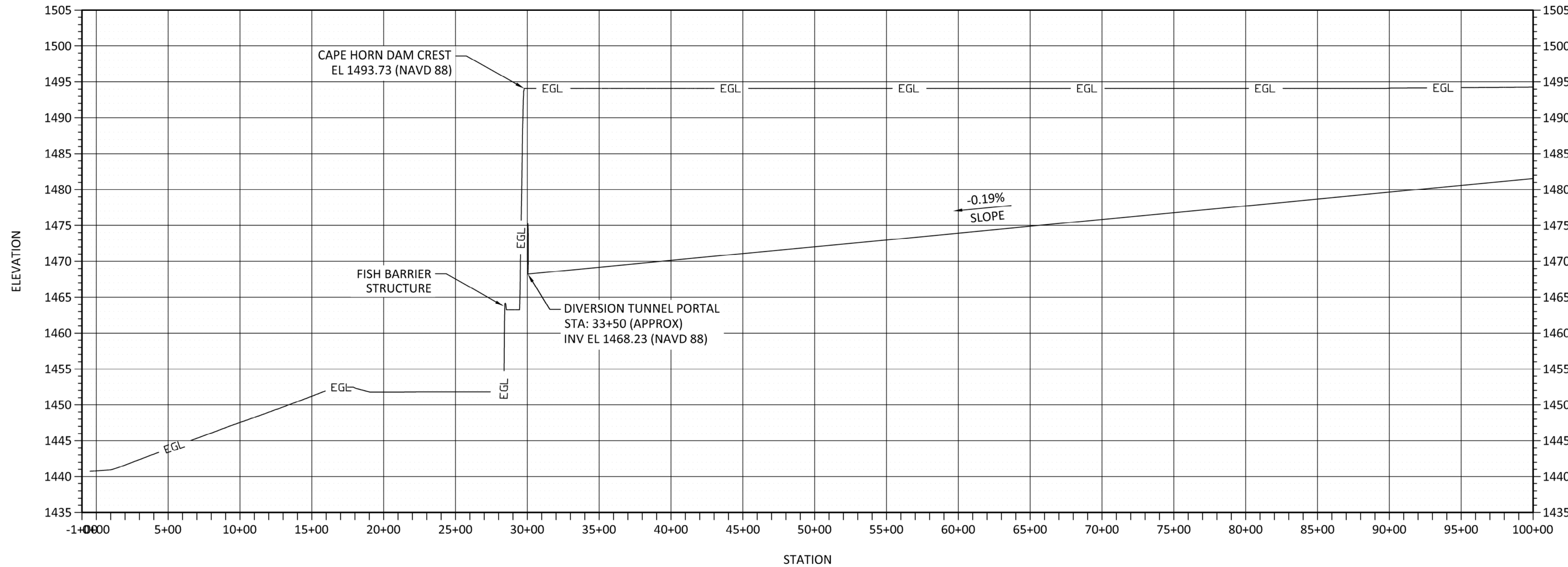

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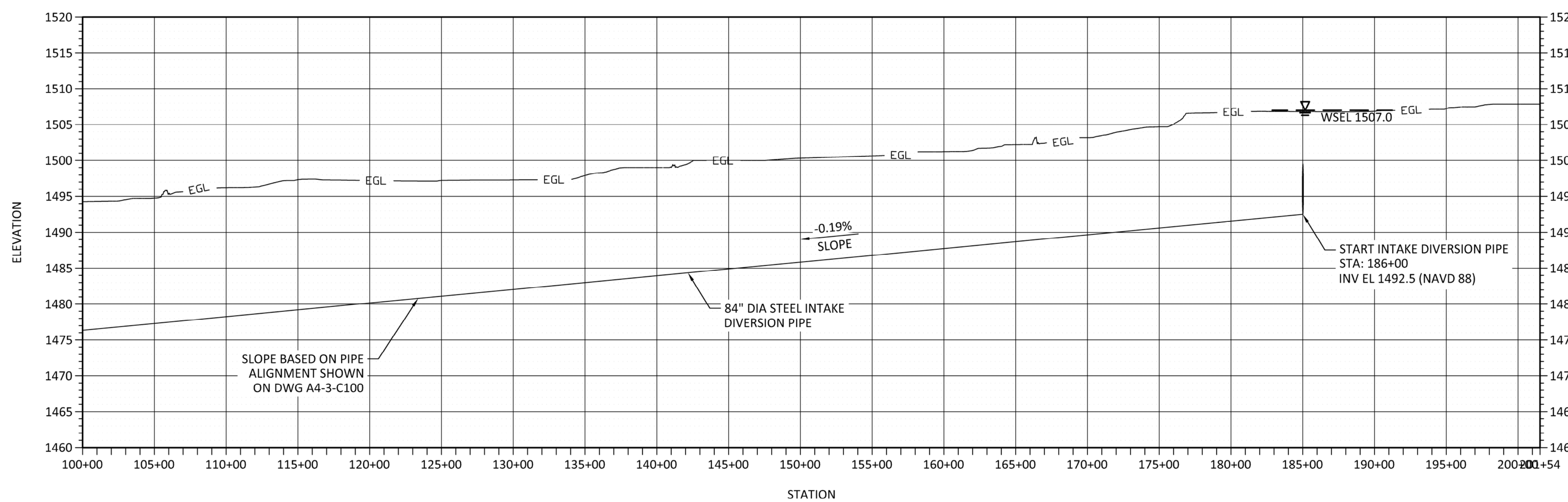
VERT 1"= 10'



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McMILLEN JACOBS ASSOCIATES

SONOMA COUNTY WATER AGENCY (SCWA)
POTTER VALLEY POWERHOUSE FEASIBILITY STUDY

INTAKE ALTERNATIVES
DIVERSION PIPELINE ALIGNMENT PLAN

DESIGNED J. WOODBURY
DRAWN J. WOODBURY
CHECKED
PROJECT DATE 01/24/20

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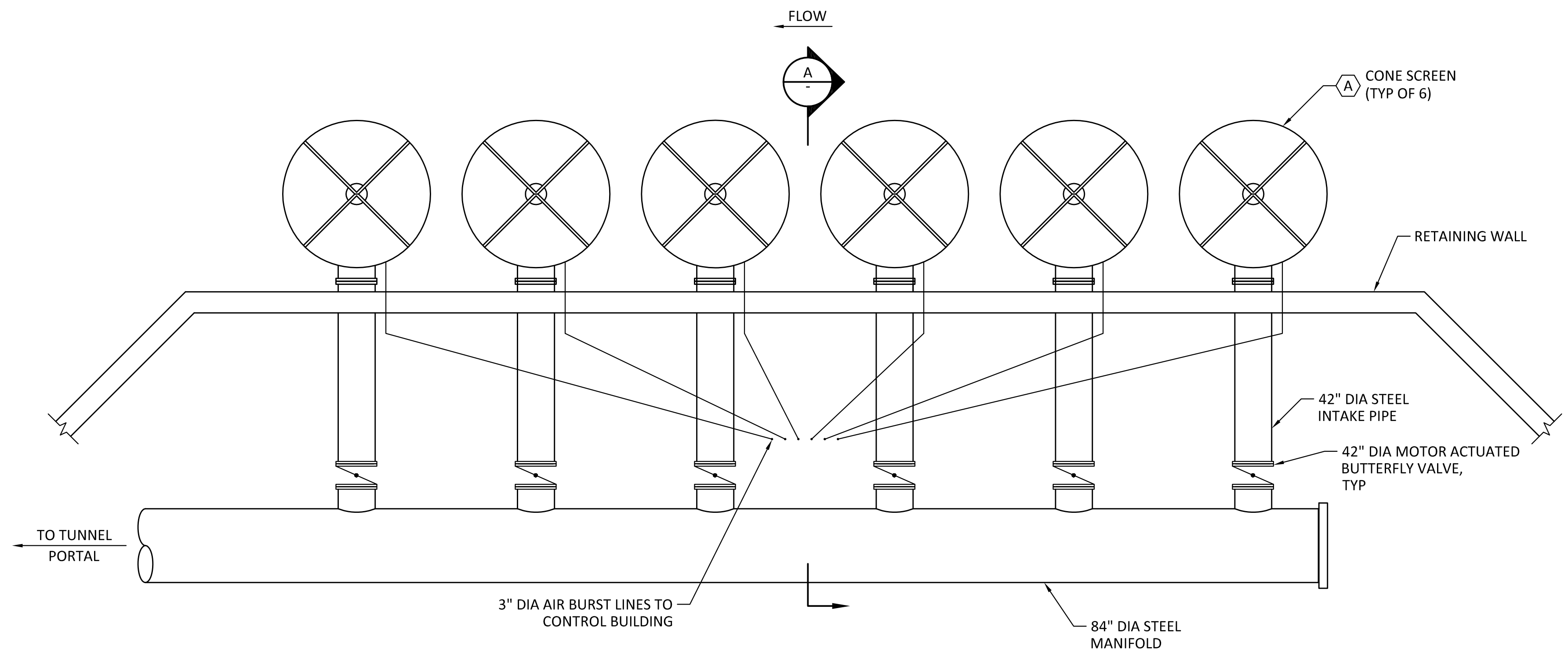

INTAKE ALTERNATIVE 1 - CONE SCREEN

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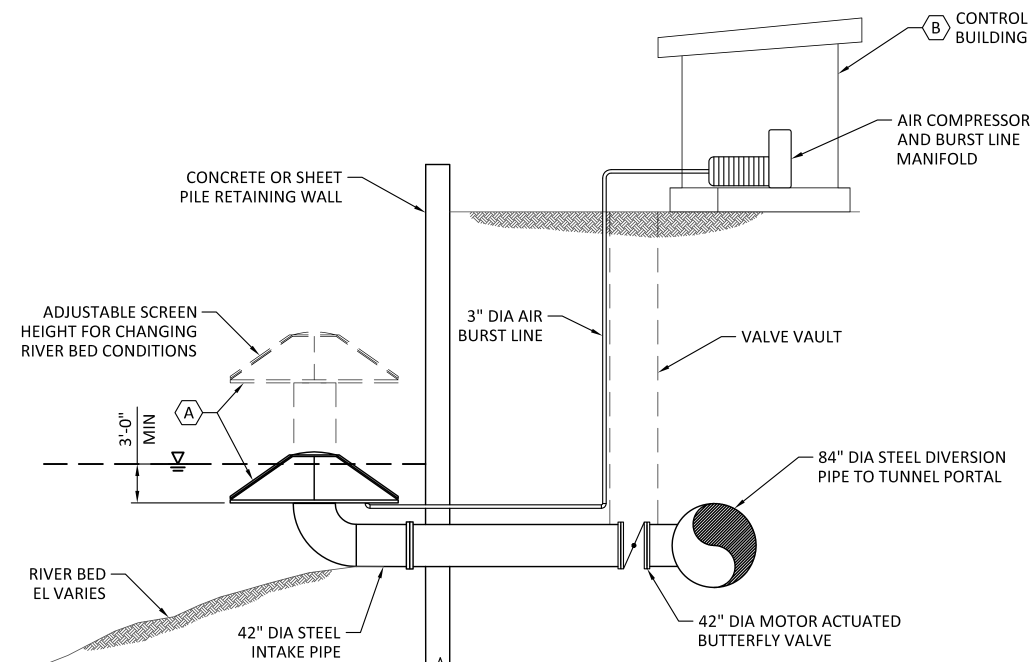

SECTION A / -

SCALE: 1/8"= 1'-0"   0' 8' 16'

SHEET NOTES:

1. THIS DRAWING WAS DEVELOPED FOR THE FEASIBILITY LEVEL ALTERNATIVES EVALUATION.

SHEET KEY NOTES:

A CONE SCREENS BY INTAKE SCREENS, INC. IS BASIS OF DESIGN. CONE SCREENS SHALL BE FITTED WITH MECHANICAL BRUSHES AND AIR BURST SYSTEMS TO REMOVE SEDIMENT AND DEBRIS.
   1. FLOW RATE: 59.9 CFS (EACH), 359.4 CFS (SYSTEM TOTAL).
   2. APPROACH VELOCITY: 0.33 FPS (MEETS NMFS CRITERIA FOR ACTIVE SCREENS).
   3. SCREEN OPEN AREA: 50%
   4. SCREEN OPENING WIDTH" 1.75mm (0.069 IN)
   5. SCREEN HEIGHT SHALL BE ADJUSTABLE WITH THE ADDITION OR REMOVAL OF 42" DIA RISER PIPES.
   6. MINIMUM WATER DEPTH OF 3 FT REQUIRED.

B CONTROL BUILDING EQUIPPED WITH CONTROL SYSTEM (PLC/SCADA), AIR COMPRESSOR, AND BACKUP GENERATOR.

REV	DATE	BY	DESCRIPTION
B	02/28/20	KJ	CONCEPTUAL DESIGN
A	07/24/19	KJ	CONCEPTUAL DESIGN

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WARNING
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McMILLEN JACOBS ASSOCIATES

Sonoma Water

SONOMA COUNTY WATER AGENCY
POTTER VALLEY PROJECT

INTAKE ALTERNATIVES
CONE SCREEN

DESIGNED J. WOODBURY
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PROJECT DATE 02/28/20

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JOB NO: 000000

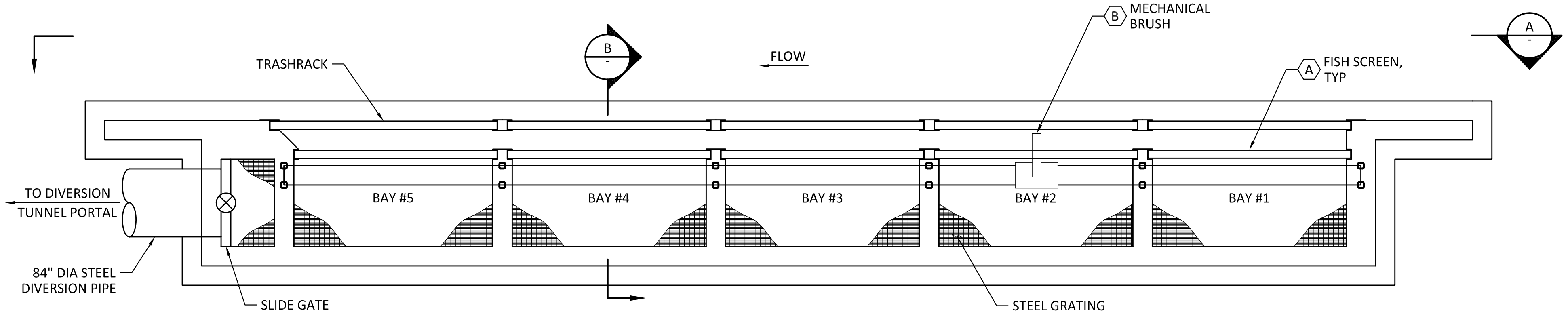
SHEET NOTES:

1. THIS DRAWING WAS DEVELOPED FOR THE FEASIBILITY LEVEL ALTERNATIVES EVALUATION.
2. FISH SCREEN DIMENSIONS BASED ON ASSUMED RIVER DEPTH. FINAL SCREEN DIMENSIONS WILL VARY DEPENDING ON ACTUAL SITE CONDITIONS.

SHEET KEY NOTES:

A. FISH SCREENS (TYP OF 5) CONSIST OF STAINLESS STEEL WEDGE WIRE OR PROFILE BAR (HENDRICK'S OR EQUAL). SCREENS CAN BE MANUFACTURED IN SINGLE UNITS (15'x20') OR IN SECTIONS (5'x20') TO REDUCE HOIST LIFTING CAPACITY REQUIRED. SEE REPORT FOR NMFS FISH SCREEN CRITERIA.

B. MECHANICAL BRUSH BY CON-VEY IS BASIS OF DESIGN. MECHANICAL BRUSH TO ACTIVATE AT 5 MINUTE INTERVALS (OR LESS) OR WHEN THERE IS 0.1FT OF HEAD DIFFERENTIAL ACROSS SCREEN, PER NMFS CRITERIA. MECHANICAL BRUSH SYSTEM WILL REQUIRE PLC. SCADA SYSTEM IS OPTIONAL.



INTAKE ALTERNATIVE 2 - VERTICAL INTAKE SCREEN

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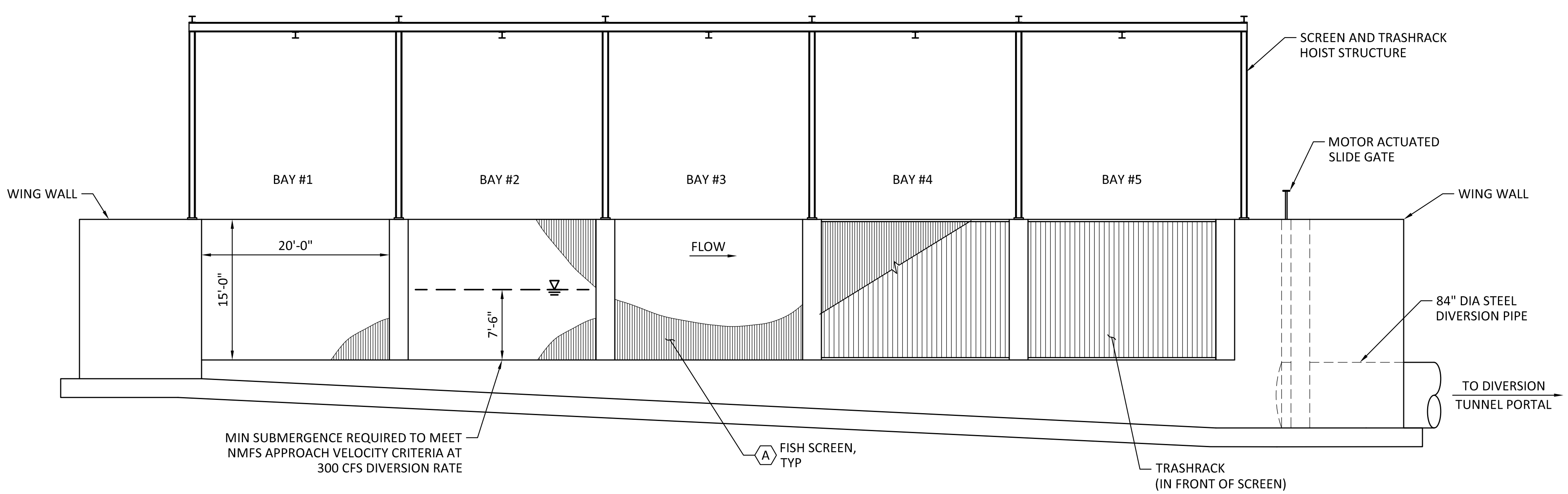

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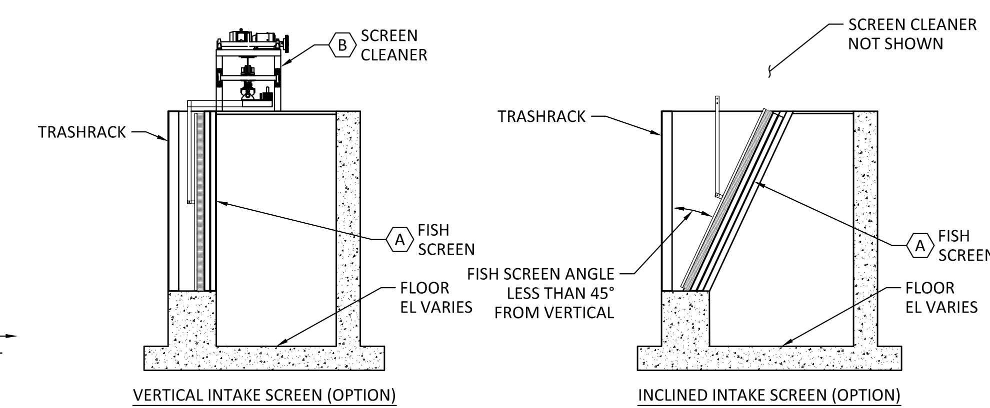

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McMILLEN JACOBS ASSOCIATES

Sonoma Water

SONOMA COUNTY WATER AGENCY
POTTER VALLEY PROJECT

INTAKE ALTERNATIVES
VERTICAL INTAKE SCREENS

DESIGNED J. WOODBURY
DRAWN J. WOODBURY
CHECKED
PROJECT DATE 02/28/20

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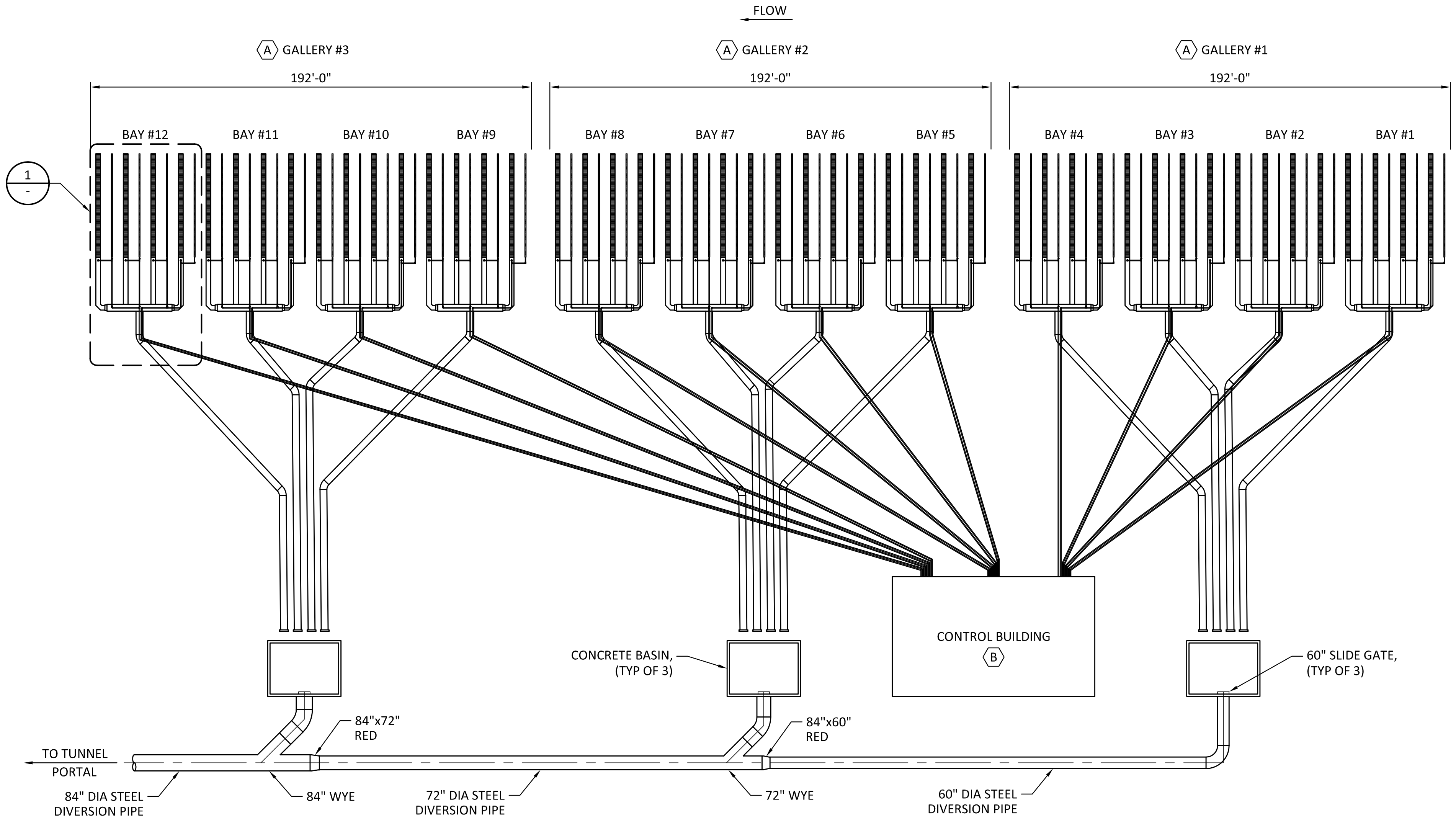

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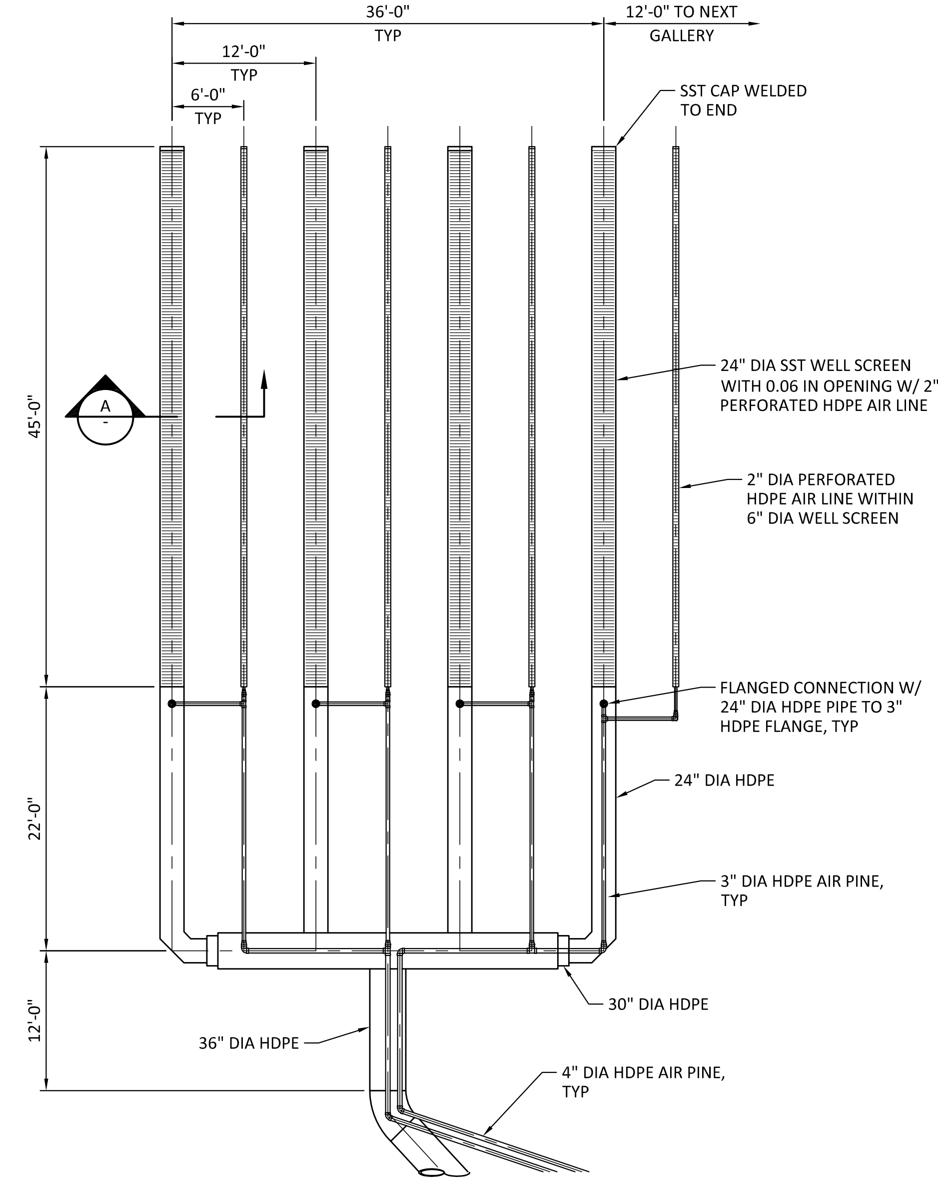

DETAIL

SCALE: 1/8"= 1'-0"

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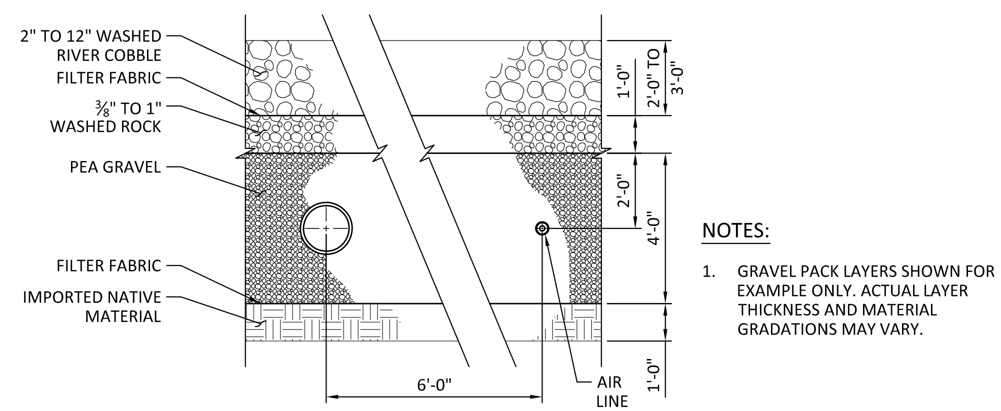

NOTES:

1. GRAVEL PACK LAYERS SHOWN FOR EXAMPLE ONLY. ACTUAL LAYER THICKNESS AND MATERIAL GRADATIONS MAY VARY.

SECTION

SCALE: 3/8"= 1'-0"

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SHEET NOTES:

1. THIS DRAWING WAS DEVELOPED FOR THE FEASIBILITY LEVEL ALTERNATIVES EVALUATION.
2. THE INFILTRATION GALLERY DESIGN SHOWN IS BASED ON TURLOCK IRRIGATION DISTRICTS' TOULUME RIVER INFILTRATION GALLERY. FINAL DESIGN FOR AN EEL RIVER INFILTRATION GALLERY MAY VARY SIGNIFICANTLY.

SHEET KEY NOTES:

A INFILTRATION GALLERIES (3 TOTAL) COMPRISE OF FOUR (4) 25 CFS CAPACITY BAYS FOR A TOTAL DESIGN YIELD OF 300 CFS. EACH BAY IS COMPOSED OF FOUR (4) WELL SCREENS. EACH WELL SCREEN IS FITTED WITH A 2" DIA AIR BURST LINE TO BLOW OUT ACCUMULATED SEDIMENT FROM GRAVEL PACK. ALL DIMENSIONS SHOWN ON THIS SHEET ARE FOR EXAMPLE ONLY. FINAL DIMENSIONS WILL DEPEND ON SITE SPECIFIC DESIGN PARAMETERS. IF THIS ALTERNATIVE IS PURSUED FURTHER IT IS RECOMMENDED THAT THE SYSTEM DESIGN YIELD INCLUDE A FACTOR OF SAFETY TO INSURE DIVERSION RATES ARE MET.

B CONTROL BUILDING TO CONTAIN:
- AIR COMPRESSOR FOR AIR BURST SYSTEM
- PLC AND/OR SCADA SYSTEM
- BACKUP GENERATOR

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McMILLEN JACOBS ASSOCIATES

Sonoma Water

SONOMA COUNTY WATER AGENCY

POTTER VALLEY PROJECT

INTAKE ALTERNATIVES
INFILTRATION GALLERY

DESIGNED J. WOODBURY
DRAWN J. WOODBURY
CHECKED
PROJECT DATE 02/28/20

DRAWING
A4-3-C104

JOB NO: 000000

APPENDIX 3
Capital Modifications Analysis Report

Potter Valley Project Capital Modifications Feasibility Study Report

Potter Valley Project,

FERC No. 77-110

FINAL REPORT

REGISTERED PROFESSIONAL ENGINEER
MORTON D. McMILLEN
79290
CIVIL
STATE OF CALIFORNIA
7/30/2018

McMILLEN JACOBS ASSOCIATES

July 2018

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Distribution

To:	Sonoma Water
Via:	Richard Roos-Collins Water and Power Law Group PC
From:	Morton D. McMillen McMillen Jacobs Associates
Prepared By:	Morton D. McMillen McMillen Jacobs Associates
	Jeff Heindel McMillen Jacobs Associates
Reviewed By:	Derek Nelson McMillen Jacobs Associates

1.0 Introduction

1.1 Introduction

Section 1 presents a summary of the overall feasibility study including purpose, scope, and background as well as the Feasibility Study Report (FSR) organization.

1.2 Purpose

On behalf of Sonoma Water, McMillen Jacobs Associates (McMillen Jacobs) was retained to complete a high-level feasibility study of potential alternatives for capital modifications of the Potter Valley Project (PVP). That project is undergoing relicensing, which began in April 2017. The feasibility analysis addresses four of the potential alternatives that stakeholders have proposed for the Federal Energy Regulatory Commission's (FERC) consideration in this proceeding. These include maintenance of existing facilities without significant capital modification, modification of such facilities to improve fish passage for anadromous fish in the Eel River, and full project decommissioning.

1.3 Scope

A range of capital modification alternatives has been addressed including alternatives associated with complete decommissioning of facilities within the PVP study area. The scope of work for the combined tasks addressed in the Scope of Services agreement includes developing conceptual design alternatives for *existing* upstream/downstream fish passage facilities at Cape Horn Dam as well as *potential* upstream/downstream facilities at Scott Dam.

1.4 Background

The study dams are located within Mendocino (Cape Horn Dam) and Lake (Scott Dam) counties and are owned and operated by Pacific Gas and Electric Company (PG&E). The PVP, FERC No. 77, dates to the early 1900s with the construction of Cape Horn Dam (1908 completion) followed by Scott Dam (1922 completion). The PVP was first licensed as a hydroelectric plant in 1922 by the Federal Power Commission (precursor to FERC). PG&E acquired the PVP from Snow Mountain Water and Power in 1930 and assumed the FERC license. The original license expired in 1972 and after a series of environmental reviews involving primarily water flow impacts to anadromous salmonids in the Eel River, FERC issued the current PVP license, which covers operations through April 14, 2022.

1.5 Report Organization

This FSR is a record of conceptual design alternatives for potential capital modifications to Cape Horn and Scott dams. The FSR is intended to document the conceptual design alternatives development and evaluation process. The major report sections are described in Table 1-1.

Table 1-1. Major Report Sections and Purpose

Section	Description	Purpose
1	Introduction	Outlines the purpose of the report, scope of work, project background, and report organization.
2	Pertinent Data	Summarizes the existing available pertinent data for biological and engineering disciplines as well as watershed and hydrologic criteria.
3	Alternatives Development	Presents the development of alternatives for capital modifications including general descriptions, major components, and anticipated operations.
4	Alternatives Evaluation	Presents evaluation criteria and evaluation based on biological effectiveness, constructability, environmental impacts, operation, design flexibility, construction sequencing, cost, schedule, advantages and disadvantages.
5	Conclusions and Recommendations	Presents the conclusions and recommendations based on the analysis completed within the feasibility study.
6	References	Lists the references used during the study.
Appendix A	Supplemental Data	Presents supplemental and supporting data used for alternatives development.
Appendix B	Feasibility Level Sketches of Alternatives	Presents the feasibility-level sketches that have been prepared for each alternative.

2.0 Pertinent Data

2.1 Introduction

Section 2 presents a general description of the Eel River Basin (Figures 2-1 and 2-2), overview of the existing project area, summary of data sources used to obtain information, and available pertinent data used to support the conceptual alternatives development.

2.2 Existing Project Description

The focus of this study is on the upper main stem Eel River and involves two existing dams and associated reservoir storage facilities owned and operated by PG&E:

- Cape Horn Dam/Van Arsdale Reservoir
- Scott Dam/Lake Pillsbury

Major design features of each dam and associated reservoir are provided in Table 2-1.

Table 2-1. Potter Valley Project Design features; Cape Horn Dam/Van Arsdale Reservoir and Scott Dam/Lake Pillsbury, Eel River Basin

Feature	Cape Horn Dam	Scott Dam
Impoundment	Van Arsdale Reservoir	Lake Pillsbury
Dam Height (ft.)	96	130
Dam Length (ft.)	515	805
Top Elevation (ft. above sea-level)	1,519	1,838.5
Spillway Elevation (ft. above sea-level)	1,490.3	1,818.3
Top of Water Supply Pool (ft. above sea-level)	1,490.3	1,828.3
Upstream Watershed Area (square miles)	345	298
Total Reservoir Capacity (acre-feet; 1983 estimate)	700	80,560
Maximum Surface Area (acres)	163	2,003
Mean Reservoir Depth (ft.)	4.3	40.2

Source: FERC, 2000

As noted in Section 1.4, the PVP was initiated in the early 1900s with the construction of Cape Horn Dam (1908 completion) followed by Scott Dam (1922 completion). Additionally, a key component to the PVP is an 8-foot-diameter, approximately 1-mile-long diversion tunnel, penstock and associated 9.4-megawatt (MW) powerhouse.

While serving its primary purpose of hydroelectric power generation, the PVP diverts water from the Eel River Basin to the headwaters of the Russian River. Mean annual water diversions to the Russian River system vary significantly and are affected by Eel River Basin precipitation. Water diverted to the Russian River Basin is used for multiple purposes including hydroelectric power production, irrigation, recreation, aesthetic enhancement, fishery improvement, and municipal water supplies for both Mendocino and Sonoma county users. The PVP provides multi-use benefits to communities and ecosystems in both river basins (FERC, 2000).

2.2.1 Cape Horn Dam/Van Arsdale Reservoir

The Cape Horn Dam and associated water diversion structures were completed in 1908 by the Snow Mountain Water and Power Company (SMWPC). The facilities operated in a "run-of-river" capacity from 1908 until 1922, when Scott Dam was completed. PG&E acquired SMWPC in 1930 and has owned and operated the PVP since then.

Cape Horn Dam is a concrete gravity and earth-filled structure that impounds the Eel River, forming Van Arsdale Reservoir. The dam is approximately 96 feet in height and has a total length of 515 feet. Van Arsdale Reservoir serves as a forebay for the diversion tunnel leading to the 9.4-MW powerhouse located on the headwaters of the east branch (fork) of the Russian River. Van Arsdale Reservoir has a maximum surface area of approximately 163 acres and a mean depth of approximately 4.3 ft (FERC, 2000).

Cape Horn Dam currently has both juvenile and adult fish passage facilities (see Appendix A, Figures A-1 and A-2), broodstock collection capabilities, and screened intake systems (diversion tunnel) to prevent fish entrainment. A 63-foot-high concrete pool-and-weir fish ladder allows anadromous fish access to main stem (~ 12 miles) and tributary spawning habitats between the two dams (FERC, 2000). Species diversity and facility fish count information is provided in Section 2.4.2 (below).

2.2.2 Scott Dam/Lake Pillsbury

Construction of Scott Dam was initiated in 1920 and completed in 1922. Lake Pillsbury, the resulting storage reservoir behind Scott Dam, began to fill in 1922 with an original water storage capacity of approximately 94,400 acre-feet (Porterfield and Dunnam, 1964).

Scott Dam is a cyclopean concrete, ogee gravity dam that is approximately 130 feet in height with a total length of 805 feet (see Appendix A, Figure A-3). Located approximately 12 miles upstream of the Cape Horn Dam/Van Arsdale complex, Scott Dam/Lake Pillsbury provides year-round, store-and-release operations to manage both flow and temperature at Van Arsdale Reservoir (FERC, 2000). Scott Dam was constructed without any adult/or juvenile fish passage facilities.

2.3 Data Sources

The data presented in this section were collected from the Potter Valley Irrigation District website (http://pottervalleywater.org/history.html), California Department of Fish and Game (CDFG) biological reports, and FERC Project No. 77 relicensing documents. The majority of the data used in the development of these conceptual alternatives was obtained from the following sources:

- Available as-built drawings for Cape Horn and Scott dams and associated facilities
- Eel River stream flow data
- CDFG Recovery Strategies (CDFG, 2004)
- FERC Project No. 77 Final Environmental Impact Statement (EIS; FERC 2000)

2.4 Pertinent Data

Pertinent data for the PVP include selected as-constructed drawings and anadromous fish count data. These items are described in additional detail below. Hydrology information specific to the PVP is provided in Section 2.5.2.

2.4.1 As-constructed Drawings

Limited as-constructed drawings for the existing dams illustrated the basic plan and arrangement of each facility as well as a representative section through the dams. Basic layout and orientation of the fish passage facilities at Cape Horn Dam were also utilized. Though limited in scope, the available as-constructed drawings provide sufficient data to complete the initial feasibility level alternatives development and analysis. If the identified alternatives are advanced to a more detailed analysis, a more comprehensive package of as-constructed drawings will be required that illustrate the specific structural, mechanical, and geotechnical design aspects of the existing dams and projects. The analysis presented in this report focused on the existing dams and their related facilities. A detailed review and analysis of the diversion tunnel, powerhouse, and conveyance and storage facilities within the PVP were not required for this feasibility analysis, so as-constructed drawings were not requested for these facilities.

2.4.2 Fish Counts

The FERC *Final Environmental Impact Statement* (FERC, 2000) provides a detailed list of 30 different fish species that exist within the PVP area. The primary focus of this feasibility study is to address current and conceptual fish passage facilities for three key anadromous salmonid species that occur in the study area:

- Chinook Salmon *Oncorhynchus tshawytscha*; fall-run
  - U.S. Endangered Species Act (ESA) status: *Threatened*
- Coho Salmon *O. kisutch*; winter-run
  - ESA status: *Threatened*
- Steelhead Trout *O. mykiss*
  - ESA status: *Threatened*

In addition to the key listed salmonid stocks in the study area, current and future feasibility studies should continue to address an important anadromous *non-salmonid* present in the study area:

- Pacific Lamprey *Lampetra tridentata / Entosphenus tridentatus*

Although currently not listed under the ESA, Pacific Lamprey remain an important native fish species to Pacific Northwest ecosystems and are an important subsistence and ceremonial species for Native American tribes throughout the region.

Anadromous adult salmonid trapping and escapement data were obtained from online CDFG sources and the most recent 10-year dataset for Chinook and steelhead returning to the Van Arsdale Fisheries Station is summarized in Appendix A (see Figure A-4 and Table A-1).

If the feasibility study results in recommendations to replace or modify existing facilities or to construct new fish passage facilities, current biological criteria standards as provided by NOAA and/or CDFG will be applied. Appendix A provides general biological design criteria (Table A-2) and target species information (Table A-3).

2.5 Eel River Basin Description

The study area is located within the upper main stem Eel River in northwestern California (Figure 2-1).

2.5.1 Watershed Description

The Eel River (Eel) enters the Pacific Ocean approximately 14 miles south of Eureka, California, and is the third largest river system in California, with a watershed encompassing approximately 3,684 square-miles within the counties of Colusa, Glenn, Humboldt, Lake, Mendocino, and Trinity. The total watershed contains approximately 3,448 miles of streams with an estimated mean annual discharge of approximately 6 million acre-feet (CDFG, 2004). The annual hydrograph for the study area in the upper Eel generally peaks in January and February and is lowest from July through September (FERC, 2000).

2.5.2 Hydrology

Scott Dam and Cape Horn Dam have drainage areas of 290 square-miles and 349 square-miles, respectively, as illustrated in Figure 2-2. There are two main U.S. Geological Survey (USGS) gaging stations, one located downstream of each dam. The gage downstream of Scott Dam (USGS 11470500) has collected flow data since 1922, with 93 annual peak streamflow data points. The gage downstream of Cape Horn Dam (USGS 11471500) has collected flow data since 1909, with 105 annual peak streamflow data points. A flood frequency analysis in accordance with Bulletin 17B was performed for each gage to estimate the peak flow for a given annual return flood, as presented in Table 2-2. Plots of the Bulletin 17B statistical analysis for Scott Dam and Cape Horn Dam are in Figures 2-3 and 2-4.

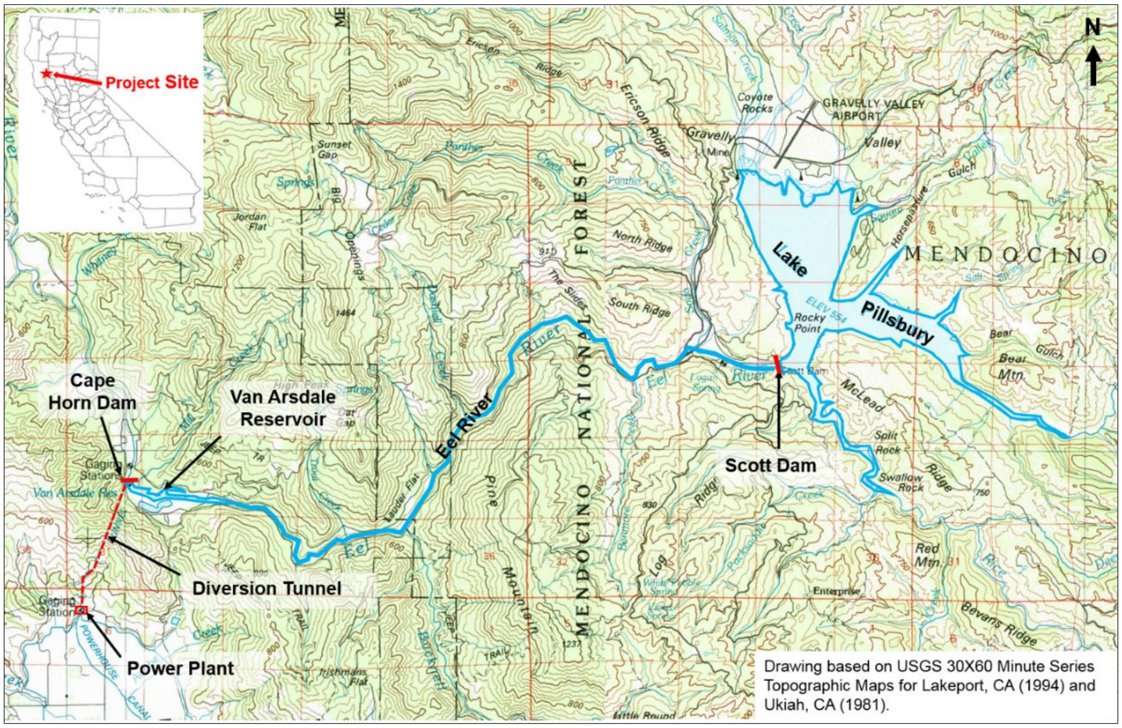

Figure 2-1. Potter Valley Project Study Area; Eel River Basin, California

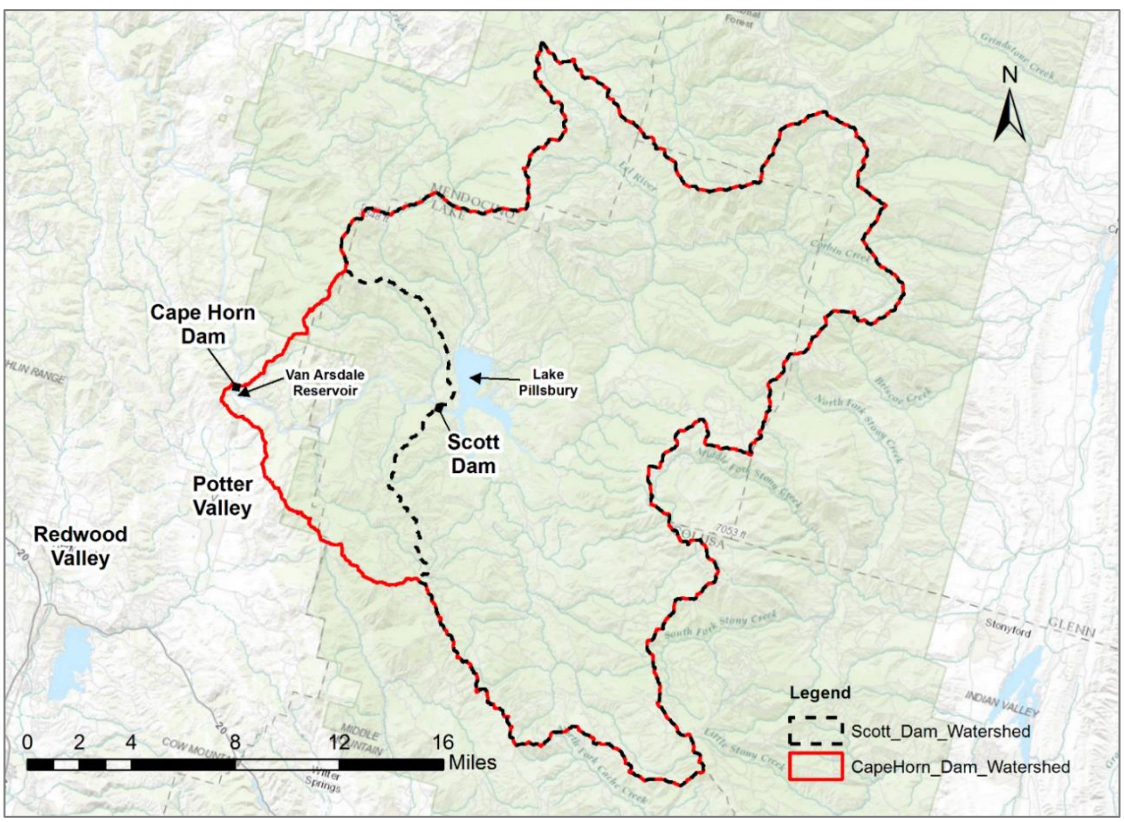

Figure 2-2. Cape Horn Dam and Scott Dam Watersheds

Table 2-2. Bulletin 17B Statistical Analysis of USGS Gages

Percent Chance Exceedance	Annual Return Frequency (years)	d/s Scott Dam Bulletin 17B Peak Flow Analysis (cfs)	d/s Cape Horn Dam Bulletin 17B Peak Flow Analysis (cfs)
99.0	1.01	195.6	703.5
95.0	1.05	828.2	1,885.9
90.0	1.11	1,623.3	3,035.5
80.0	1.25	3,364.0	5,164.5
50.0	2	10,560.3	12,510.3
20.0	5	24,535.4	25,739.8
10.0	10	34,262.8	35,329.8
5.0	20	42,978.1	44,566.7
2.0	50	52,876.8	56,175.5
1.0	100	59,199.7	64,466.8
0.5	200	64,615.3	72,318.4
0.2	500	70,553.4	82,013.7

cfs = cubic feet per second

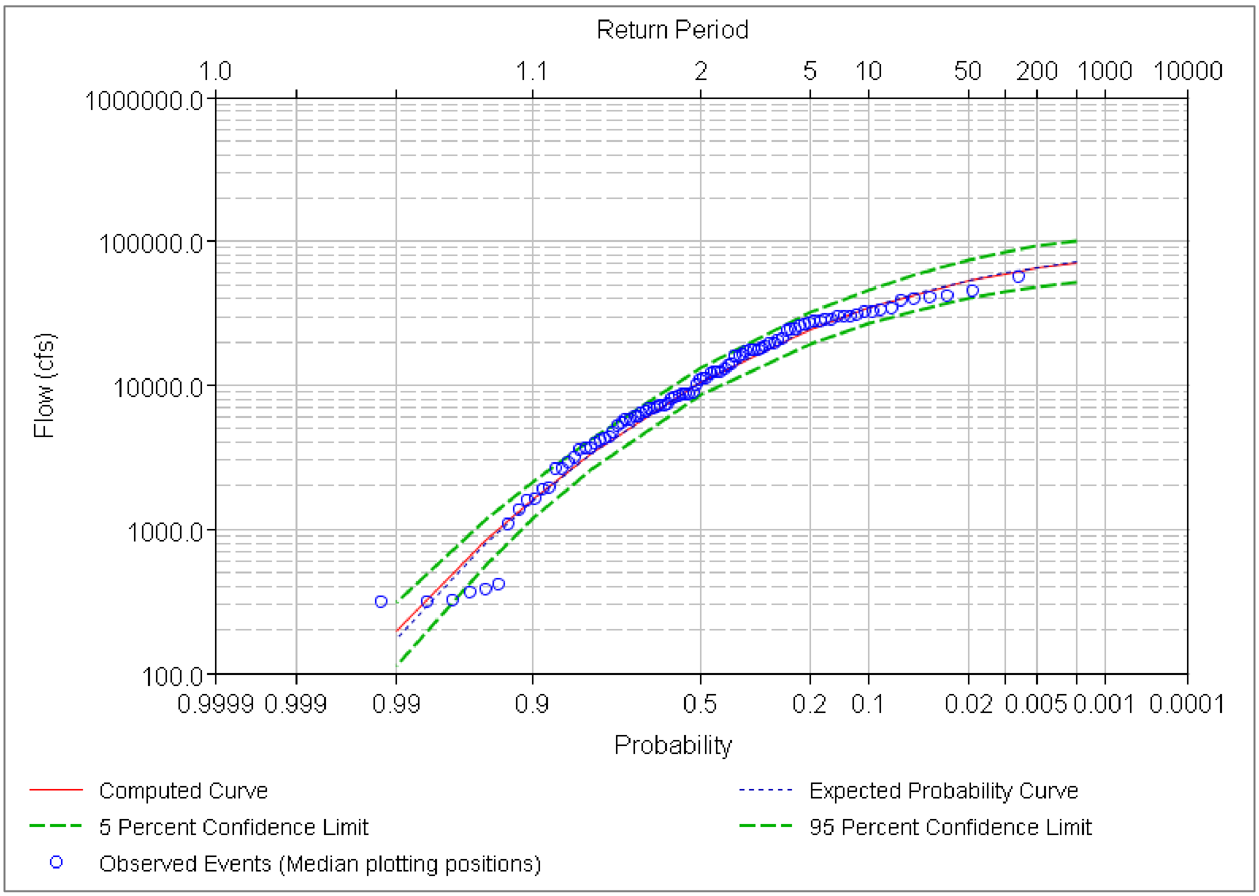

Figure 2-3. Scott Dam Bulletin 17B Peak Flow Analysis

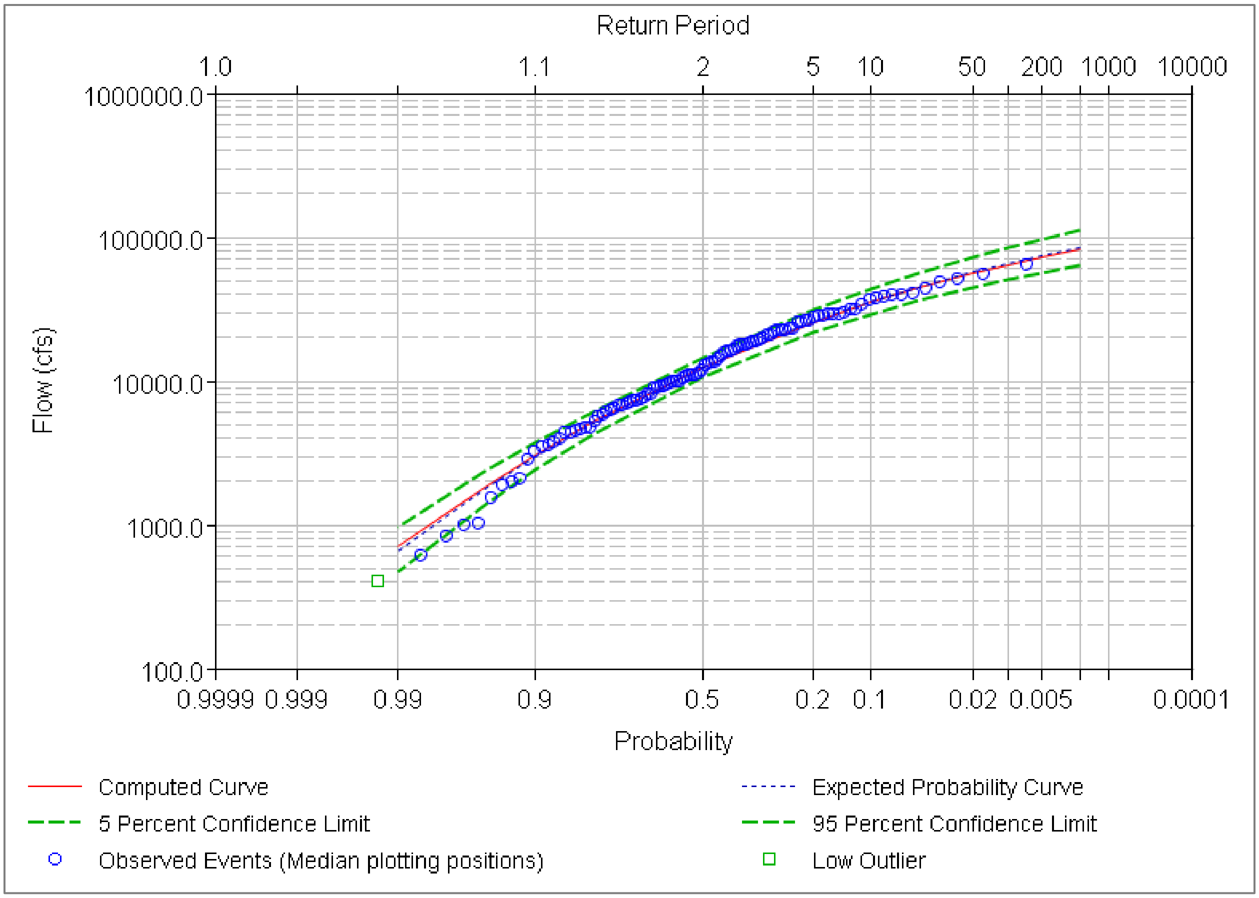

Figure 2-4. Cape Horn Dam Bulletin 17B Peak Flow Analysis

3.0 Alternatives Development

3.1 Introduction

Section 3 outlines the alternatives evaluated for the feasibility study for potential modifications to PVP facilities. Alternatives evaluated provide a wide range of potential options, ranging from improvements to conventional fish passage conditions to full project decommissioning for both Cape Horn and Scott dams. A basic description of the identified alternatives is presented in Section 3 with the subsequent evaluation of each alternative presented in Section 4.

3.2 General Approach and Objectives

As presented in Section 1, the feasibility analysis is intended to provide a high-level study of potential modifications to Cape Horn and Scott dams. The alternatives range from simply maintaining and operating the existing facilities with minimal improvements to full dam removal and decommissioning. The general approach to identifying and developing alternatives consisted of the following:

- Identify basic options for Cape Horn Dam.
- Identify basic options for Scott Dam.
- Develop alternatives that consist of combinations of options for each dam.

As a starting point, a baseline facilities alternative was established that consists of maintaining the existing dams and facilities in their current configurations and operations. The minimum required level of improvements required to maintain operations was identified to establish the minimum capital investment cost for each alternative. From the baseline alternative, additional alternatives were developed that range from incremental increases in fish passage facilities to full dam removal and decommissioning. This approach provides a full range of potential capital modification alternatives and the associated capital investment costs. A basic description of the options identified for each dam is presented in the following paragraphs, followed by descriptions of the Project Alternatives.

3.3 Dam-Specific Options

Table 3-1 presents a summary of the dam-specific options identified for Cape Horn Dam and Scott Dam. A brief description of each option is presented in the following paragraphs. The drawings that illustrate each of the basic option features are indicated in Table 3-1 and are included in Appendix B.

Table 3-1. Summary of Project-Specific Options

Option No.	Description	Reference Drawing No.
	Cape Horn Dam	
	Baseline	CH-BL-1
A	Improve Upstream Fish Passage	CH-A-1
B	Improve Downstream Fish passage	CH-B-1

Option No.	Description	Reference Drawing No.
C	Partial Decommissioning	CH-C-1
D	Full Decommissioning with Sediment Management	CH-D-1
E	Full Decommissioning with Sediment Removal	CH-E-1
	Scott Dam	
	Baseline	SD-BL-1
A	Provide Upstream Fish Passage	
A1	Volitional Fish Ladder	SD-A1-1.1, -1.2
A2	Trap and Haul	SD-A2-1.1, -1.2
B	Provide Downstream Fish Passage	
B1	Corner Collector	SD-B1-1.1
B2	Floating Surface Collector	SD-B2-1
B3	Tributary Collector	SD-B3-1
C	Partial Decommissioning	SD-C-1
D	Full Decommissioning with Sediment Management	SD-D-1
E	Full Decommissioning with Sediment Removal	SD-E-1

3.3.1 Cape Horn Dam

The existing dam is fitted with both upstream and downstream fish passage facilities. The existing fish ladder provides upstream fish passage to the existing fish hatchery and habitat located between Cape Horn Dam and Scott Dam. For the options outlined below, it was assumed that the existing fish passage facilities would be modified to address potential operation, maintenance, or fish passage improvements, but full replacement would not occur.

Baseline Option

The baseline option consists of maintaining the basic configuration and operation of the existing Cape Horn Dam facilities. This would include the fish ladder, intake and fish screen, and dam. With this option, water would continue to be diverted to the Potter Valley powerhouse for generation and subsequent delivery to the Potter Valley Irrigation District or release to the East Fork of the Russian River. With the baseline option, minimal modifications to the existing structures would be implemented to ensure reliable operation and address potential dam safety issues. These modifications may include repairing damaged concrete, replacing aging gates and mechanical systems, and upgrading the electrical and instrumentation systems. The basic system components at Cape Horn Dam associated with the Baseline Option are illustrated on drawing CH-BL-1 (Appendix B).

Option A – Improve Upstream Fish Passage

The existing fishway located on the left abutment of the dam currently provides reliable upstream fish passage conditions. After the original construction, the upstream fishway was modified to improve the fishway entrance and lower fishway level as well as the water release structures at the dam. Option A consists of implementing modifications to the existing fishway to optimize the fishway operation and extend the facility life to a minimum period of 30 years. The anticipated modifications include repairing deteriorated concrete, replacing aging mechanical systems, upgrading the electrical and instrumentation systems, and improving hydraulic flow conditions within the ladder, if required. With this option, the current operation and diversions to the Potter Valley Powerhouse would be maintained. Water in excess of the Potter Valley Project's capacity would be spilled over the dam. The basic system components at Cape Horn Dam associated with Option A are illustrated on Drawing CH-A-1 (Appendix B).

Option B – Improve Downstream Fish Passage

With this option, the existing intake and fish screen would be modified to optimize operation and reliability. The existing screen structure has experienced structural integrity issues that impact the ability to operate at higher flows during heavy debris periods. With this option, the structural support system would be modified to increase the structural capacity and improve system reliability. The mechanical air burst system used to clean the fish screens has also experienced issues. This system would be upgraded to provide a more frequent cleaning cycle and reliable monitoring systems. Additional modifications to the electrical and instrumentation systems would also be provided to ensure effective monitoring and incorporation of systems to protect the screen structure during very large debris load conditions. The existing upstream fishway structure was assumed to be maintained in its current configuration. No improvements to the fishway structure were included with Option B. With this option, the current operation and flow diversions to the Potter Valley Powerhouse would be maintained. Water in excess of the Potter Valley Project's capacity would be spilled over the dam. The basic system components at Cape Horn Dam associated with Option B are illustrated on Drawing CH-B-1 (Appendix B).

Option C – Partial Decommissioning

Option C consists of partial decommissioning of Cape Horn Dam. The existing dam, intake and fish screen, and upstream fishway would be maintained with minimal improvements to ensure reliable operation. The primary decommissioning element associated with this option would be modifying flow diversions to provide additional flows in the Eel River during critical upstream and downstream fish migration periods. During these periods, the flow diversions to the Potter Valley Powerhouse would be reduced. The existing fishway structure would continue to provide upstream fish passage over the dam. Similarly, the existing intake and screen would screen fish from entering the diversion tunnel. The basic system components at Cape Horn Dam associated with Option C are illustrated on Drawing CH-C-1 (Appendix B).

Option D – Full Decommissioning with Sediment Management

For the purpose of this analysis, full decommissioning would consist of removal of Cape Horn Dam and restoration of the natural river flows. The intake structure, fish ladder, and all associated features would be removed. The diversion tunnel would be plugged on both ends and the powerhouse removed. The natural river channel would be re-established upstream and downstream from the dam site providing natural fish passage through the project reach. The remaining sediment would be stabilized within the channel using natural systems and replanting the riparian river zones. It may be possible to dispose of the demolished concrete and earth material on the overbank areas on the right bank of the dam. The ability to divert flows would be eliminated with Option D. The basic system components at Cape Horn Dam associated with Option D are illustrated on Drawing CH-D-1 (Appendix B).

With the full decommissioning option, the existing fish hatchery water supply and fishway would be impacted. This would require that the lower fishway section be maintained and a new water supply intake and pipeline be constructed to provide flow to the hatchery. Alternatively, the hatchery could be decommissioned.

Option E – Full Decommissioning with Sediment Removal

This option is identical to Option D with the addition of sediment removal from the reservoir. The accumulated sediment would be excavated and transported to the overbank areas on the right abutment of the dam. The material would be placed, then stabilized through vegetation erosion protection measures. Due to the higher flow velocities that pass through the project reach during the spring, the amount of sediment within the reservoir is relatively small. Consequently, removal and disposal of this material in the river overbank areas would be feasible. The basic system components at Cape Horn Dam associated with Option E are illustrated on Drawing CH-E-1 (Appendix B).

3.3.2 Scott Dam

Baseline Option

The baseline option consists of maintaining the existing dam in its current configuration. No fish passage facilities would be provided with the baseline option. Upgrades to the existing dam facilities including the spillway gates, dam safety improvements, and the low level outlet completion would provide a fully functional dam facility with minimal capital investment for the anticipated 30- to 50-year project life. The basic system components at Scott Dam associated with the Baseline Option are illustrated on Drawing SD-BL-1 (Appendix B).

Option A – Provide Upstream Fish Passage

Two basic options were identified for upstream fish passage. Option A1 consists of a volitional fish ladder located on the left abutment of the dam. The ladder would be designed to allow upstream fish migrants to freely move over the dam. Because the reservoir elevations vary throughout the year, a pump station would be required to pump water to the fish ladder exit to maintain year-round operation. Fish would pass over a false weir and then be conveyed to the reservoir via a flume or pipe. An alternative to this option would be to maintain a constant reservoir elevation during the upstream migration periods; this alternative would restrict the ability to release flows for downstream use. The basic system components at Scott Dam associated with Option A1 are illustrated on Drawings SD-A1-1.1 and SD-A1-1.2 (Appendix B).

Option A2 consists of a conventional trap-and-haul facility. With this option, the facility consists of a fishway entrance in the dam tailrace, a water supply, fishway to bring fish up to a holding pool, a sorting area, and truck loading. Fish would migrate up the fishway to the holding pool where they would be sorted, then loaded onto a transport truck for upstream transport and release. The water supply would be located on the upstream side of the dam with a penetration through the dam for a water supply pipe. A screened intake would be provided in the reservoir, fitted with an air burst system for routine cleaning. The basic system components at Scott Dam associated with Option A2 are illustrated on Drawings SD-A2-1.1 and SD-A2-1.2 (Appendix B).

Option B – Provide Downstream Fish Passage

The options identified for downstream fish passage include Option B1 – Corner Collector, Option B2 – Floating Surface Collector, and Option B3 – Tributary Collector. Option B1 would consist of a floating collector or tower with multiple entrances located on the right abutment of the dam. The system would be designed to collect downstream migrants as the reservoir level fluctuates. The fish would then be directed to a floating holding facility and hopper for downstream transport and release, or directed to a fish return pipeline. The basic components of Option B1 are illustrated on Drawings SD-B1-1.1 and SD-B1-1.2 (Appendix B).

Option B2 would consist of a floating surface collector (FSC) similar to those installed at the Baker River hydroelectric projects, Swift Dam, and the North Fork Dam in the Pacific Northwest. As shown on Drawing SD-B2-1, this option consists of improving the existing log boom to maximize debris exclusion and installing a barrier net designed to guide downstream fish migrants to the mouth of the FSC. The FSC structure would consist of a fish screen, holding raceways, transport tanks, and a series of pumps used to create an attraction flow and return the pumped flow to the reservoir. A floating dock would be installed on the left abutment of the dam along with a jib crane located at the top of the dam. The dock and crane would be used to provide access and the mechanical systems to lift the transport fish tanks from a work boat to the top of the dam for subsequent transfer to a truck. The fish tanks would then be transported to a downstream location to release fish. A photograph of the Upper Baker Lake floating collector is presented in Appendix A, Figure A-5.

Option B3 would consist of a tributary collector, either fixed or floating, located on the major tributaries entering the reservoir (see Drawing SD-B3-1). A fish screen would be used to guide downstream migrants to a holding raceway where they would then be crowded into a fish hopper and transported on trucks for downstream release. In general, the tributary collectors would be very similar to the FSC except smaller in scale. Their installation near the upstream end of the reservoir would be intended to minimize fish losses within the reservoir itself during the outmigration period. A prototype tributary collector was constructed and tested at the Cougar Dam reservoir by the U.S. Army Corps of Engineers (USACE). An illustration of this option is presented in Appendix A, Figure A-6.

Option C – Partial Decommissioning

With this option, Scott Dam would be partially decommissioned with dam removal down to the spillway crest. An overflow spillway would extend across the entire dam crest with all water releases routed over the spillway. The low-level outlet would be maintained to provide full draining of the reservoir if required. The primary reason for this option would be to minimize sediment removal from the reservoir. Over 20,000 acre-feet of sediment has deposited in the reservoir since the dam’s construction. Removal of this sediment could impact downstream fish habitat as well as overwhelm and bury the Van Arsdale Reservoir and Cape Horn Dam facilities. The basic system components at Scott Dam associated with Option C are illustrated on Drawing SD-C-1 (Appendix B).

Option D – Full Decommissioning with Sediment Management

This option would consist of full decommissioning and dam removal. The existing dam, low level intake, valve house, and related structures would be completely removed. A new river channel would be established through the reservoir area and would be excavated through the reservoir with the material disposed of in the river overbank areas. The remaining sediment would be maintained within the reservoir. This would require selected excavation to bench and stabilize the deposited materials. Both structural and vegetative erosion control measures would be required to provide effective stabilization of the sediment. However, it could still be expected that some of this material would be eroded and transported downstream during large flood events. The basic system components at Scott Dam associated with Option D are illustrated on Drawing SD-D-1 (Appendix B).

Option E – Full Decommissioning with Sediment Removal

This option is identical to Option D except for the addition of sediment removal from the reservoir and disposal. This option was developed to attempt to define the estimated cost associated with sediment removal from the reservoir area. The original storage capacity of Lake Pillsbury was listed as 94,400 acre-feet (Porterfield and Dunnam, 1964). In 2006, the estimated remaining storage was approximately 74,993 acre-feet (USGS, 2008). Current sediment deposition rates in the reservoir are estimated at 230–280 acre-feet per year (FERC 2000), which results in an estimated total sediment deposition of approximately 21,607 acre-feet. This corresponds to a volume of 34 million cubic yards of sediment behind Scott Dam. Option E was identified to represent the potential cost associated with removing the sediment within the reservoir. This option is not considered feasible due to the sheer volume of material that would need to be excavated and transported to an offsite disposal site. The basic system components at Scott Dam associated with Option E are illustrated on Drawing SD-E1-1 (Appendix B).

3.4 Project Alternatives

Using the options developed for Cape Horn and Scott dams, project alternatives were developed to represent the full range of potential capital modification alternatives for the PVP as a whole. A baseline alternative consisting of maintaining the current project operations with minimal improvements was used as the starting point for comparison of subsequent alternatives. The subsequent alternatives represent combinations of specific options for each dam. Table 3-2 presents a summary of the alternatives considered. These alternatives are not intended to be fully inclusive of all possible alternatives; rather, they represent alternatives ranging from maintaining current operations through complete dam removal and project decommissioning. A brief description of each alternative is presented in the following paragraphs. Full descriptions of each project-specific option are presented in the previous paragraphs. A high-level evaluation of the alternatives is presented in Section 4.

Table 3-2. Summary of Project Alternatives

Alternative No.	Description	Reference Drawing No.
	Baseline	
	Cape Horn Dam – Baseline Option	CH-BL-1
	Scott Dam – Baseline Option	SD-BL-1
1	**Provide Volitional Fish Passage**	
	Cape Horn Dam – Option A – Improve Existing Fish Ladder	CH-A-1
	Cape Horn Dam – Option B – Improve Existing Fish Screen	CH-B-1

Alternative No.	Description	Reference Drawing No.
	Scott Dam – Option A1 – Volitional Fish Ladder	SD-A1-1.1, -1.2
	Scott Dam – Option B1 – Corner Collector	SD-B1-1.1, -1.2
2	**Provide Fish Passage**	
	Cape Horn Dam – Option A - Improve Existing Fish Ladder	CH-A-1
	Cape Horn Dam – Option B - Improve Existing Fish Screen	CH-B-1
	Scott Dam – Option A2 – Trap and Haul	SD-A2-1.1, -1.2
	Scott Dam – Option B1 – Corner Collector	SD-B1-1.1, -1.2
3	**Partial Decommissioning**	
	Cape Horn Dam – Option C – Partial Removal	CH-C-1
	Scott Dam – Option C – Partial Removal	SD-C-1
	Scott Dam – Option A2 – Trap and Haul	SD-A2-1.1, -1.2
4	**Full Decommissioning with Sediment Management**	
	Cape Horn Dam – Option D – Full Removal	CH-D-1
	Scott Dam – Option D – Full Removal	SD-D-1
5	**Full Decommissioning with Sediment Removal**	
	Cape Horn Dam – Option E – Full Removal with Sediment Removal	CH-E-1
	Scott Dam – Option E – Full Removal with Sediment Removal	SD-E-1

3.4.1 Baseline Alternative

For this alternative, the Cape Horn and Scott dams would be improved to address major operational or safety issues required to ensure an additional 30 years of operations. The baseline alternative is intended to represent the existing facility conditions and operations with minimal improvements to ensure reliable, continued operations.

3.4.2 Alternative 1 – Provide Volitional Fish Passage

This alternative would consist of providing volitional fish passage for both upstream and downstream fish migrants through the project. For Cape Horn Dam, it was assumed that the existing upstream fishway would be improved to optimize fish passage conditions, as described for Option A. This work could include repairing damaged concrete surfaces, replacing aging mechanical equipment, and upgrading the electrical/instrumentation systems. Similarly, the existing fish screen structure located on the intake of the diversion tunnel would be improved, as presented in Option B. The fish screens would require structural modifications to improve reliability during heavy debris conditions. The existing air cleaning system would also require upgrades along with the instrumentation system designed to monitor and protect the intake and screening systems. The current operations would be maintained, with the diversions to the powerhouse, deliveries to the Potter Valley Irrigation District, and releases to the East Fork Russian River.

At Scott Dam, Option A1 would be implemented for upstream fish passage. This option would consist of a new volitional fish passage facility located on the left abutment of the dam. The fishway would allow upstream migrants to enter the fishway at the base of the dam and progress upstream to the reservoir. Mechanical systems would be required at the fishway exit to accommodate the full range of reservoir fluctuations. Option B1, consisting of a corner collector, would be implemented for downstream fish passage. The corner collector would be located on the right abutment of the dam. Downstream migrants would be collected using a fish screen located within the corner collector. The screened water would be routed to the existing lower outlet structure and valve house. The amount of flow entering the corner collector would be controlled through the existing valve house. Similar to Cape Horn Dam, the current operation of Scott Dam would be maintained, providing stored water for downstream diversion and power production at Cape Horn Dam.

3.4.3 Alternative 2 – Provide Fish Passage

Alternative 2 is nearly identical to Alternative 1 with the exception that Option A2, a trap-and-haul facility, would be provided at Scott Dam instead of the volitional fishway. The trap-and-haul facility would be located on the left abutment of the dam. Upstream migrants would enter the fishway exit and continue up to a holding pool where they would be crowded into a fish hopper, then loaded into a truck for upstream transport and release. The trap-and-haul facility would not require the complicated mechanical equipment required to provide volitional fish passage over the full range of reservoir levels. The remaining system components as well as system operation would identical to those of Alternative 1.

3.4.4 Alternative 3 – Partial Decommissioning

This alternative was developed assuming the Potter Valley Project diversions would be reduced as necessary to maintain higher flows within the Eel River during critical fish migration periods. With this alternative, the existing upstream fishway at Cape Horn Dam would be maintained with essentially no improvements. Upstream fish migrants would continue to use the volitional passage route through the fishway from the dam tailrace to the forebay. Similarly, the diversion intake and fish screen would be maintained. For these structures, modifications to improve the structural integrity of the system as well as to improve the screen cleaning and monitoring would be made.

For Scott Dam, Option C, consisting of partial removal of Scott Dam, would be implemented. This consists of removing the existing spillway gates and lowering the spillway to provide essentially an overflow spillway section. A portion of the spillway structure would be lowered to provide a concentrated location for downstream migrant passage over the dam into the tailrace. The primary objective of this alternative would be to maintain and stabilize the existing sediment within Lake Pillsbury reservoir. The low-level outlet would be used only for draining the reservoir for dam safety purposes, if required. With the spillway modifications, the dam would operate essentially as a run-of-river facility.

3.4.5 Alternative 4 – Full Decommissioning with Sediment Management

With this alternative, Cape Horn Dam including the dam, diversion intake and screens, and main dam section would be removed (Option D). The upper level of the fish ladder would be removed, but the lower level would be maintained to provide fish passage up to the existing fish hatchery. A new water intake structure and pipeline would be required to deliver water to the fishway and the hatchery. Alternatively, the entire hatchery facility could be decommissioned and removed along with the entire fishway structure. The intake structure and fish screen structure would be removed and concrete plugs placed in the diversion tunnel. The powerhouse would also be removed. Review of aerial photos indicates that a possible onsite disposal site may be available on the right abutment upstream from the existing dam. The concrete and earthfill material could be disposed of at this location, with the structural steel, mechanical equipment, and electrical debris disposed of at an offsite location. The river channel upstream and downstream from the dam site would be restored to its natural alignment and grade. Sediment deposits outside the natural channel alignment would be stabilized and maintained in place. Full planting of the riparian and overbank areas would be completed as part of the river channel restoration.

With this alternative, Scott Dam including the dam, low level outlet, and associated structures would be removed (Option D). A new river channel would be excavated through the reservoir. This would require excavation through the large sediment deposits located within the reservoir. The remaining sediment would be stabilized in place and replanted. When completed, Alternative 4 would provide a fully connected river channel from downstream of Cape Horn Dam to upstream of Scott Dam. With this alternative, all ability to divert flows to the Potter Valley Powerhouse would be eliminated.

3.4.6 Alternative 5 – Full Decommissioning with Sediment Removal

Alternative 5 is essentially identical to Alternative 4 except that the sediment located in the reservoirs above Cape Horn and Scott Dams would be excavated and disposed of in the overbank areas or at an offsite location, depending on the reservoir being excavated. For Cape Horn Dam (Option E), the amount of sediment within the existing reservoir is relatively limited. Excavation and offsite disposal of this material would not be as extensive as the excavation that would be associated with Scott Dam. It is likely that the excavated sediment at Cape Horn Dam could be disposed of on the right abutment overbank areas within the existing reservoir bank that would be exposed with the dam removal.

As discussed under Scott Dam, Option E, removal of the sediment within Lake Pillsbury would be very costly and is infeasible. Simply finding an area within the proximity of the reservoir site where this amount of material could be placed would be very difficult. The excavation and transport costs associated with removing this material would be excessive. Alternative 5 was developed to estimate the level of effort and the capital cost that would be required to remove the accumulated sediment.

3.4.7 Alternative 6 – Scott Dam Full Decommissioning with Sediment Management and Cape Horn Dam Partial Decommissioning

Alternative 6 consists of a partial decommissioning of Cape Horn Dam and full decommissioning of Scott Dam with sediment management. Under this alternative, the Potter Valley Project diversions would be reduced as necessary to maintain higher flows within the Eel River during critical fish migration periods. With this alternative, the existing upstream fishway at Cape Horn Dam would be maintained with essentially no improvements. Upstream fish migrants would continue to use the volitional passage route through the fishway from the dam tailrace to the forebay. Similarly, the diversion intake and fish screen would be maintained. For these structures, modifications to improve the structural integrity of the system as well as to improve the screen cleaning and monitoring would be made.

For Scott Dam, the dam, low-level outlet, and associated structures would all be removed (Option D). The existing dam, low level intake, valve house, and related structures would be completely removed. A new river channel would be established through the reservoir area and would be excavated through the reservoir with the material disposed of in the river overbank areas. The remaining sediment would be maintained within the reservoir. This would require selected excavation to bench and stabilize the deposited materials. Both structural and vegetative erosion control measures would be required to provide effective stabilization of the sediment. However, it could still be expected that some of this material would be eroded and transported downstream during large flood events. Alternative 6 was developed to estimate the level of effort and the capital cost that would be required to maintain the ability to divert water to Potter Valley, while at the same time providing volitional fish passage through the rehabilitated natural river system upstream of Cape Horn Dam.

4.0 Alternatives Evaluation

4.1 Introduction

Section 4 presents a general review and evaluation of the alternatives developed and presented in Section 3. The evaluation presented in this section is intended to provide a general overview of the challenges and risks associated with each alternative.

4.2 Preliminary Cost Estimates

4.2.1 General Approach

The American Association of Cost Engineering (AACE) provides guidelines for development of cost estimates for various levels of project definition (see Table 4-1).

Table 4-1. American Association of Cost Engineering Guidelines

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges (a)	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 (b)
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study of Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Notes:

(a) The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the dost estimate after application of contingency (typically at a 50% level of confidence) for give scope.

(b) If the range index value of “1” represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

Source: AACE International Recommended Practice No. 17R-97

For this project, Class 4 cost estimates have been prepared; these are also called feasibility level estimates, as defined by AACE International. This level of estimates is deemed appropriate for the feasibility design level, which corresponds to a range of 1% to 15% level of design development. Class 4 costs estimates are prepared for several purposes, such as detailed strategic planning, business development, project screening, alternative scheme analysis, confirmation of economic or technical feasibility, and preliminary budget approval.

4.2.2 Basis of Cost Estimates

McMillen Jacobs developed feasibility level design details for the options outlined in the previous sections. To support the initial cost estimate preparation, past project data were used to determine an order-of-magnitude level cost estimate for each option. To prepare the cost estimates presented herein, our specific past project experience was used, along with published costs for constructed fish passage facilities. In addition, dam decommissioning costs were obtained (Oldham, 2009; Randle et al., 2015). Table 4-2 presents a summary of the anticipated dam-specific option cost estimates. Table 4-3 presents the cost estimates for the system alternatives comprised of combinations of options identified for each dam.

Table 4-2. Summary of Preliminary Dam Options Order-of-Magnitude Cost Estimates

Option No.	Description	Construction Cost[1]	Total Project Cost[2,3]
	Cape Horn Dam		
	Baseline	$1,000,000[4]	$1,500,000
A	Improve Upstream Fish Passage	$2,000,000	$2,600,000
B	Improve Downstream Fish passage	$2,000,000	$2,600,000
C	Partial Decommissioning	$5,000,000	$6,500,000
D	Full Decommissioning with Sediment Management	$30,000,000	$39,000,000
E	Full Decommissioning with Sediment Removal	$40,000,000	$52,000,000
	Scott Dam		
	Baseline	$1,000,000[4]	$1,500,000
A	Provide Upstream Fish Passage		
A1	Volitional Fish Ladder	$20,000,000	$26,000,000
A2	Trap and Haul	$10,000,000	$13,000,000
B	Provide Downstream Fish Passage		
B1	Corner Collector	$25,000,000	$32,500,000
B2	Floating Surface Collector	$35,000,000	$45,500,000
B3	Tributary Collector	$35,000,000	$45,500,000
C	Partial Decommissioning	$10,000,000	$13,000,000
D	Full Decommissioning with Sediment Management	$50,000,000	$65,000,000
E	Full Decommissioning with Sediment Removal[5]	$86,500,000	$112,400,000

1. Order of magnitude cost estimates based on similar projects at hydroelectric and dam projects.
2. Estimated construction costs plus engineering, planning, environmental, permitting, and construction management equal Total Project Costs. The construction cost was increased by a factor of 30% to estimate the Total Project Costs.
3. Level of accuracy is -25/+50 percent for the cost estimates.
4. Assumed construction value to maintain existing facilities in operation. Field review and assessment of existing facilities and equipment would be required to refine the baseline cost assumptions.
5. Total Project Cost for Scott Dam Option E was calculated by adding the estimated construction cost for sediment management determined by EAG (2018) to the Total Project Cost for Scott Dam Option D. The Construction Cost for Scott Dam Option E was then back-calculated by dividing the Total Project Cost for Scott Dam Option E by 130%.

Table 4-3. Project Alternatives Preliminary Cost Estimates

Alternative No.	Description	Total Project Cost[1,2]
	Baseline	$3,000,000
	Cape Horn Dam - Baseline	
	Scott Dam - Baseline	
1	**Provide Volitional Fish Passage**	$63,700,000
	Cape Horn Dam – Option A	
	Cape Horn Dam – Option B	
	Scott Dam – Option A1	
	Scott Dam – Option B1	
2	**Provide Fish Passage**	$50,700,000
	Cape Horn Dam – Option A	
	Cape Horn Dam – Option B	
	Scott Dam – Option A2	
	Scott Dam – Option B1	
3	**Partial Decommissioning**	$32,500,000
	Cape Horn Dam – Option C	
	Scott Dam – Option C	
	Scott Dam – Option A2	
4	**Full Decommissioning with Sediment Management**	$104,000,000
	Cape Horn Dam – Option D	
	Scott Dam – Option D	
5	**Full Decommissioning with Sediment Removal**	$164,400,000
	Cape Horn Dam – Option E	
	Scott Dam – Option E	
6	**Scott Dam Full Decommissioning with Sediment Management and Cape Horn Dam Partial Decommissioning**	$71,500,000
	Cape Horn Dam – Option C	
	Scott Dam – Option D	

1. Total Project Costs for each alternative were developed by adding the option costs presented in Table 4-2.
2. Level of accuracy is -15/+50 percent for the cost estimates.

4.2.3 Precision of Cost Estimates

As stated above, a Class 4 cost estimate has been prepared for this project. Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the complexity of the project, appropriate reference information, and inclusion of an appropriate contingency determination. For this project, a 30% contingency has been applied to the construction costs and an appropriate accuracy range of -15% to +50% is assumed by McMillen Jacobs.

4.3 Evaluation Tools

Two evaluation tools were developed to aid in the evaluation and comparison of options and subsequent formulated alternatives: (1) an evaluation summary table, which outlines the basic advantages, disadvantages, beneficial use, and overall cost for each alternative; and (2) an evaluation matrix designed to provide a side-by-side comparison of each alternative using a wide range of evaluation criteria. The first step was to prepare the summary evaluation table and matrix for each of the options identified for Cape Horn Dam and Scott Dam (see Tables 4-13 and 4-14). This provides an evaluation of each option associated with the specific project, gaining an understanding of the option as it applies to the dam. A comparison of specific options applicable to each dam can be made from this initial evaluation. The evaluation was then repeated considering the alternatives developed for the overall project (see Tables 4-15 and 4-16). A brief summary of each of these tools is presented in the following paragraphs.

4.3.1 Evaluation Summary Table

Table 4-14 was organized to illustrate the major features of the options, including the following:

- Advantages and disadvantages associated with each option.
- General consideration of the anticipated capital and operation and maintenance costs.
- Comments on a specific feasibility of the option and operational considerations.

The summary table was completed first for the options identified for each dam. This provides a clear understanding of each option as it relates to the specific dam, as illustrated in Table 4-14. The analysis was then applied to each alternative, as shown in Table 4-16. As discussed previously, the alternatives consist of the site-specific options identified for each dam. The alternatives analysis was completed focusing on the configuration considering both dams and the combined PVP operation.

4.3.2 Evaluation Matrix

A range of criteria was developed and organized in a matrix, as illustrated in Table 4-13. The intent of the evaluation matrix is to provide a snapshot comparison of the options and alternatives. These criteria are grouped into major categories designed to capture the alternative's development and implementation. A description of each criterion is presented in the following paragraphs.

<u>Biological Efficiency</u>

This criterion presents a measure of the ability of the proposed option to attract, guide, and pass fish over the dam. For upstream fish migrants, measures of success include: far-field attraction, which is the ability to attract fish from the river to an area near the fishway entrance; near-field attraction, which represents the ability of the fishway entrance flow conditions to bring fish into the fishway; entrance conditions and orientation; fishway passage efficiency; and the fishway exit conditions including fallback potential and resting areas. Similar measures are used for downstream fish passage, which are designed to attract and bypass downstream migrants.

Constructability Challenges

In some cases, the construction challenges associated with a specific option or alternative can lead to elimination of the option or alternative due to insurmountable construction challenges, such as lack of space to build a new facility, or geotechnical stability issues. This criterion (Table 4-4) is intended to identify those construction challenges that could lead to such a fatal flaw, which would prevent selection of the proposed option or alternative.

Table 4-4. Constructability Subcriteria

Subcriteria	Definition
Space Availability	Determines if sufficient space is available to support construction of the project features.
Access Availability	Determines if adequate routes are available to access the site and complete the project construction.
Geotechnical Stability	Considers potential geotechnical stability issues that could impact the project construction such as unstable slopes or unsuitable foundation materials.
Utilities Available	Determines if utilities such as power, water, and sanitary facilities are available to support the project construction.
In Service Date	Reflects how quickly the alternative could be implemented and brought online.
Dewatering Conditions	Considers the potential dewatering issues associated with the site such as rock foundation versus a permeable gravel and cobble subsurface.

Environmental Impact – During Construction

This criterion (Table 4-5) is intended to identify environmental impacts during construction that could make the project difficult or costly to construct or difficult to permit. Similar to the analysis for constructability challenges, this analysis is intended to identify potential fatal flaws that would prevent the alternative from being implemented. These criteria would be applied considering only the construction phase of the alternative implementation. Potential long-term, post-construction impacts to these areas are presented with the next criteria group.

Table 4-5. Environmental Impact during Construction Subcriteria

Subcriteria	Definition
Riparian Areas	Determines if the construction activities would impact existing riparian areas within the alternative’s footprint.
Water Quality	Considers potential impacts to Eel River water quality due to construction activities.
Wildlife	Determines if wildlife movement and uses would be impacted during construction such as access to the creek, forage areas, etc.

Subcriteria	Definition
Aesthetics	Considers aesthetic impacts by the construction activities and associated disturbances.

Environmental Impact – Post-Construction

Post-construction environmental considerations are important to ensure that project configuration and operation have minimal impact to the natural resources and environment. This criteria group (Table 4-6) is designed to identify potential long-term impacts to the same subcriteria presented in the previous paragraph.

Table 4-6. Environmental Impact Post-Construction Subcriteria

Subcriteria	Definition
Riparian Areas	Determines if riparian areas would be permanently impacted by project construction and operation.
Water Quality	Considers if facility operation and maintenance would impact the receiving river water quality.
Wildlife	Determines if normal wildlife movement and uses would be impacted by the project location, footprint, and operation.
Aesthetics	Considers if the aesthetic value of the project site would be permanently impacted by the completed project.

Operational Impact

The operational criteria (Table 4-7) are intended to capture the potential impacts of operations under the option or alternative operation as well as overall general operation complexity and challenges.

Table 4-7. Operational Impact Subcriteria

Subcriteria	Definition
Water Storage	Operational requirements to effectively store and release water for downstream water uses.
Sediment	Ability to pass sediment loads or sufficient storage allocated for sediment accumulations within the reservoir.
Hydro Generation	Ability to maintain operation of the existing powerhouse
Debris Handling	Allows effective debris handling and exclusion from the intake tower.
Spillway Releases	Provides sufficient capacity and simplicity to pass the Probable Maximum Flood (PMF) as well as the full range of flood event flows.
Water Quality	Impact of storage releases on downstream water quality in the Eel River.

Design Approach

The design approach criteria (Table 4-8) are intended to determine which options and alternatives would be the most successful at developing relatively simple system designs with proven technologies. In general, the increasing level of design complexity could result in higher levels of operation and maintenance.

Table 4-8. Design Approach Subcriteria

Subcriteria	Definition
Design Complexity	In general, determines how complex the facility design and required controls would be to operate the facility.
Proven Technology	Considers if the proposed design has been utilized successfully at multiple full-scale locations.
Compatibility with Other Facilities	Considers if the facility components would be compatible with other potential uses.
Flexibility for Adaptation Post-Construction	Ability to modify the constructed facility based on observed field operating conditions and future regulatory requirements.

Cost

This criteria group (Table 4-9) captures the anticipated capital, operation and maintenance, and overall anticipated life of the option or alternative. The intent of this criteria group is to determine which options and alternatives would provide the best value, considering all cost aspects.

Table 4-9. Cost Subcriteria

Subcriteria	Definition
Capital	Considers the anticipated level of capital investment including construction, engineering, planning, regulatory and permitting, and administration that would be associated with the alternative implementation.
Operation and Maintenance (O&M)	Evaluates the anticipated annual O&M level of effort and associated costs.
Certainty in Capital Estimate	Risk of site conditions or unknown factors that could result in an increase in capital costs.
Life Span	Considers the anticipated project life in years and potential major rehabilitation work that would be required during the project life to maintain effective operation.

Regulatory and Permitting

This criterion (Table 4-10) is intended to encompass the anticipated regulatory and permitting effort associated with each option and alternative. As a first step in the evaluation, any fatal flaws that would make an alternative unlikely to garner regulatory approval are identified. Once this initial screening is completed, then a ranking specific to the anticipated complexity and duration is made. Ultimately, the goal of this criterion is to distinguish between those alternatives that might have similar benefits, but to identify alternatives that could have significantly more streamlined regulatory requirements.

Table 4-10. Regulatory and Permitting Subcriteria

Subcriteria	Definition
Federal Energy Regulatory Commission (FERC)	Considers the anticipated complexity related to obtaining a new FERC license or surrendering the license as associated with project decommissioning.
Federal	Determines what level of federal regulatory coordination and permitting would be required.
State	Considers what level of state regulatory coordination and permitting would be required.
Local	Determines what level of local regulatory coordination and permitting would be required.

Safety Risk

This criteria group (Table 4-11) is intended to capture the inherent safety risk associated with the option or alternative as it relates to construction, operation, and overall dam safety.

Table 4-11. Safety Risk Subcriteria

Subcriteria	Definition
During Construction	When the facility would be under construction, considers if unique safety challenges would be present.
During Operation	Considers if project operation would present unique safety risks to the operators or the public.
Public	Potential risk to public safety associated with the project.

Ranking

A wide range of ranking techniques has been used in the application of an evaluation matrix. These techniques range from quantitative numerical ranking of individual criteria to qualitative general evaluation. Both approaches are designed to provide a comparison of the identified alternatives to support selection of a preferred alternative. For this feasibility study, the qualitative approach was applied using the following ranking system (Table 4-12).

Table 4-12. Alternative Criteria Ranking

Ranking	Description
Very Good	Would be successful or have no impact.
Good	Would have a high likelihood of success or minimal impact.
Average	Would have a moderate likelihood of success or a significant impact.

Ranking	Description
Poor	Would have a poor likelihood of success or a significant impact.

4.4 Alternatives Evaluation

Utilizing the evaluation criteria, a preliminary analysis was completed for each of the criteria groups. The evaluation provided a general ranking of the alternatives for comparison purposes. A brief discussion of each of the alternatives is presented in the following paragraphs.

4.4.1 Baseline

As discussed previously, the baseline alternative was developed to represent the existing project configuration and operations. The existing dam configuration and operating conditions would be maintained. As the feasibility analysis is advanced, a thorough evaluation of the existing infrastructure should be completed to determine the existing facilities' condition, life, and potential operation or dam safety issues, and to determine any modifications or improvements that should be incorporated to provide an effective and reliable system operation. To complete a comprehensive system assessment, the full project records and as-constructed drawings would be required from PG&E. For the purposes of this study effort, a baseline level of capital investment was assumed for Cape Horn and Scott dams.

4.4.2 Alternative 1 – Provide Volitional Fish Passage

Alternative 1 was developed to provide volitional fish passage over Cape Horn and Scott dams for upstream and downstream fish migrants. At Cape Horn Dam, the existing upstream fishway successfully provides upstream fish passage over the dam. The existing intake fish screen, with improvements, would also provide effective exclusion of downstream migrants from the intake and tunnel. Incorporation of system improvements designed to address deteriorating system components, to upgrade mechanical and electrical systems, and to provide long-term reliable operations would meet the objective of providing reliable volitional fish passage systems over the dams.

At Scott Dam, developing volitional fish passage conditions at the dam would be challenging, considering reservoir fluctuations. The upstream fishway would need to have a fishway exit designed to operate over the full range of reservoir elevations. This would require a pumped water supply, or a fishway with multiple exits and gates. The highly mechanical system would increase the capital cost.

This study effort did not include evaluating fish passage conditions downstream from Cape Horn Dam or between the two dams. This would require an in-depth analysis of the river flow and fish passage conditions as well as consideration for both habitat and stranding potential.

4.4.3 Alternative 2 – Provide Fish Passage

This alternative was developed to maintain current project operations and diversions while also providing fish passage over Cape Horn and Scott dams. The existing facilities at Cape Horn Dam would be improved to optimize fish passage conditions. These work activities would be completed within the footprint of the existing facilities with minimal constructability issues, impacts to the environment, and changes to project operations. The proposed modifications would provide more effective fish passage conditions with an expected improvement in the overall biological efficiency of the Cape Horn Dam facilities.

At Scott Dam, to maintain current project operations and primary function of water storage, the upstream fish passage facility would consist of a trap-and-haul facility. These types of facilities are quite common and are often used in applications where a volitional fishway is not feasible due to the dam height or extensive reservoir fluctuations. The site-specific characteristics of the left abutment would be the primary constructability challenge. Limited access and construction on relatively steep terrain would be required. A cofferdam would also be required to construct the fishway entrance. On the reservoir side, a new water supply intake with a deep intake would be required to supply water to the trap-and-haul facility. A new penetration through the dam and a submerged intake would require diving support to construct. Overall, the design of the trap-and-haul facilities would be relatively straightforward and would be based on proven technology.

The downstream fish passage facility at Scott Dam would be more difficult to design and construct. This facility would need to have a floating component to allow the facility to move with reservoir fluctuations. Fish would be collected on the floating structure, and then transported to the top of the dam for transfer and release. Most of the work effort would be completed in the wet, requiring extensive diving to construct. The nature of the work within the reservoir would also present a higher risk for constructability issues and potential environmental impacts during construction. More extensive protection measures would be required due to the in-river work.

From a biological perspective, the upstream fish passage facility would be expected to provide effective fish passage conditions. This type of facility has proven successful at a number of locations. The downstream fish passage facility would also be based on proven project experience. The success of such a facility at Scott Dam, however, would be based on site-specific characteristics, flow patterns within the reservoir, and fish behavior. The greatest risk would be associated with the fish behavior and potential for fish to simply not move into the collection facility. Post-construction monitoring and potential field modifications would be required.

Alternative 2 is designed to maintain current water storage operations and diversions to the Potter Valley Powerhouse. Project operations would not be impacted with this alternative.

4.4.4 Alternative 3 – Partial Decommissioning

Alternative 3 was developed to represent modifications of project operations to provide Eel River flows to optimize fish passage conditions downstream from Cape Horn Dam. At Cape Horn Dam, the existing facilities would be maintained in the current condition with minimal modifications incorporated to ensure reliable operations (see Cape Horn Dam, Option C). Reductions in diversions to the Potter Valley Powerhouse would be the main component of the partial decommissioning. At Scott Dam, the existing spillway would be lowered to provide a lower hydraulic drop to support direct passage of juvenile fish over the spillway as well as to provide for a volitional passage fishway. Reservoir operations would be changed to run-of-river, with the river flows passing over the spillway or through the fishway.

At Cape Horn Dam, this alternative would require minimal construction work activities. The limited modifications to the existing facilities would be implemented within the existing facilities' footprint. As a result, the environmental impacts during and post-construction would be minimal. The major operational impact would be to reduce diversions to Potter Valley Powerhouse and the resulting reductions in power generation and amounts of water available to downstream water users. Implementation of this alternative could be expected to increase passage efficiencies for both upstream and downstream migrants.

At Scott Dam, construction of the upstream passage fishway would require significant construction activities on the left abutment of the dam. The work effort would require clearing of the work area, installation of a cofferdam, and flow diversion. The reservoir side work could be scheduled to occur during the low reservoir and flow conditions, simplifying the work activities. The environmental impacts both during and post-construction would be minimal. Implementation of this alternative would have significant impacts on project operations. Water storage in Lake Pillsbury would be eliminated, with the project then being operated as a run-of-river project. The typical release and diversion of stored water would be eliminated. The addition of an upstream fishway and ability to safely pass the juvenile fish over the spillway would improve the passage conditions at the project.

4.4.5 Alternative 4 – Full Decommissioning with Sediment Management

This alternative would consist of full removal of the two dams and decommissioning of the project, as described in Option D for both dams. Alternative 4 would maintain the sediment within the reservoirs. At Cape Horn Dam, the natural river channel would be re-established through the reservoir reach. Sediment removed to reconstruct the channel would be placed in the river overbank areas. The new river channel and overbank areas would then be stabilized using both structural and vegetative techniques. A similar approach would be used at Scott Dam. The much larger volume of sediment within Lake Pillsbury would require more extensive channel work to recreate the natural river channel. The sediment stabilization work effort would also be much more extensive.

Sediment management is frequently a major concern in dam removal projects with little long-term knowledge and application of documented techniques available to resource managers. While system hydrology, sediment storage volume and sediment particle size generally dictate the approach to sediment management, stabilization of impounded sediments upstream of dam removal sites is usually addressed with a combination of management techniques (i.e. placement of stone, vegetation, grade control structures, etc.).

Alternative 4 would result in complete removal of the dams and would end diversions to the Potter Valley Powerhouse. The Eel River within the project reach would be returned to a free-flowing river system with unimpeded fish passage conditions for both upstream and downstream fish migrants. This alternative would result in major impacts to the Potter Valley Project generation and supplies to downstream users. Construction activities during the dam removal process would require extensive demolition, material excavation, and disposal. Much of this work activity could be managed to minimize impacts to the environment during the construction work activities. Identifying debris disposal sites for the concrete, soil, and sediment removed from the project to restore the natural channel would be one of the biggest challenges. At Cape Horn Dam, there may be sufficient area on the right abutment of the dam to dispose of the suitable materials. Scott Dam would have a much larger volume of debris requiring a more significant disposal area.

4.4.6 Alternative 5 – Full Decommissioning with Sediment Removal

This alternative would consist of the same components as Alternative 4 with the exception that the sediment behind each dam would be removed from the river channel. At Cape Horn Dam, the accumulated sediment volumes within the reservoir area could be excavated and placed on the right abutment of the dam. It is anticipated that the sediment volumes would be much smaller than for Scott Dam due to the relatively limited reservoir footprint.

While extensive sediment sampling would be required to confirm the presence, range and concentration of potential contaminants deposited behind each of the dams, similar contaminant studies as well as historical mining activities within the basin suggest the presence of contaminated soils behind each of the sites. If sediment could be safely removed and disposed of in suitable offsite locations, current sedimentation estimates for Lake Pillsbury suggest approximately 21,600 acre-feet of fill material behind the existing dam (over 34,000,000 cubic yards of material; would require over 1,700,000 truck-trips using 20-yard dump trucks).

At Scott Dam, it is unrealistic to consider removing the accumulated sediment. The cost associated with removing this material would far exceed the actual dam removal cost. Identifying a suitable site for the material would also be a challenge. Potential contaminated soils could also be present within the reservoir due to the historic mining activity within the watershed upstream from the dam. For these reasons, this alternative is not considered feasible and is provided only to estimate the full potential cost of sediment removal from Lake Pillsbury.

4.4.7 Alternative 6 – Scott Dam Full Decommissioning with Sediment Management and Cape Horn Dam Partial Decommissioning

Alternative 6 was developed to estimate the level of effort and the capital cost that would be required to maintain the ability to divert water to Potter Valley, while at the same time providing volitional fish passage through the rehabilitated natural river system upstream of Cape Horn Dam.

At Cape Horn Dam, the existing facilities would be maintained in the current condition with minimal modifications incorporated to ensure reliable operations (see Cape Horn Dam, Option C). Reductions in diversions to the Potter Valley Powerhouse would be the main component of the partial decommissioning. This alternative would require minimal construction work activities at Cape Horn Dam. The limited modifications to the existing facilities would be implemented within the existing facility's footprint. As a result, the environmental impacts during and post-construction would be minimal. The major operational impact would be to reduce diversions to Potter Valley Powerhouse and the resulting reductions in power generation and amounts of water available to downstream water users. Implementation of this alternative could be expected to increase passage efficiencies for both upstream and downstream migrants.

At Scott Dam, full decommissioning with sediment management would provide volitional fish passage through a natural river system. Alternative 6 would maintain the sediment within Lake Pillsbury. Sediment removed to reconstruct the channel would be placed in the river overbank areas. The new river channel and overbank areas would then be stabilized using both structural and vegetative techniques. The large volume of sediment within Lake Pillsbury would require extensive channel work to recreate the natural river channel. The sediment stabilization work effort would also be quite extensive.

Sediment management is frequently a major concern in dam removal projects with little long-term knowledge and application of documented techniques available to resource managers. While system hydrology, sediment storage volume and sediment particle size generally dictate the approach to sediment management, stabilization of impounded sediments upstream of dam removal sites is usually addressed with a combination of management techniques (i.e. placement of stone, vegetation, grade control structures, etc.).

Alternative 6 would result in complete removal of Scott Dam. The Eel River above Cape Horn Dam would be returned to a free-flowing river system with unimpeded fish passage conditions for both upstream and downstream fish migrants. This alternative would result in limited impacts to the Potter Valley Project generation and supplies to downstream users. Construction activities during the dam removal process would require extensive demolition, material excavation, and disposal. Much of this work activity could be managed to minimize impacts to the environment during the construction work activities. Identifying debris disposal sites for the concrete, soil, and sediment removed from the project to restore the natural channel would be one of the biggest challenges.

Table 4-13. Evaluation Matrix for Options at Cape Horn Dam and Scott Dam

	Cape Horn Dam & Collection Facilities						Scott Dam					
	Baseline	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**	**Baseline**	**Option A**	**Option B**	**Option C**	**Option D**	**Option E**
Option Detail	Maintain Current Operations; Structural and Safety Upgrades to Maintain *Status Quo* Operations	Improve Upstream Fish Passage	Improve Downstream Fish Passage	Partial Decommissioning	Full Decommissioning and Dam Removal w/ Sediment Management	Full Decommissioning/Dam Removal with Complete Sediment Removal	Maintain Current Operations; Structural and Safety Upgrades to Maintain *Status Quo* Operations	Provide Upstream Fish Passage	Provide Downstream Fish Passage	Partial Decommissioning	Full Decommissioning and Dam Removal w/ Sediment Management	Full Decommissioning/Dam Removal with Complete Sediment Removal
Biological Efficiency												
Far Field Attraction	Average	Good	NA	Good	NA	NA	Poor	Average	Average	Good	NA	NA
Near Field Attraction	Good	Good	NA	Good	NA	NA	Poor	Good	Good	Good	NA	NA
Entrance Conditions/Orientation	Good	Good	NA	Good	NA	NA	Poor	Good	Average	Good	NA	NA
Fishway Passage	Good	Good	Good	Good	NA	NA	Poor	Average	Good	Average	Good	Good
Fishway Exit Conditions Fallback Potential	Good	Good	NA	Good	NA	NA	Poor	Good	Good	Good	NA	NA
Constructability Challenges												
Space Availability	NA	Good	Average	Good	Average	Average	NA	Average	Poor	Poor	Poor	Poor
Access Availability	NA	Good	Average	Good	Average	Average	NA	Poor	Poor	Poor	Average	Average
Geotechnical Stability	NA	Good	Good	Good	Good	Good	NA	Average	Average	Average	Average	Poor
Utilities Available	NA	Good	Good	Good	Good	Good	NA	Poor	Poor	Poor	Poor	Poor
Dewatering Conditions	NA	Good	Average	Good	Average	Average	NA	Average	Poor	Poor	Poor	Poor
Environmental Impact – During Construction												
Riparian Areas	NA	Good	Good	Good	Good	Good	NA	Average	Good	Average	Good	Good
Water Quality	NA	Good	Good	Good	Good	Good	NA	Good	Average	Average	Good	Average
Wildlife	NA	Good	Good	Good	Good	Good	NA	Good	Good	Good	Good	Average
Aesthetics	NA	Average	Average	Average	Good	Good	NA	Average	Average	Average	Good	Average
Environmental Impact – Post Construction												
Riparian Areas	Average	Good	Good	Very Good	Good	Very Good	Average	Good	Good	Good	Good	Very Good
Water Quality	Average	Good	Good	Very Good	Good	Good	Average	Good	Good	Good	Good	Very Good
Wildlife	Average	Good	Good	Good	Good	Very Good	Average	Average	Good	Good	Good	Very Good
Stranding	Average	Good	Good	Very Good	Good	Good	Average	Good	Good	Average	Good	Good
Opportunity for Fish Assessment and Monitoring	Good	Good	Average	Average	Poor	Poor	Poor	Good	Good	Poor	Poor	Poor
Aesthetics	Average	Average	Average	Good	Good	Very Good	Average	Average	Average	Average	Average	Very Good
Operational Impact												
Fishway Headpond Control Requirements	Average	Good	Good	Good	NA	NA	NA	Poor	Average	Good	NA	NA
Flood Control	NA	NA	NA	NA	NA	NA	Good	Good	Good	Average	NA	NA
Power Production	Good	Good	Good	Poor	Poor	Poor	Good	Good	Good	Poor	Poor	Poor
Operational Reliability	Good	Good	Good	Good	NA	NA	Good	Good	Average	Good	NA	NA
Design Approach												
Design Complexity	NA	Good	Average	Average	Good	Average	NA	Average	Average	Average	Average	Poor
Proven Technology	NA	Good	Good	Good	Good	Good	NA	Good	Good	Average	Good	Average
Compatibility with Other Facilities	NA	Good	Good	Good	Poor	Poor	NA	Good	Average	Poor	Poor	Poor
Flexibility for Adaption Post-Construction	NA	Average	Average	Average	Poor	Poor	NA	Good	Good	Poor	Poor	Poor
Cost												
Capital	Good	Good	Average	Average	Poor	Poor	Good	Average	Average	Average	Poor	Poor
O&M	Average	Average	Average	Average	Average	Low	Average	Average	Average	Good	Average	Average
Certainty in Capital Estimate	Good	Good	Average	Average	Average	Poor	Good	Average	Average	Average	Poor	Poor
Life	20+	30	30	30	50	50	20+	30	30	30	30	30
Safety Risk												
During Construction	NA	Good	Good	Good	Good	Good	NA	Good	Average	Average	Average	Average
During Operation	Good	Good	Good	Good	NA	NA	Good	Good	Average	Good	Good	Good
Public	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
To Headworks Structure	Good	Good	Good	Good	NA	NA	Good	Good	Good	Good	NA	NA

Table 4-14. Evaluation Summary Table for Options at Cape Horn Dam and Scott Dam

Alternative	Title	Advantages	Disadvantages	Cost		Comments
				Capital*	O&M	
Cape Horn Dam & Collection Facilities – Baseline	Maintain Current Operations; Structural and Safety Upgrades to Maintain *Status Quo* Operations	• Unchanged public recreational areas, activities • Continued benefits to downstream water users (irrigation, municipalities) • Low capital cost • Maintains power generation and diversions to Potter Valley Powerhouse	• Does not address issues related to fish passage conditions downstream from Cape Horn Dam	$1,500.000	Moderate	Full evaluation of the existing dam facilities and power generation equipment required to verify capital cost.
Cape Horn Dam & Collection Facilities – Option A	Improve Upstream Fish Passage	• Potential increased resident/anadromous fish production • Modifications are to existing facilities with minimal environmental impact during or post-construction • Continued benefits to downstream water users (irrigation, municipalities) • Maintains power generation and diversions to Potter Valley Powerhouse	• Does not address issues related to fish passage conditions downstream from Cape Horn Dam	$ 2,600,000	Moderate	Existing upstream fishway would be improved to optimize fish passage conditions and reliability.
Cape Horn Dam & Collection Facilities – Option B	Improve Downstream Fish Passage	• Potential increased resident/anadromous fish production • Continued benefits to downstream water users (irrigation, municipalities) • Maintains power generation and diversions to Potter Valley Powerhouse	• Does not address issues related to fish passage conditions downstream from Cape Horn Dam	$2,600,000	Moderate	Existing intake fish screen would be improved to optimize fish passage conditions and reliability.
Cape Horn Dam & Collection Facilities – Option C	Partial Decommissioning	• May reduce some dam-specific operations, maintenance and safety concerns • Potential increased resident/anadromous fish production • Over time, may restore potions of ecosystem to pre-dam state • Maintains some level of diversions to Potter Valley Powerhouse during high flow conditions • Over time, may provide increased water quality • Would provide volitional fish passage conditions • Would address stakeholder concerns related to fish passage conditions downstream of Cape Horn Dam by bypassing more flow during critical fish passage periods	• Lost hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Reduced flexibility and quantity of inter-basin water transfers • Reduced flow diversion and subsequent impacts to downstream water users (irrigation, municipalities) • Requires ongoing operation and maintenance of the dam facilities • Reduces available revenue stream associated with Potter Valley diversion	$6,500,000	Moderate	Existing facilities would be upgraded to provide reliable operation. The flow diversion to Potter Valley would be reduced to provide more flow downstream of Cape Horn Dam during critical fish passage periods.
Cape Horn Dam & Collection Facilities – Option D	Full Decommissioning and Dam Removal w/ Sediment Management	• Would eliminate dam-specific operations, maintenance and safety concerns • Potential increased resident/anadromous fish production • Would restore historic ecosystem function & dynamics • Over time, may restore potions of ecosystem to pre-dam state • Would provide more flow downstream from Project for fish passage and habitat enhancement • Would provide a more "natural" water temperature profile w/o storage reservoir • Over time, may provide increased water quality • Over time, decreased permitting obligations, requirements (FERC) • Would address concerns related to fish passage conditions downstream of Cape Horn Dam by bypassing more flow during critical fish passage periods	• Lost hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Reduced flexibility and quantity of inter-basin water transfers • Dam removal and resulting material disposal • Assumed contaminated sediments (historical mining); riverine transport and/or disposal pre-and post-removal • Long-term sediment transport issues from modified landscape • Multiple long-term sediment stabilization management strategies • Changed public recreational areas, activities • Post-activity ecosystem monitoring, mitigation • Impacts to downstream water users (irrigation, municipalities) due to lost flow diversion to Potter Valley • Reduces available revenue stream associated with Potter Valley diversion	$39,000,000	Moderate to low	Ability to divert flows to Potter Valley is eliminated.
Cape Horn Dam & Collection Facilities – Option E	Full Decommissioning/Dam Removal with Complete Sediment Removal	• Would eliminate dam-specific operations, maintenance and safety concerns • May reduce some dam-specific operations, maintenance and safety concerns • Potential increased resident/anadromous fish production • Would restore historic ecosystem function & dynamics • Over time, may restore potions of ecosystem to pre-dam state • Would provide a more "natural" water temperature profile w/o storage reservoir • Over time, may provide increased water quality • Over time, decreased permitting obligations, requirements (FERC)	• Lost hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Reduced flexibility and quantity of inter-basin water transfers • Dam removal and resulting material disposal • Assumed contaminated sediments (historical mining); riverine transport and/or disposal pre-and post-removal • Requires off-site sediment disposal site with large potential cost • Changed public recreational areas, activities • Post-activity ecosystem monitoring, mitigation • Impacts to downstream water users (irrigation, municipalities) • Reduces available revenue stream associated with Potter Valley diversion	$52,000,000	Moderate to low	Ability to divert flows to Potter Valley is eliminated.

Alternative	Title	Advantages	Disadvantages	Cost		Comments
				Capital*	O&M	
		• Would address concerns related to fish passage conditions downstream of Cape Horn Dam by passing more flow during critical fish passage periods				
Scott Dam – Baseline	Maintain Current Operations; Structural and Safety Upgrades to Maintain *Status Quo* Operations	• Potentially-contaminated sediments undisturbed • Existing biological communities unchanged • Unchanged public recreational areas, activities • Continued benefits to downstream water users (irrigation, municipalities) • Would maintain storage for power generation and diversion to Potter Valley Powerhouse	• Continued sediment deposition and reduction in flow storage within the reservoir • No fish passage over Scott Dam to upper watershed	$1,500,000	Moderate	Full evaluation of the existing dam facilities is required to verify capital cost.
Scott Dam – Option A	Provide Upstream Fish Passage					
Option A1	Volitional Fishway	• Potential increased resident/anadromous fish production • Would maintain the current operation of the dam for water storage and release • Would provide volitional passage over the dam • Accessible from existing access roads • Would maintain storage for power generation and flow diversion to Potter Valley	• Requires extensive mechanical systems at the fishway exit to accommodate the reservoir fluctuation OR the reservoir level has to be maintained within a set range to support operation • May not be fully effective during summer periods due to change in water temperature due to the surface draw of the fishway and lower level release to the river • Dam height and resulting length of the fishway may limit fish passage for specific fish species or during warmer water periods • Would require extensive excavation and construction activities on the left abutment of the dam	$26,000,000	Moderate	
Option A2	Trap and Haul Fishway	• Would provide effective fish passage over the full range of reservoir elevations • Would allow collected fish to be transported and released at optimum locations upstream • Would provide ability to monitor and evaluate fish movement • Would utilize gravity water supply • Minimal power requirements • Proven technology and relatively simple design • Would maintain the current operation of the dam for water storage and release • Water supply intake could be positioned near the same elevation as the existing dam low level intake allowing the fishway water supply to match river temperatures	• Would require manpower and equipment to operate • Not a fully volitional fish passage system • Would require extensive excavation and construction activities on the left abutment of the dam • Would require a low-level water supply intake and associated dam penetration	$13,000,000	Moderate	
Scott Dam – Option B	Provide Downstream Fish Passage					
Option B1	Corner Collector	• Would provide operation over full range of reservoir elevations • Would utilize a gravity flow system by connecting to the existing low level outlet • Close to dam allowing more efficient transfer of collected fish to the top of the dam for transport • Would not require a guidance net • Would not be impacted by sediment accumulation within the reservoir • Would not impact current dam operation for water storage and release • Would maintain storage for power generation and diversions to Potter Valley Powerhouse	• May require an intake tower or fixed pipe connection to the low level outlet to fully collect fish. • Fish passage over the spillway will still occur during large flow events • Effective debris management will be required at the collector • Would require manpower and equipment to operate • Would require access across the top of the dam to access the collector • Would require in-water and extensive diving to construct • May not fully collect downstream migrants due to fish loss in reservoir	$32,500,000	High	

Alternative	Title	Advantages	Disadvantages	Cost		Comments
				Capital*	O&M	
Option B2	Floating Surface Collector	• FSC facilities have been constructed and operated at several facilities • Would not require modifications to the dam or the low-level outlet • Would allow positioning with the reservoir at optimum location for fish collection • Would provide operation over full range of reservoir elevations • Would not require physical connection to the low-level outlet • Would not impact current dam operation for water storage and release • Would minimize fish passage over the spillway • Would maintain storage for power generation and flow diversion to Potter Valley	• Would require a guidance net to direct fish to the FSC entrance • Debris accumulation on the net will require extensive maintenance • Would require fish transport from the collector to the top of dam • Would require extensive power to supply the pumps on the FSC • Would require in-water and diving to construct • May not fully collect downstream migrants due to fish loss in reservoir • Effective debris management will be required at the FSC • Would require manpower and equipment to operate	$45,500,000	High	
Option B3	Tributary Collector	• Would not require modifications to the dam or the low-level outlet • Would allow positioning near the upper end of the reservoir minimizing fish loss within the reservoir • Would provide operation over full range of reservoir elevations • Would not require physical connection to the low-level outlet • Would not impact current dam operation for water storage and release • Would minimize fish passage over the spillway • Would maintain storage for power generation and flow diversion to Potter Valley	• May require a guidance net to be effective which would be prone to debris accumulation and failure • Debris accumulation on the collector will require extensive maintenance • Would require fish transport from the collector to the top of dam or the reservoir bank • Would require extensive power to supply the pumps on the collector • Would require in-water and diving to construct • Would require manpower and equipment to operate	$45,500,000	High	
Scott Dam – Option C	Partial Decommissioning	• Potential increased resident/anadromous fish production • Would restore historic ecosystem function & dynamics • Over time, may restore potions of ecosystem to pre-dam state • May provide a more "natural" water temperature profile w/o storage reservoir • Over time, may provide increased water quality • Over time, decreased permitting obligations, requirements (FERC) • Would maintain potentially contaminated sediment in place behind dam	• Lost hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Potential Sacramento Pikeminnow expansion downstream • Dam removal and resulting material disposal • Assume contaminated sediments; riverine transport and/or disposal pre-and post-modifications • Long-term sediment transport issues from modified landscape • Changed public recreational areas, activities • Post-activity ecosystem monitoring, mitigation • Impacts to downstream water users (irrigation, municipalities) • Reduced flood-control options below system	$13,000,000	Moderate to low	Ability to store water for later diversion to Potter Valley Powerhouse would be eliminated or significantly impacted.
Scott Dam – Option D	Full Decommissioning and Dam Removal w/ Sediment Management	• Would eliminate dam-specific operations, maintenance and safety concerns • Potential increased resident/anadromous fish production • Would restore historic ecosystem function & dynamics • Over time, may restore potions of ecosystem to pre-dam state • Would provide a more "natural" water temperature profile w/o storage reservoir • Over time, may provide increased water quality • Over time, decreased permitting obligations, requirements (FERC)	• Lost hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Potential Sacramento Pikeminnow expansion downstream • Loose ability to store water and flow diversion to Potter Valley • Dam removal and resulting material disposal • Assume contaminated sediments; riverine transport and/or disposal pre-and post-removal • Long-term sediment transport issues from modified landscape • Changed public recreational areas, activities • Post-activity ecosystem monitoring, mitigation • Impacts to downstream water users (irrigation, municipalities) • Reduced flood-control options below system	$65,000,000	Moderate to low	Ability to divert flows to Potter Valley is eliminated.
Scott Dam – Option E	Full Decommissioning/Dam Removal with Complete Sediment Removal	• Same as listed for Option D • Fully restored natural channel	• Same as for Option D • Would require identification of site for sediment disposal • May encounter contaminated soils associated with historic mining activities upstream from the dam • Extremely high implementation cost • Estimated 34M cubic-yards of sediment; >1.7M truck-trips to remove/relocate material	$112,400,000	Moderate	Ability to divert flows to Potter Valley is eliminated.

*Capital Cost: Order of magnitude construction cost estimates based on similar projects at hydroelectric and dam projects.

Table 4-15. Evaluation Matrix for Project Alternatives (considering system of Cape Horn Dam and Scott Dam)

Option Detail	Baseline	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 5[1]
	Maintain Current Operations; Structural and Safety Upgrades to Maintain *Status Quo* Operations	Provide Volitional Fish Passage	Provide Fish Passage	Partial Decommissioning	Full Decommissioning and Dam Removal w/ Sediment Management	Full Decommissioning/Dam Removal with Complete Sediment Removal	Scott Dam Full Decommissioning with Sediment Management and Cape Horn Dam Partial Decommissioning
Biological Efficiency							
Far Field Attraction	Poor	Average	Average	Good	NA	NA	Good/NA
Near Field Attraction	Poor	Good	Good	Good	NA	NA	Good/NA
Entrance Conditions/Orientation	Poor	Good	Good	Good	NA	NA	Good/NA
Fishway Passage	Poor	Average	Average	Average	Good	Very Good	Good
Fishway Exit Conditions Fallback Potential	Poor	Good	Good	Good	NA	NA	Good/NA
Constructability Challenges							
Space Availability	NA	Average	Poor	Poor	Poor	Poor	Good/Poor
Access Availability	NA	Poor	Poor	Poor	Average	Average	Good/Average
Geotechnical Stability	NA	Average	Average	Average	Good	Poor	Good/Poor
Utilities Available	NA	Poor	Poor	Poor	Poor	Poor	Good/Poor
Dewatering Conditions	NA	Poor	Poor	Poor	Poor	Poor	Good/Poor
Environmental Impact – During Construction							
Riparian Areas	NA	Average	Good	Average	Good	Good	Good
Water Quality	NA	Good	Average	Average	Good	Average	Good/Average
Wildlife	NA	Good	Good	Good	Good	Average	Good/Average
Aesthetics	NA	Average	Average	Average	Good	Average	Average
Environmental Impact – Post-Construction							
Riparian Areas	Good	Good	Good	Good	Good	Very Good	Very Good
Water Quality	Average	Good	Good	Good	Good	Very Good	Very Good
Wildlife	Good	Average	Good	Good	Good	Very Good	Good/ Very Good
Stranding	Average	Good	Good	Average	Good	Very Good	Very Good/Good
Opportunity for Fish Assessment and Monitoring	Average	Good	Good	Poor	Poor	Poor	Average/Poor
Aesthetics	Average	Average	Average	Average	Good	Very Good	Good/Very Good
Operational Impact							
Fishway Headpond Control Requirements	Good	Poor	Average	Good	NA	NA	Good/NA
Flood Control	Good	Good	Good	Average	Poor	Poor	NA
Power Production	Good	Good	Good	Poor	Poor	Poor	Poor
Operational Reliability	Good	Good	Average	Good	NA	NA	Good/NA
Design Approach							
Design Complexity	Good	Average	Average	Average	Average	Poor	Average/Poor
Proven Technology	Good	Good	Good	Average	Average	Average	Good/Average
Compatibility with Other Facilities	Good	Good	Average	Good	Poor	Poor	Good/Poor
Flexibility for Adaption Post-Construction	Good	Good	Good	Good	Poor	Poor	Average/Poor
Cost							
Capital	Good	Average	Average	Average	Poor	Poor	Average/Poor
O&M	Good	Average	Average	Good	Average	Average	Average
Certainty in Capital Estimate	Good	Average	Average	Average	Poor	Poor	Average/Poor
Life	20+	30+	30+	30+	50+	50+	30
Safety Risk							
During Construction	Good	Good	Average	Average	Average	Average	Good/Average
During Operation	Good	Good	Average	Good	Good	Good	Good
Public	Good	Good	Good	Good	Good	Good	Good
To Headworks Structure	Good	Good	Good	Good	NA	NA	Good/NA

[1] Items in this column that are separated by a forward slash represent evaluations of the alternative with respect to Cape Horn Dam *before* the slash, and Scott Dam *after* the slash.

Table 4-16. Evaluation Summary for Project Alternatives (considering system of Cape Horn Dam and Scott Dam)

Alternative	Title	Advantages	Disadvantages	Cost		Comments
				Capital*	O&M	
	Baseline Maintain Current Operations; Structural and Safety Upgrades to Maintain *Status Quo* Operations	• Would maintain current water storage and diversion to Potter Valley • Would require minimal capital expenditures • Would provide upstream and downstream fish passage at Cape Horn Dam	• Would provide no fish passage at Scott Dam • Would not address potential fish passage issues in river channel downstream from Cape Horn Dam	$2,000,000	Moderate	Full evaluation of the existing dam facilities and power generation equipment required to verify capital cost.
1	Volitional Fish Passage	• Potential increased resident/anadromous fish production • Cape Horn dam modifications to existing facilities are limited in scope and will have minimal construction or environmental impacts • Would maintain current water storage and diversion to Potter Valley • Would provide upstream and downstream fish passage at Scott Dam over the full range of reservoir elevations • Would provide the ability to monitor and evaluate fish migration • Downstream fish passage facilities are close to the dam providing access for fish transfer and release • Fish passage facilities will not be impacted by sediment accumulation in the reservoir • Would not require a guidance net for the downstream fish passage facilities	• Would require extensive mechanical systems at the fishway exit to accommodate reservoir fluctuations at Scott Dam OR the reservoir elevation has to be maintained within a set range to support operation • May not be fully effective at Scott Dam due to changes in water temperature between fishway and river • Dam height and resulting length of the fishway may limit fish passage for specific fish species or during warmer water periods • May require an intake tower or fixed pipe connection to the low level outlet to fully collect fish • Fish passage over the spillway will still occur during large flow events • Effective debris management required at the collector • Would require manpower and equipment to operate corner collector • Would require extensive in-water work and diving to construct	$63,700.000	High	
2	Provide Fish Passage	• Potential increased resident/anadromous fish production • Cape Horn dam modifications to existing facilities are limited in scope and will have minimal construction or environmental impacts • Would maintain current water storage and diversion to Potter Valley • Would provide upstream and downstream fish passage at Scott Dam over the full range of reservoir elevations • Would provide ability to monitor and evaluate fish migration • Downstream fish passage facilities are close to the dam providing access for fish transfer and release • Fish passage facilities are not impacted by sediment accumulation in the reservoir • Would not require a guidance net for the downstream fish passage facilities • Would utilize a gravity water supply • Water intake for upstream fish passage facility can be located near the same elevation as the existing dam low level allowing the fishway water supply to match river temperatures	• Would require manpower and equipment to operate • Not a fully volitional fish passage system • Would require a low-level water supply intake and associated dam penetration • May require an intake tower or fixed pipe connection to the low level outlet to fully collect fish • Fish passage over the spillway will still occur during large flow events • Effective debris management required at the collector • Would require manpower and equipment to operate corner collector • Would require extensive in-water work and diving to construct	$50,700,000	High	
3	Partial Decommissioning	• May reduce some dam-specific operations, maintenance and safety concerns • Potential increased resident/anadromous fish production • Would restore historic ecosystem function & dynamics • Over time, may restore potions of ecosystem to pre-dam state • May provide a more "natural" water temperature profile w/o storage reservoir • Over time, may provide increased water quality • Over time, decreased permitting obligations, requirements (FERC)	• Lost or minimized hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Potential Sacramento Pikeminnow expansion downstream • Dewatering costs and resulting lost storage ability • Dam removal and resulting material disposal • Changed public recreational areas, activities • Impacts to downstream water users (irrigation, municipalities) • Reduced flood-control options below system	$32,500,000	High	Ability to store water for later diversion to Potter Valley Powerhouse would be eliminated or significantly impacted.

Alternative	Title	Advantages	Disadvantages	Cost		Comments
				Capital*	O&M	
4	Full Decommissioning and Dam Removal w/ Sediment Management	• Would eliminate dam-specific operations, maintenance and safety concerns • Potential increased resident/anadromous fish production • Would restore historic ecosystem function & dynamics • Over time, may restore potions of ecosystem to pre-dam state • Would provide a more “natural” water temperature profile w/o storage reservoir • Over time, may provide increased water quality • Over time, decreased permitting obligations, requirements (FERC)	• Lost or minimized hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Unknown change to biological communities, ecosystem both upstream/downstream; few long-term studies on post-removal effects • Potential Sacramento Pikeminnow expansion downstream • Would eliminate ability to store water or to divert water to Potter Valley Powerhouse • Dam removal and resulting material disposal • Contaminated sediments; riverine transport and/or disposal pre-and post-removal • Long-term sediment transport issues from modified landscape • Changed public recreational areas, activities • Post-activity ecosystem monitoring, mitigation • Impacts to downstream water users (irrigation, municipalities) • Reduced flood-control options below system	$104,000,000	Moderate to low	Ability to divert flow to Potter Valley Powerhouse would be eliminated.
5	Full Decommissioning/ Dam Removal with Complete Sediment Removal	• Same as listed for Alternative 4 • Fully restored natural channel	• Same as for Alternative 4 • Would require identification of site for sediment disposal • May encounter contaminated soils associated with historic mining activities upstream from the dam • Extremely high implementation cost	$164,400,000	Moderate	Ability to divert flow to Potter Valley Powerhouse would be eliminated.
6	Scott Dam Full Decommissioning with Sediment Management and Cape Horn Dam Partial Decommissioning	• Would reduce some dam-specific operations, maintenance and safety concerns • Potential increased resident/anadromous fish production • Would restore historic ecosystem function & dynamics • Over time, may restore portions of ecosystem to pre-dam state • Would provide a more “natural” water temperature profile w/o storage reservoir • Over time, may provide increased water quality • Over time, decreased permitting obligations, requirements (FERC)	• Lost or minimized hydropower generation (corresponding impacts to use of fossil fuels, greenhouse gases, air pollution, non-renewable energy) • Potential Sacramento Pikeminnow expansion downstream • Dewatering costs and resulting lost storage ability • Dam removal and resulting material disposal • Changed public recreational areas, activities • Impacts to downstream water users (irrigation, municipalities) • Reduced flood-control options below system • Unknown change to biological communities, ecosystem both upstream/downstream; few long-term studies on post-removal effects • Contaminated sediments; riverine transport and/or disposal pre-and post-removal • Long-term sediment transport issues from modified landscape • Post-activity ecosystem monitoring, mitigation	$71,500,000	Moderate to High	Ability to store water for later diversion to Potter Valley Powerhouse would be eliminated.

*Capital Cost: Order of magnitude construction cost estimates based on similar projects at hydroelectric and dam projects.

4.5 Summary

A range of options was identified and evaluated for potential capital modifications at Cape Horn and Scott dams. These options included improving the existing fish passage facilities at Cape Horn Dam, implementing new upstream and downstream fish passage facilities at Scott Dam, partial decommissioning, and full decommissioning of the project. Each of the options was evaluated based on the site-specific characteristics of the dam using a wide range of criteria. The site-specific options were then combined to provide a range of system-wide alternatives for potential capital modifications at the two-dam Project.

Alternatives 1 and 2 would include upgrades to the existing fish passage facilities at Cape Horn Dam and construction of new fish passage facilities at Scott Dam. The primary objective of these alternatives was to maintain the current project operations and diversions to the Potter Valley Powerhouse. The addition of fish passage facilities at Scott Dam would allow the current water storage and release operations to be maintained. Alternative 2, consisting of a new trap-and-haul facility and a corner fish collector, would be the preferred traditional fish passage alternative at Scott Dam. The trap-and-haul facility would have the following advantages over the volitional fishway:

- The trap-and-haul facility would allow the water supply intake to be located at the same elevation in the reservoir as the existing dam low level outlet. This would provide a water supply to the fishway that would have the same approximate water temperature as the main river release from the low-level outlet. This design approach would eliminate any potential for fish to reject the fishway due to a change in water temperature.
- The trap-and-haul facility would allow the upstream migrants to be collected and released at the optimum upstream locations. The trap facility could also be used as a management tool to sort fish by destination to remove fish that may not be beneficial to pass upstream.
- The complicated mechanical systems required to operate the volitional fishway exit would not be required for the trap-and-haul facility. The full range of reservoir fluctuations could be easily accommodated with the trap-and-haul facility.

Alternative 3 would include a partial decommissioning of the project, allowing some level of diversions to the Potter Valley Powerhouse to be maintained. The existing fish passage facilities at Cape Horn Dam would be maintained with minimal improvements to maintain reliable operations. At Scott Dam, the dam height would be lowered to provide a suitable height for incorporation of a volitional fish passage facility. With this modification, the dam would operate as a run-of-river facility with a relatively constant water surface elevation to operate the volitional fishway exit. With this alternative, the storage function of Scott Dam would essentially be eliminated, which would impact the total volume of water that could be diverted to the Potter Valley Powerhouse. The Potter Valley Project would operate as a run-of-river facility with diversions to the Potter Valley Powerhouse occurring only during high flow periods. Additional flows would be passed downstream from Cape Horn Dam during critical fish passage conditions. The primary objective of this alternative would be to provide volitional fish passage and additional flow downstream from Cape Horn Dam without fully removing the dam. This alternative would have a lower capital cost than the cost of full dam removal and decommissioning.

Alternative 4 would include a full dam removal and project decommissioning with sediment management. With this alternative, the Eel River would return to natural flow conditions throughout the year. Removal of the dams would require an extensive capital investment, identification and permitting of a location for debris disposal, and extensive river channel restoration and sediment stabilization. With this alternative, all diversions to the Potter Valley Powerhouse would be eliminated.

Alternative 5 was developed to provide a cost estimate for full removal of sediment within the reservoirs. The majority of the work effort would be at Lake Pillsbury, which has extensive sediment deposits. It is also important to consider the potential for exposing contaminated soils within the sediment due to the historic mining activities that occurred upstream from the dam.

Alternative 6 was developed to estimate the level of effort and the capital cost that would be required to maintain the ability to divert water to Potter Valley, while at the same time providing volitional fish passage through the rehabilitated natural river system upstream of Cape Horn Dam. The alternative would include full decommissioning of Scott Dam, with sediment management (i.e. excavation, transport, and stabilization) within the reservoir.

5.0 Conclusions and Recommendations

5.1 Conclusions

This feasibility study was designed to identify and evaluate potential capital modification alternatives for Cape Horn and Scott dams. At Cape Horn Dam, there are existing upstream and downstream fish passage facilities that can be improved to optimize fish passage conditions and provide reliable operation. There are no fish passage facilities at Scott Dam. Consequently, new upstream and downstream fish passage facilities would be required at the dam for fish passage to begin there. The study was organized to develop and evaluate capital modification options for each dam, then combine these options to present capital modification alternatives for the project. A baseline alternative was developed representing the existing facilities with minimal improvements to ensure reliable operation. From this baseline condition, conventional fish passage alternatives were developed for the two-dam complex. For Alternatives 1 and 2, the intent was to maintain the current project operation and diversion to the Potter Valley Powerhouse.

Alternative 3 would include a partial decommissioning approach designed to maintain the Cape Horn diversion capability while also providing volitional fish passage at both dams. This would require modifying Scott Dam and eliminating the ability to store water in Lake Pillsbury. The primary benefits of this alternative would be to minimize the capital cost associated with decommissioning the project, provide fish passage, and allow some diversions to the Potter Valley Powerhouse to continue.

Alternatives 4 and 5 would include full dam removal and decommissioning of the project. Under Alternative 4, sediment would be maintained within Lake Pillsbury. The natural river channel would be re-established and the sediment stabilized within the river overbank areas. The extensive sediment deposition within Lake Pillsbury would require this type of approach. Removal of the accumulated sediment, as presented in Alternative 5, would be cost prohibitive and could expose potentially contaminated soils originating from historic mining activities within the upper watershed.

Alternative 6 is a combination of Alternatives 3 and 4, with partial decommissioning of Cape Horn Dam and full decommissioning of Scott Dam with sediment management. Under this alternative, the diversion capability of Cape Horn Dam would be maintained, as would volitional fish passage. In addition, Scott Dam would be fully decommissioned and sediment would be excavated, re-deposited, and stabilized within the reservoir, while a restored channel through the reservoir would be constructed. This would allow volitional passage of fish upstream of Cape Horn Dam through a natural river system.

5.2 Recommendations

The objective of this study was to identify and evaluate potential alternatives for capital modifications at Cape Horn and Scott dams. The analysis was not designed to select a recommended alternative; rather, the study identified the potential range of alternatives, the issues associated with each, and the potential costs. Starting with a baseline alternative that represents the existing facilities with minimal improvements, the alternatives represent increasing levels of improved fish passage conditions leading to the ultimate dam removal and project decommissioning. The alternatives are also presented to provide opportunities to provide fish passage while also maintaining diversions to the Potter Valley Powerhouse, to full elimination of these diversions and maintenance of natural river flow conditions in the Eel River.

The analysis did not attempt to address the estimated biological benefits associated with providing additional Eel River flows downstream from Cape Horn Dam.

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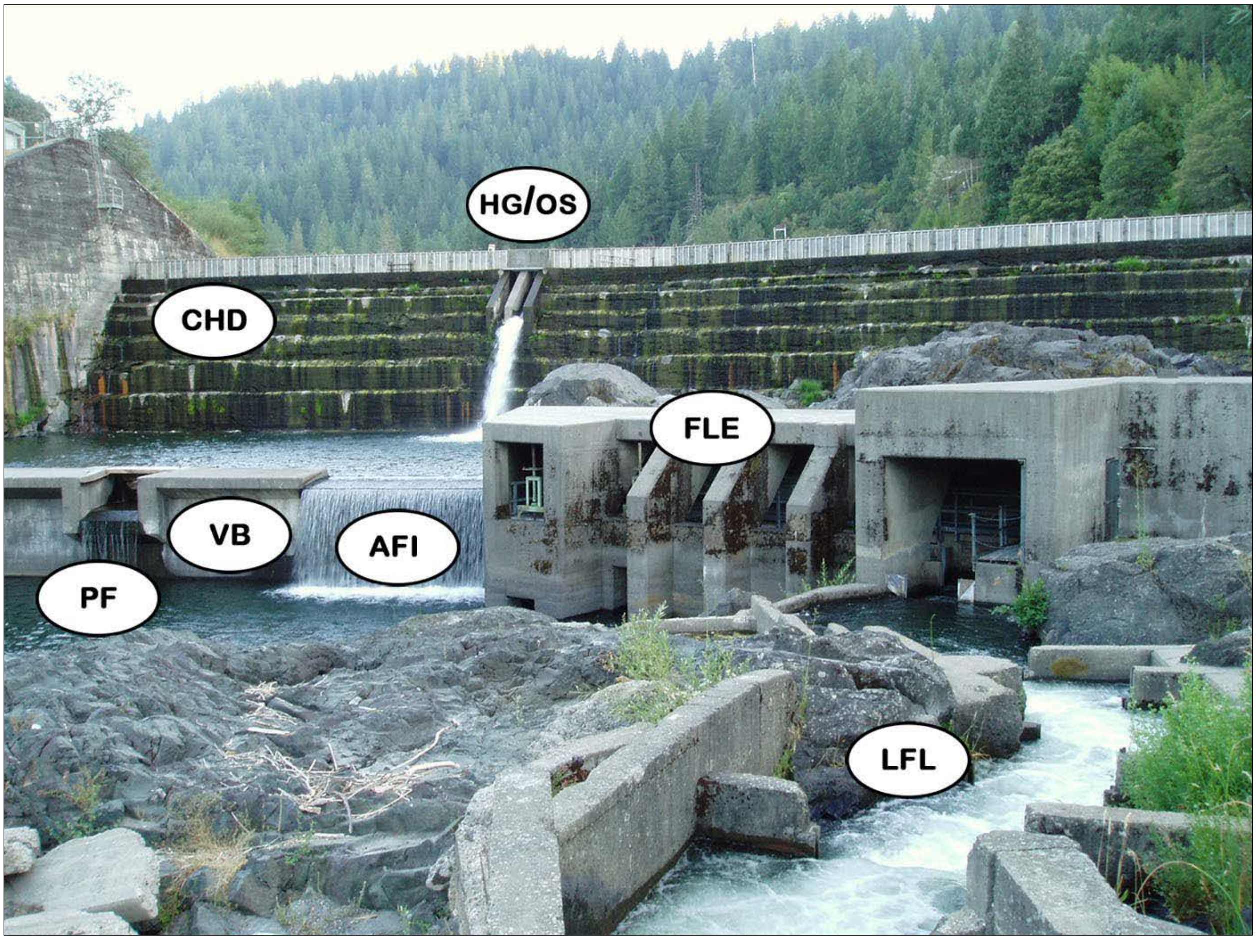
Appendices

Appendix A

Supplemental Data

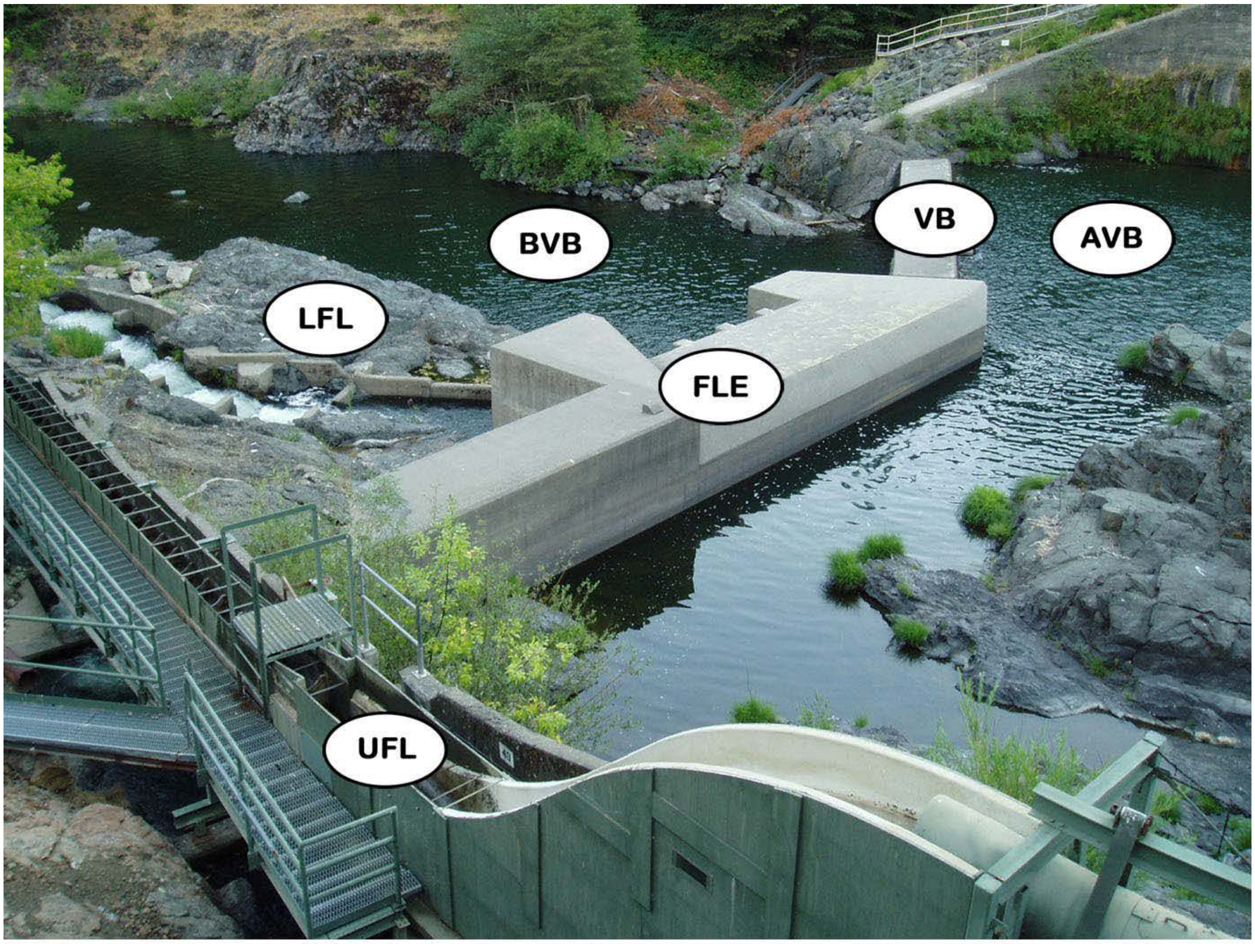


View Looking Upstream; Cape Horn Dam

LEGEND

AFI - supplemental attraction flow intake with fish screen
CHD - Cape Horn Dam (shown with 4-foot flash boards in place)
FLE - fish ladder entrance (*fish hotel, bunker*)
HG/OS - hydraulic gates with ogee spillway (east and west gates)
LFL - lower fish ladder
PF - Parshall flume
VB - velocity barrier (fish barrier)

Figure A-1. Cape Horn Dam (Source: PG&E - Pikeminnow Adaptive Management and Suppression Operation Plans; October 2015).



View Looking Downstream; Cape Horn Dam

LEGEND

AVB - suppression pool above the velocity barrier
BVB - suppression pool below the velocity barrier
FLE - fish ladder entrance (*fish hotel, bunker*)
LFL - lower fish ladder
UFL - upper fish ladder shown with ogee spillway and outmigrant *mini-ladder*
VB - velocity barrier (fish barrier)

Figure A-2. Cape Horn Dam (Source: PG&E - Pikeminnow Adaptive Management and Suppression Operation Plans; October 2015).

View Looking Upstream; Scott Dam Spillway

View Looking Downstream; Scott Dam Spillway Chute

Figure A-3. Scott Dam (Source: D. Hinton, B. Hughes and E. Zapel. 2015. Scott Dam Spillway – Comparing Physical Model Study. Hydrovision 2015 Presentation; Session Number 1l3. Portland, OR). http://www.nhcweb.com/upload/news/Scott_Dam_Spillway_-_HydroVision_2015_-_R1.pdf)

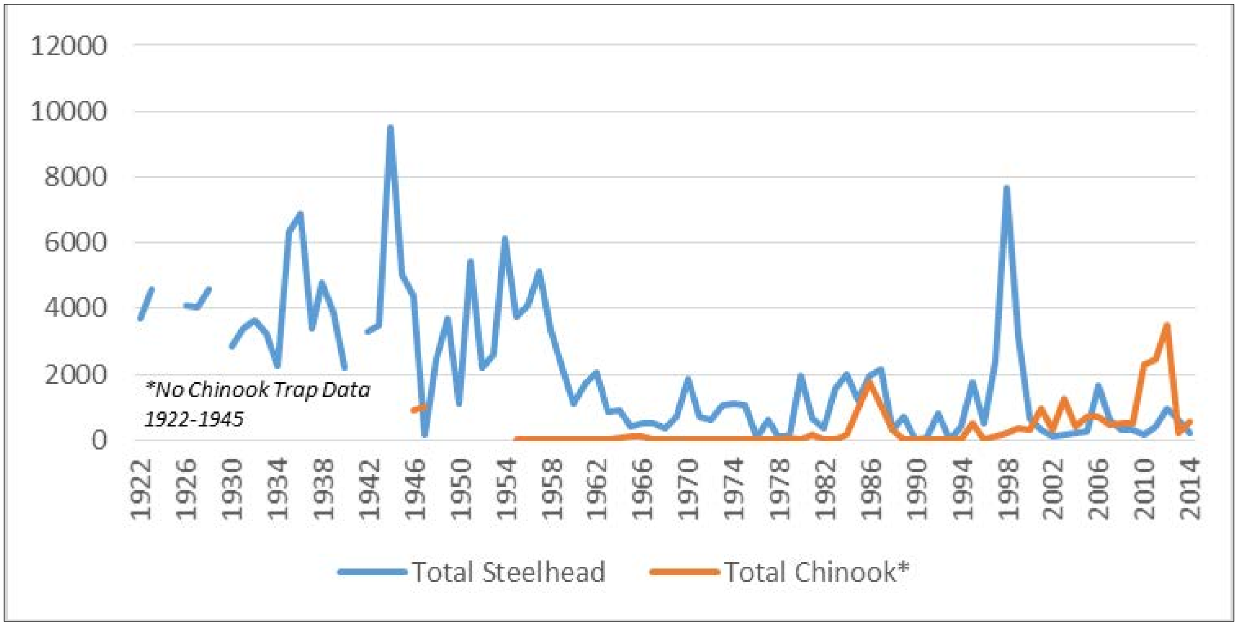


Figure A-4. Total Adult Steelhead and Chinook Trapped at Van Arsdale Fisheries Station; 1922–2014 (from CDFW counts)

Figure A-5. Upper Baker Lake Floating Surface Collector

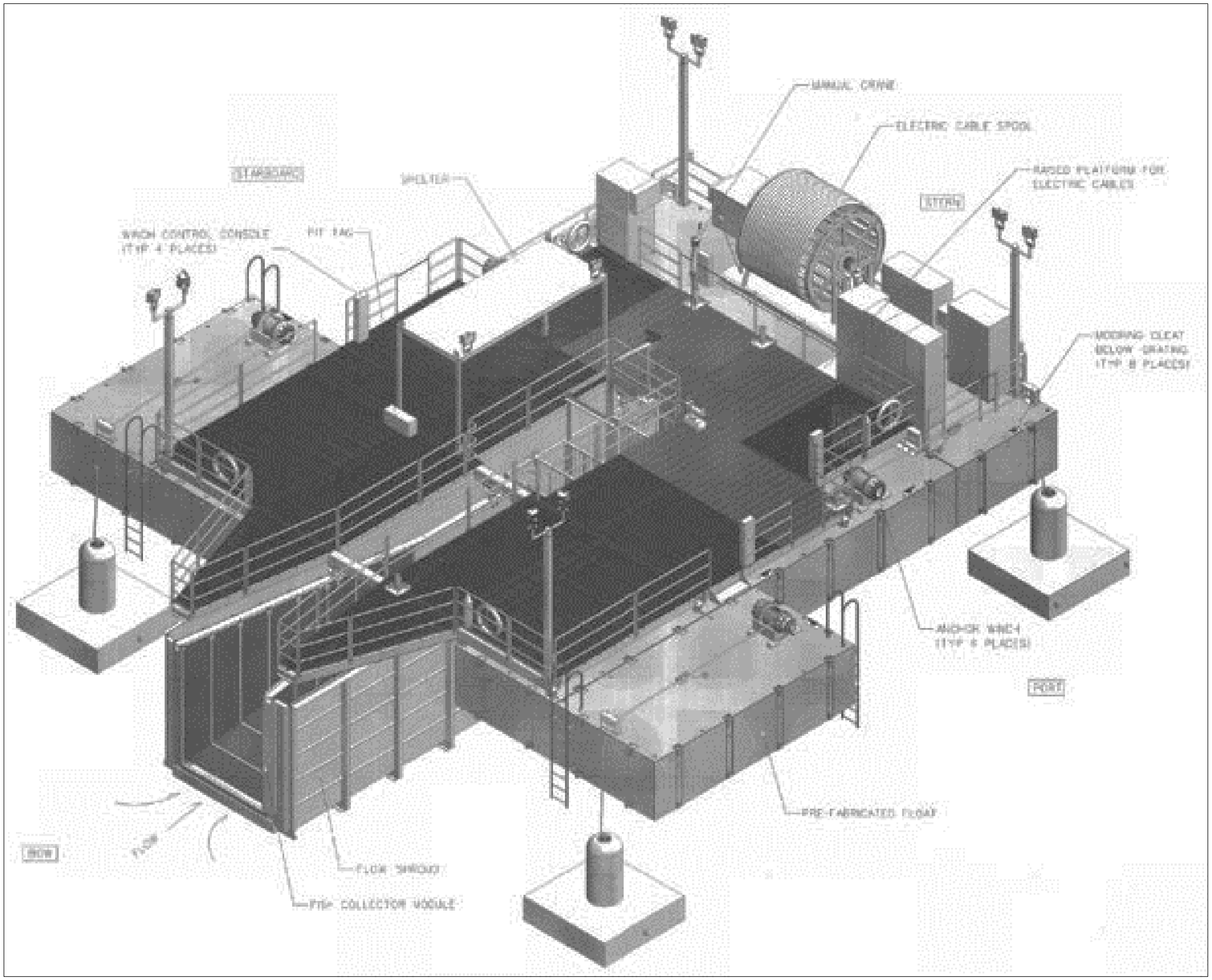


Figure A-6. Portable Floating Fish Collector

Table A-1. Number of Upstream Migrating Adult Steelhead *Oncorhynchus mykiss* and Chinook *O. tshawytscha* Trapped Annually at Van Arsdale Fisheries Station; 1990-2015 (Source: CDFW)

Steelhead			
Season	Number Wild	Number Hatchery	Total Count
1990/1991	19	12	31
1991/1992	26	34	60
1992/1993	52	771	823
1993/1994	23	11	34
1994/1995	116	318	434
1995/1996	158	1585	1743
1996/1997	104	407	511
1997/1998	175	2218	2393
1998/1999	355	7324	7679
1999/2000	189	2961	3150
2000/2001	250	391	641
2001/2002	226	82	308
2002/2003	99	3	102
2003/2004	149	0	149
2004/2005	234	0	234
2005/2006	184	69	253
2006/2007	492	1143	1635
2007/2008	423	199	622
2008/2009	305	10	315
2009/2010	324	0	324
2010/2011	166	0	166
2011/2012	423	0	423
2012/2013	934	1	935
2013/2014	609	0	609
2014/2015	215	0	215
10 year mean (2005-2015):			**550**
10 year STDEV:			448

Chinook			
Season	Number Wild	Number Hatchery	Total Count
1990/1991	na	na	0
1991/1992	na	na	5
1992/1993	na	na	4
1993/1994	na	na	1
1994/1995	na	na	21
1995/1996	525	0	525
1996/1997	26	0	26
1997/1998	106	1	107
1998/1999	141	59	200
1999/2000	232	107	339
2000/2001	223	80	303
2001/2002	641	314	955
2002/2003	268	61	329
2003/2004	997	236	1233
2004/2005	309	83	392
2005/2006	620	105	725
2006/2007	697	2	699
2007/2008	478	0	478
2008/2009	496	0	496
2009/2010	518	1	519
2010/2011	2314	0	2314
2011/2012	2436	0	2436
2012/2013	3471	0	3471
2013/2014	215	0	215
2014/2015	583	0	583
10 year mean (2005-2015):			**1194**
10 year STDEV:			1117

Table A-2. NOAA Biological Design Criteria; Anadromous Salmonid Fish Passage			
Criteria	**Units**	**Value**	**Comments**
Fishway Entrance			
Attraction Flow	%	5-10 % of fish passage design high flow	Attraction flow from the fishway entrance should be between 5% and 10% of fish passage design high flow for streams with mean annual streamflows exceeding 1000 cfs. For smaller streams, when feasible, use larger percentages (up to 100%) of streamflow. NMFS 4.2.2.3.
Hydraulic Head Drop	Ft	1 to 1.5	The fishway entrance hydraulic drop must be maintained between 1 and 1.5 feet, depending on the species present at the site, and designed to operate from 0.5 to 2.0 feet of hydraulic drop. NMFS 4.2.2.4.
Minimum Width	Ft	4	
Minimum Depth	Ft	6	The minimum depth can be varied with a telescopic gate to adjust to the entrance flow. NMFS 4.2.2.5.
Approach Conditions	n/a	-	Similar to ambient depth, velocity, flow direction, and turbulence, Per Bell, 1991.
Transport Velocity	Ft/s	1.5 to 4.0	NMFS 4.2.2.12.
Auxiliary Water Systems - Diffuser			
Diffuser bar clear spacing	Inch	1 max	If smaller species or life stage of fish is present, smaller clear spacing may be required. NMFS 4.3.2.
Diffuser velocity	Ft/s	0.5 max for horizontal diffusers 1 max for vertical diffusers	Velocity based on total diffuser panel area and should be nearly uniform. NMFS 4.3.2.1.
AWS Pool Energy Dissipation Factor	Ft-lb/s	16 max	NMFS 4.3.6.1.
Auxiliary Water Systems Intake – Fine Trash Racks			
Fine trash rack clear spacing	Inch	7/8 max	NMFS 4.3.3.
Fine trash rack Velocity	Ft/s	1 max	Calculated by dividing the maximum flow by the entire fine trash rack area. NMFS 4.3.3.
Slope	n/a	1:5 H:V max	Install fine trash rack at slope for ease of cleaning. NMFS 4.3.3.
Head differential across intake screen	Ft	0.3 max	NMFS 4.3.3.
Transport Channels			
Transport Velocity	Ft/s	1.5 to 4.0	NMFS 4.4.2.1.
Minimum Width	Ft	4	
Minimum Depth	Ft	5	

Table A-2. NOAA Biological Design Criteria; Anadromous Salmonid Fish Passage			
Criteria	**Units**	**Value**	**Comments**
Fish Ladder			
Vertical Slot Passage Corridor Width	ft	1.0 to 1.25	Slots should never be less than 1 foot wide for anadromous salmonids. NMFS 4.5.2.1.
Hydraulic drop between fish ladder pools	Ft	1 max	NMFS 4.5.3.1.
Flow Depth	Ft	1 min	Fishway overflow weirs should provide at least 1 foot of flow depth over the weir crest.
Minimum Pool Length	Ft	8	NMFS 4.5.3.3.
Minimum Pool Width	Ft	6	NMFS 4.5.3.3.
Minimum Pool Depth	Ft	5	NMFS 4.5.3.3.
Turning Pools	n/a	-	Turning pools should be at least double the length of a standard fishway pool, as measured along the centerline of the fishway flow path. NMFS 4.5.3.4.
Fish Ladder Pool Energy Dissipation Factor	Ft-lb/s	4 max	NMFS 4.5.3.5.
Fish Ladder Pool Freeboard	Ft	3 min	NMFS 4.5.3.6.
Orifice Dimensions	Inch	15 high 12 wide	The top and sides should be chamfered 0.75 inches on the upstream side, and chamfered 1.5 inches on the downstream side of the orifice. NMFS 4.5.3.7.
Change in Flow Direction greater than 60°	n/a	45° vertical miters or 2 foot vertical radius.	
Counting Stations			
Velocity through counting station	Ft/s	1.5	NMFS 4.6.2.1.
Counting Window Dimensions	Ft	5 wide Full water depth	NMFS 4.6.3.5.
Counting Window slot width	Inch	18 min	NMFS 4.6.3.6.
Picket Lead Angle of deflection	n/a	45° relative to the fishway flow	Provide picket leads upstream and downstream of counting window slot. Picket orientation, clearance, and maximum allowable velocity shall meet diffuser specifications. NMFS 4.6.3.7.
Combined head differential through *both* sets of pickets	Ft	0.3 max	NMFS 4.6.3.7.
Transition ramp slope	n/a	1:8 (V:H)	NMFS 4.6.3.8.

Table A-2. NOAA Biological Design Criteria; Anadromous Salmonid Fish Passage			
Criteria	**Units**	**Value**	**Comments**
Fishway Exit			
Hydraulic Drop	Ft	0.25 to 1.0	NMFS 4.7.2.1.
Length	n/a	2 standard ladder pools, min	NMFS 4.7.2.2.
Coarse Trash Rack Velocity	Ft/s	1.5	Velocity through the gross area of the coarse trash rack. NMFS 4.8.2.1.
Coarse Trash Rack Depth	n/a	Equal to the pool depth in the fishway.	NMFS 4.8.2.2.
Coarse Trash Rack Slope	n/a	1:5 H:V max	Install fine trash rack at slope for ease of cleaning. NMFS 4.8.2.3.
Coarse Trash Rack Bar Spacing	Inch	10 min if Chinook are present 8 min in all other instances 24 min for lateral support spacing	NMFS 4.8.2.5.
Coarse Trash Rack Orientation	n/a	45° relative to the fishway flow	NMFS 4.8.2.6.
Adult Trapping Systems			
Distribution Flume Dimensions	Inch	15 wide 24 tall	Horizontal and vertical radius of curvature should be at least 5 times flume width to minimize risk of fish strike injuries. NMFS 6.4.1.4.
Inflow	Ft/s	1 max	NMFS 6.4.1.6.
Holding Pond Volume	Ft^3	0.25 ft^3 per pound of fish.	For long term holding (greater than 72 hours), trap holding pool volumes should be increased by a factor of three. If water temperatures are greater than 50° F, the poundage of fish held should be reduced by 5% for each degree over 50° F. NMFS 6.5.1.2.
Holding Pond Flow	gpm	0.67 gpm per adult fish	For long term holding (greater than 72 hours), trap holding pool flow rates should be increased by a factor of three. NMFS 6.5.1.3.
Holding Pond Freeboard	Ft	5 min	NMFS 6.5.1.4.
Crowder Clear Bar Spacing	Inch	7/8 max	Side gaps must not exceed 1 inch. NMFS 6.5.1.6.
Hopper Water Volume	Ft^3	0.15 ft^3 per pound of fish.	NMFS 6.7.2.1.
Hopper Egress Opening	Ft^2	3 min	NMFS 6.7.2.5.

Table A-2. NOAA Biological Design Criteria; Anadromous Salmonid Fish Passage			
Criteria	**Units**	**Value**	**Comments**
Fish Screen and Bypass Facilities			
Screen Approach Velocity	Ft/s	0.40 for active screens 0.20 for passive screens	Approach velocity is calculated by dividing the maximum screened flow amount by the vertical projection of the effective screen area. NMFS 11.6.1.1.
Screen Submergence	%	85 max for rotating drum screens 65% min drum diameter	NMFS 11.6.1.3.
Sweeping Velocity	Ft/s	0.8 to 3	Screens longer than 6 feet must be angled and must have sweeping velocity greater than approach velocity. For screens longer than 6 feet, sweeping velocity must not decrease along the length of the screen. NMFS 11.6.1.5.
Inclined Screen Face		45° max	NMFS 11.6.1.6.
Circular Screen Openings	Inch	3/32 max	NMFS 11.7.1.1.
Slotted or Rectangular Screen Openings	Inch	1/16 max	NMFS 11.7.1.2.
Square screen openings	Inch	3/32 max	NMFS 11.7.1.3.
Screen Open Area	%	27 min	NMFS 11.7.1.6.
Active Screen Cleaning Frequency	Min	5 minutes, min	Or triggered by a max head differential of 0.1 ft over clean screen conditions. NMFS 11.10.1.2.
Passive Screen Cleaning		River flow rate 3 cfs max	NMFS 11.10.1.3.
Bypass Channel Velocity	Ft/s	0.2 Max	NMFS 11.9.1.8.
Bypass Entrance Velocity		110% min of the maximum canal velocity upstream of the bypass entrance.	NMFS 11.9.2.2.
Bypass Entrance Dimensions	Ft	18 wide for more than 3 cfs 12 wide for less than 3 cfs	NMFS 11.9.2.4.
Bypass Conduit Bends		R/D ratio greater than or equal to 5.	NMFS 11.9.3.4.
Bypass Flow	%	5% of the total diverted flow amount	NMFS 11.9.3.7.
Bypass Velocity	Ft/s	6 to 12	NMFS 11.9.3.8

Table A-2. NOAA Biological Design Criteria; Anadromous Salmonid Fish Passage			
Criteria	**Units**	**Value**	**Comments**
Bypass Depth	%	40% of the bypass pipe diameter, min	NMFS 11.9.3.9.
Bypass Outfall Ambient River Velocity	Ft/s	4 min	NMFS 11.9.4.1.
Bypass Outfall Impact Velocity	Ft/s	25 max	NMFS 11.9.4.2.

Table A-3. Biological Design Criteria; Target Fish Species

Criteria	Units	Value	Comments
Target Species	-		
Steelhead	N/A		
Coho Salmon (Winter Run)	N/A		
Chinook Salmon (Fall Run)	N/A		
Sea Run Cutthroat	N/A		
Pacific Lamprey	N/A		
Fish Size			
Steelhead	mm	340-1,050	Fork length
Coho Salmon (Winter Run)	mm	340-1,050	Fork length
Chinook Salmon (Fall Run)	mm	450-1,130	Fork length
Sea Run Cutthroat	mm	400	Fork Length
Pacific Lamprey	mm	152-910	Total length
Average Fish Weight (Adult)			
Steelhead	lb	4-5	
Coho Salmon (Winter Run)	lb	4-6	
Chinook Salmon (Fall Run)	lb	18-22	
Sea Run Cutthroat	lb	1.5	
Pacific Lamprey	lb	1.0	
Swimming Capabilities **(sustained/burst)**		Adults	
Steelhead	fps	3.0 / 20.3	Jones et al. 1974 / Bell 1991
Coho Salmon (Winter Run)	fps	4.0 / 21.0	Bell 1991
Chinook Salmon (Fall Run)	fps	5.0 / 14.0	Geist et al. 2003 / Hunter and Mayor 1986
Sea Run Cutthroat	fps	3.0 / 14.0	Bell 1991
Pacific Lamprey	fps	1.3 / 2.7	Moursund et al. 2003
Migration Timing			
Steelhead	mo.	Dec-Apr	Higgins 2010
Coho Salmon (Winter Run)	mo.	-	Limited return data
Chinook Salmon (Fall Run)	mo.	Oct-Dec	Higgins 2010
Sea Run Cutthroat	mo.	-	Limited return data
Pacific Lamprey	mo.	Variable	Luzier et al. 2001
Numbers of Fish			
Steelhead; mean annual (STD)	total	550 (448)	2005-2015 mean counts
Coho; mean annual (STD)	total	na	
Chinook; mean annual (STD)	total	1,194 (1,117)	
Pacific Lamprey (mean annual)	total	na	

Appendix B

Feasibility Level Sketches of Alternatives

CAPE HORN DAM BASELINE OPTION PLAN

SCALE: 1"= 60'

0' 60' 120'

OPTION DESCRIPTION:

BASELINE OPTION CONSISTS OF MAINTAINING THE EXISTING PROJECT CONFIGURATION AND OPERATION. WITHIN THE BASELINE OPTION AT CAPE HORN DAM, A MINIMUM LEVEL OF IMPROVEMENTS AND CAPITAL IMPROVEMENTS WILL BE INCORPORATED TO ADDRESS POTENTIAL DAM SAFETY OR O&M ISSUES.

KEY OPTION COMPONENTS:

A MAINTAIN EXISTING INTAKE, FISH SCREEN, AND DIVERSION TUNNEL. INCORPORATE MINIMUM IMPROVEMENTS TO MAINTAIN RELIABLE OPERATION.

B MAINTAIN EXISTING FISHWAY INCLUDING FISHWAY ENTRANCE, LOWER FISHWAY, UPPER FISHWAY, AND FISHWAY EXIT. NO MODIFICATIONS TO THE EXISTING FISHWAY ARE ANTICIPATED.

C MAINTAIN EXISTING CAPE HORN DAM AND WATER RELEASE STRUCTURES. INCORPORATE MINIMUM IMPROVEMENTS NECESSARY TO MAINTAIN RELIABLE OPERATION.

D MAINTAIN VAN ARSDALE RESERVOIR LEVEL AND WATER DIVERSION OPERATION. NO CHANGES TO THE CURRENTLY OPERATED MINIMUM FLOW RELEASES ARE PLANNED.

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REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

CAPE HORN DAM
BASELINE OPTION PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
CH-BL-1

JOB NO: 000000

CAPE HORN DAM UPSTREAM FISH PASSAGE PLAN

SCALE: 1"= 60'

0' 60' 120'

N

OPTION DESCRIPTION:

OPTION A CONSISTS OF MODIFICATIONS TO THE EXISTING UPSTREAM FISHWAY AT CAPE HORN DAM TO IMPROVE OVERALL FISH PASSAGE CONDITIONS AND LONG TERM OPERATION. THESE IMPROVEMENTS COULD INCLUDE REPAIRING AGING CONCRETE, MECHANICAL EQUIPMENT REPLACEMENT, UPGRADE OF ELECTRICAL/INSTRUMENTATION SYSTEMS, OR MODIFICATIONS TO THE FISHWAY TO IMPROVE HYDRAULIC CONDITIONS.

KEY OPTION COMPONENTS:

A MAINTAIN EXISTING INTAKE, FISH SCREEN, AND DIVERSION TUNNEL. INCORPORATE MINIMUM IMPROVEMENTS TO MAINTAIN RELIABLE OPERATION.

B INCORPORATE MODIFICATIONS TO THE EXISTING FISHWAY TO IMPROVE OVERALL FISH PASSAGE CONDITIONS AND EFFICIENCY, OPERATION, MAINTENANCE AND LIFE.

C MAINTAIN EXISTING CAPE HORN DAM AND WATER RELEASE STRUCTURES. INCORPORATE MINIMUM IMPROVEMENTS NECESSARY TO MAINTAIN RELIABLE OPERATION.

D MAINTAIN VAN ARSDALE RESERVOIR LEVEL AND WATER DIVERSION OPERATION. NO CHANGES TO THE CURRENTLY OPERATED MINIMUM FLOW RELEASES ARE PLANNED.

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WARNING

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IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

CAPE HORN DAM
OPTION A IMPROVE UPSTREAM FISH PASSAGE

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
CH-A-1

JOB NO: 000000

CAPE HORN DAM DOWNSTREAM PASSAGE PLAN

SCALE: 1"= 60'

0' 60' 120'

N

OPTION DESCRIPTION:

OPTION B CONSISTS OF MODIFICATIONS TO THE EXISTING FISH SCREEN STRUCTURE AT CAPE HORN DAM TO IMPROVE OVERALL FISH PASSAGE CONDITIONS AND LONG TERM OPERATION. THESE IMPROVEMENTS MAY INCLUDE UPGRADING THE STRUCTURAL SUPPORT SYSTEM, REHABILITATING THE AIR BURST/SPARGING SCREEN CLEANING SYSTEM, AND ELECTRICAL/INSTRUMENTATION SYSTEMS.

KEY OPTION COMPONENTS:

A UPGRADE THE EXISTING INTAKE AND FISH SCREEN FACILITY TO ADDRESS ONGOING STRUCTURAL ISSUES, MECHANICAL SYSTEM DEFICIENCIES, AND IDENTIFIED OPERATION ISSUES.

B INCORPORATE MODIFICATIONS TO THE EXISTING FISHWAY TO IMPROVE OVERALL FISH PASSAGE CONDITIONS AND EFFICIENCY, OPERATION, MAINTENANCE AND LIFE.

C MAINTAIN EXISTING CAPE HORN DAM AND WATER RELEASE STRUCTURES. INCORPORATE MINIMUM IMPROVEMENTS NECESSARY TO MAINTAIN RELIABLE OPERATION.

D MAINTAIN VAN ARSDALE RESERVOIR LEVEL AND WATER DIVERSION OPERATION. NO CHANGES TO THE CURRENTLY OPERATED MINIMUM FLOW RELEASES ARE PLANNED.

REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

CAPE HORN DAM
OPTION B IMPROVE DOWNSTREAM PASSAGE PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
CH-B-1

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JOB NO: 000000

CAPE HORN DAM PARTIAL DECOMMISSIONING PLAN

SCALE: 1"= 60'

0' 60' 120'

OPTION DESCRIPTION:

OPTION C CONSISTS OF PARTIAL DECOMMISSIONING OF THE PROJECT. THE ABILITY TO DIVERT FLOWS WOULD BE MAINTAINED ALONG WITH THE INTAKE FISH SCREENS. THE AMOUNT AND TIMING OF THE FLOW DIVERSION WOULD BE MODIFIED TO PROVIDE ADDITIONAL FLOW IN THE EEL RIVER DURING CRITICAL FISH PASSAGE PERIODS.

KEY OPTION COMPONENTS:

A MAINTAIN EXISTING INTAKE, FISH SCREEN, AND DIVERSION TUNNEL. INCORPORATE MINIMUM IMPROVEMENTS TO MAINTAIN RELIABLE OPERATION.

B MAINTAIN EXISTING FISHWAY INCLUDING FISHWAY ENTRANCE, LOWER FISHWAY, UPPER FISHWAY, AND FISHWAY EXIT. NO MODIFICATIONS TO THE EXISTING FISHWAY ARE ANTICIPATED.

C MAINTAIN EXISTING CAPE HORN DAM AND WATER RELEASE STRUCTURES. INCORPORATE MINIMUM IMPROVEMENTS NECESSARY TO MAINTAIN RELIABLE OPERATION.

D MAINTAIN VAN ARSDALE RESERVOIR LEVEL. WATER DIVERSION AMOUNT AND TIMING WOULD BE MODIFIED TO IMPROVE FISH PASSAGE CONDITIONS IN THE EEL RIVER DOWNSTREAM OF CAPE HORN DAM. FLOW RELEASES WOULD BE TIMED TO IMPROVE UPSTREAM FISH PASSAGE CONDITIONS DURING MIGRATION PERIODS AS WELL AS FLOW CONDITIONS TO REDUCE THE POTENTIAL FOR JUVENILE FISH STRANDING DURING OUT-MIGRATION PERIODS.

THE POTTER VALLEY POWERHOUSE WOULD BE MAINTAINED, BUT A LOW FLOW ENERGY DISSIPATION VALVE MAY BE REQUIRED FOR PERIODS WHEN INSUFFICIENT FLOW IS AVAILABLE TO OPERATE THE TURBINES.

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A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

CAPE HORN DAM
OPTION C PARTIAL DECOMMISSIONING PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
CH-C-1

JOB NO: 000000

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CAPE HORN DAM DECOMMISSIONING PLAN

SCALE: 1"= 60'

0' 60' 120'

N

OPTION DESCRIPTION:

OPTION D CONSISTS OF FULL REMOVAL OF CAPE HORN DAM AND RESTORATION OF THE NATURAL RIVER FLOWS. THE ACCUMULATED SEDIMENT WILL BE LEFT WITHIN THE EEL RIVER CHANNEL.

KEY OPTION COMPONENTS:

A REMOVE THE EXISTING INTAKE, FISH SCREEN, AND ASSOCIATED EQUIPMENT. RESTORE NATURAL RIVER CHANNEL BANK. PLACE CONCRETE PLUG IN UPSTREAM AND DOWNSTREAM END OF THE DIVERSION TUNNEL. THE EXISTING POTTER VALLEY POWERHOUSE WILL BE REMOVED AND THE SITE RESTORED.

B REMOVE THE UPPER FISHWAY. A NEW FISH BARRIER AND WATER SUPPLY WILL BE REQUIRED FOR THE EXISTING FISH HATCHERY.

C REMOVE CAPE HORN DAM INCLUDING THE CONCRETE DAM STRUCTURE, EARTHFILL DAM STRUCTURE, AND WATER RELEASE STRUCTURES.

D VAN ARSDALE RESERVOIR WILL BE DRAINED AND RETURNED TO THE NATURAL RIVER FLOW CONDITIONS. THE FLOW DIVERSION CAPABILITY TO POTTER VALLEY WILL BE REMOVED WITH THE DAM.

E ALL SEDIMENT IN THE RIVER CHANNEL WILL BE MAINTAINED IN PLACE WITH EXCEPTION OF WHERE THE NATURAL RIVER CHANNEL IS RESTORED.

F POTENTIAL ONSITE DISPOSAL AREA FOR CONCRETE AND EARTHFILL MATERIALS FROM THE DAM DEMOLITION. ALL OTHER STEEL, ELECTRICAL, AND RELATED MATERIALS WILL BE DISPOSED OF OFFSITE.

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WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

CAPE HORN DAM
OPTION D FULL DECOMMISSIONING
WITHOUT SEDIMENT REMOVAL

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
CH-D-1

JOB NO: 000000

CAPE HORN DAM DECOMMISSIONING PLAN

SCALE: 1"= 60'

0' 60' 120'

N

OPTION DESCRIPTION:

OPTION E CONSISTS OF FULL REMOVAL OF CAPE HORN DAM AND RESTORATION OF THE NATURAL RIVER FLOWS. THE ACCUMULATED SEDIMENT WILL BE REMOVED FROM THE MAIN RIVER CHANNEL AND PLACED IN UPLAND AREAS ADJACENT TO THE RIVER. THE EXCAVATED RIVER CHANNEL AND UPLAND AREAS WILL BE STABILIZED AND PLANTED TO IMPROVE THE RIPARIAN AREAS.

KEY OPTION COMPONENTS:

A REMOVE THE EXISTING INTAKE, FISH SCREEN, AND ASSOCIATED EQUIPMENT. RESTORE NATURAL RIVER CHANNEL BANK. PLACE CONCRETE PLUG IN UPSTREAM AND DOWNSTREAM END OF THE DIVERSION TUNNEL. THE EXISTING POTTER VALLEY POWERHOUSE WILL BE REMOVED AND THE SITE RESTORED.

B REMOVE THE UPPER FISHWAY. A NEW FISH BARRIER AND WATER SUPPLY WILL BE REQUIRED FOR THE EXISTING FISH HATCHERY.

C REMOVE CAPE HORN DAM INCLUDING THE CONCRETE DAM STRUCTURE, EARTHFILL DAM STRUCTURE, AND WATER RELEASE STRUCTURES.

D VAN ARSDALE RESERVOIR WILL BE DRAINED AND RETURNED TO THE NATURAL RIVER FLOW CONDITIONS. THE FLOW DIVERSION CAPABILITY TO POTTER VALLEY WILL BE REMOVED WITH THE DAM.

E ALL SEDIMENT IN THE RIVER CHANNEL WILL BE REMOVED AND DISPOSED OF IN UPLAND AREAS ADJACENT TO THE RIVER CHANNEL. THE RIVER CHANNEL WILL BE RESTORED TO NATURAL CONFIGURATION AND FLOW CONDITIONS. RIPARIAN AREA PLANTING WILL BE COMPLETED ALONG THE RIVER. THE UPLAND AREAS WILL BE STABILIZED WHERE SEDIMENT IS PLACED AND REPLANTED.

F POTENTIAL ONSITE DISPOSAL AREA FOR CONCRETE AND EARTHFILL MATERIALS FROM THE DAM DEMOLITION. ALL OTHER STEEL, ELECTRICAL, AND RELATED MATERIALS WILL BE DISPOSED OF OFFSITE.

REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

0 1/2 1

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POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

CAPE HORN DAM
OPTION E FULL DECOMMISSIONING
WITH SEDIMENT REMOVAL

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
CH-E-1

JOB NO: 000000

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OPTION DESCRIPTION:

BASELINE OPTION CONSISTS OF MAINTAINING THE EXISTING PROJECT CONFIGURATION AND OPERATION AS CURRENTLY OPERATED. WITHIN THE BASELINE OPTION AT SCOTT DAM, A MINIMUM LEVEL OF IMPROVEMENT AND CAPITAL EXPENDITURES WILL BE INCORPORATED TO ADDRESS POTENTIAL DAM SAFETY OR O&M ISSUES.

KEY OPTION COMPONENTS:

A MAINTAIN EXISTING LOW LEVEL INTAKE AND RELEASE VALVE. INCORPORATE MINIMUM IMPROVEMENTS TO MAINTAIN RELIABLE OPERATION.

B MAINTAIN EXISTING SPILLWAY AND ASSOCIATED GATES. INCORPORATE MINIMUM IMPROVEMENTS TO MAINTAIN RELIABLE OPERATION.

C MAINTAIN EXISTING LAKE PILLSBURY OPERATION RELATED TO FLOW STORAGE AND RELEASE. NO CHANGES TO THE CURRENT RESERVOIR OPERATION WILL BE INCORPORATED.

D NO UPSTREAM OR DOWNSTREAM FISH PASSAGE WILL BE PROVIDED.

SCOTT DAM SITE PLAN

SCALE: 1"= 30'

0' 30' 60'

N

REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
BASELINE OPTION PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-BL-1

JOB NO: 000000

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SCOTT DAM UPSTREAM FISH PASSAGE PLAN

SCALE: 1"= 30'

0' 30' 60'

N

OPTION DESCRIPTION:

OPTION A1 CONSISTS OF PROVIDING UPSTREAM FISH PASSAGE AT SCOTT DAM USING A VOLITIONAL FISH LADDER LOCATED ON THE LEFT ABUTMENT OF THE DAM. THIS OPTION PROVIDES ONLY UPSTREAM FISH PASSAGE. NO DOWNSTREAM FISH PASSAGE WILL BE PROVIDED.

KEY OPTION COMPONENTS:

A. LADDER ENTRANCE POOLS – 5 ENTRANCES TO ACCOUNT FOR TAILRACE FLUCTUATIONS.

B. FISH LADDER:
   1. EXTENDS FROM TAILRACE AT ASSUMED MINIMUM ELEVATION OF 1735.0' TO THE FOREBAY/SPILLWAY ELEVATION OF 1818.0'. TOTAL OF 83' OF ELEVATION GAIN OVER 800' IN LENGTH.
   2. NOAA FISHERIES CRITERIA FOR LADDER POOLS – 8' LONG, 6' WIDE, WITH MINIMUM WATER DEPTH OF 5' AND FREEBOARD OF 3'.
   3. ASSUMED 1' DROPS BETWEEN POOLS – MAXIMUM PER NOAA FISHERIES.
   4. METAL GRATING ALONG THE LENGTH OF THE TOP OF THE FISH LADDER.

C. LADDER EXIT – INTO THE FOREBAY AT ELEVATION 1818.0'. ADDITIONAL LENGTH ALONG FACE OF DAM WITH ADDITIONAL EXITS MAY BE REQUIRED. PUMP STATION MAY BE REQUIRED FOR LADDER FLOWS.

D. AUXILIARY WATER SUPPLY INTAKE – SCREENED FOR JUVENILES, POTENTIALLY A PUMPED INTAKE.

E. AUXILIARY WATER SUPPLY PIPELINE.

F. AUXILIARY WATER SUPPLY CHAMBER – PROVIDES ATTRACTION FLOWS TO THE LOWER 5 ENTRANCE POOLS DEPENDENT ON TAILRACE ELEVATION.

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REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

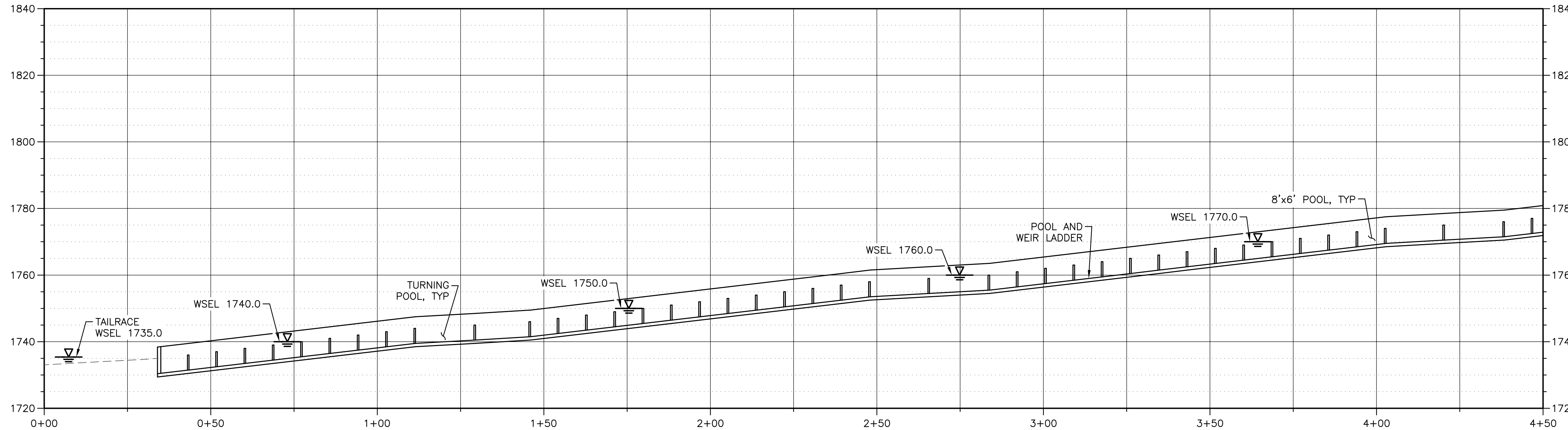
POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION A1 PROVIDE UPSTREAM FISH PASSAGE
VOLITIONAL FISH LADDER PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

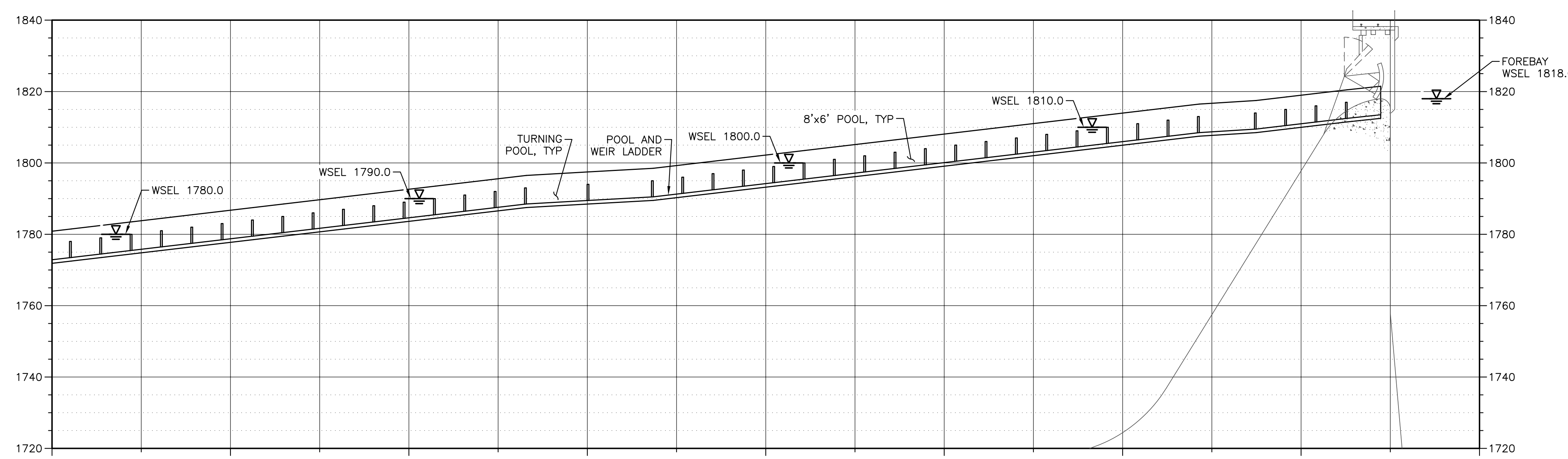
DRAWING
SD-A1-1.1

JOB NO: 000000



PROFILE
SCALE: 1"= 20'

0' 20' 40'



PROFILE
SCALE: 1"= 20'

0' 20' 40'

REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION A1 PROVIDE UPSTREAM FISH PASSAGE
VOLITIONAL FISH LADDER PROFILE

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-A1-1.2

JOB NO: 000000

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SCOTT DAM UPSTREAM FISH PASSAGE PLAN

SCALE: 1"= 30'

0' 30' 60'

N

OPTION DESCRIPTION:

OPTION A2 CONSISTS OF PROVIDING UPSTREAM FISH PASSAGE AT SCOTT DAM USING A TRAP AND HAUL FACILITY LOCATED ON THE LEFT ABUTMENT OF THE DAM. THIS OPTION PROVIDES ONLY UPSTREAM FISH PASSAGE. NO DOWNSTREAM FISH PASSAGE IS PROVIDED.

KEY OPTION COMPONENTS:

A ACCESS ROAD IMPROVEMENTS FOR FISH TRANSPORT TRUCK.

B FISH LADDER ENTRANCES – 5 ENTRANCES TO ACCOUNT FOR TAILRACE FLUCTUATIONS.

C SHORT FISH LADDER
1. EXTENDS FROM TAILRACE AT ASSUMED MINIMUM ELEVATION OF 1735.0' TO THE HOLDING POND. TOTAL OF APPROXIMATELY 13' OF ELEVATION GAIN IN 125' OF LADDER.
2. NOAA FISHERIES CRITERIA FOR LADDER POOLS – 8' LONG, 6' WIDE, WITH MINIMUM WATER DEPTH OF 5' AND FREEBOARD OF 3'.
3. ASSUMED 1' DROPS BETWEEN POOLS – MAXIMUM PER NOAA FISHERIES.
4. METAL GRATING ALONG THE LENGTH OF THE TOP OF THE FISH LADDER.

D FINGER WEIR – TRAPPING MECHANISM FOR FISH COLLECTION.

E HOLDING POND – 40' LONG BY 10' WIDE. MINIMUM OF 5' OF WATER DEPTH WITH 5' OF FREEBOARD. FISH CROWDER LOCATED WITHIN POOL TRAVELING ON POND WALLS.

F HOPPER WELL – FISH ARE CROWDED INTO THE HOPPER THAT IS INSET INTO THIS VAULT.

G HOPPER AND MONORAIL SYSTEM – HOPPER COLLECTS THE FISH AND IS LIFTED UP OUT OF THE WELL AND PLACED OVER THE TRANSPORT TRUCK WITH A MONORAIL SYSTEM. THE HOPPER TO BE DESIGNED FOR WATER TO WATER TRANSFER OF FISH INTO THE TRUCK.

H WATER SUPPLY INTAKE – PROVIDES WATER TO THE ADULT HOLDING POND, HOPPER WELL AND AUXILIARY WATER SUPPLY CHAMBER FOR ATTRACTION FLOW INTO THE FISH LADDER.

I WATER SUPPLY PIPELINE.

J AUXILIARY WATER SUPPLY CHAMBER – PROVIDES ATTRACTION FLOWS TO THE LOWER 5 ENTRANCE POOLS DEPENDENT ON TAILRACE ELEVATION.

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WARNING

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McMILLEN JACOBS ASSOCIATES

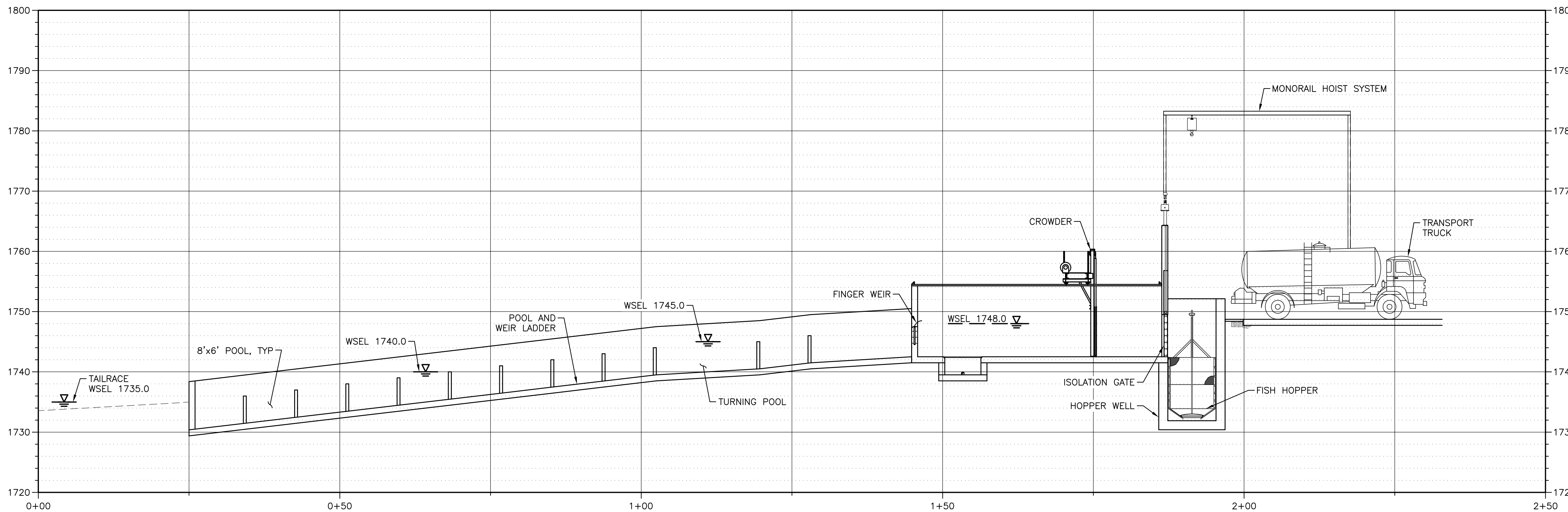
POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION A2 PROVIDE UPSTREAM FISH PASSAGE
TRAP AND HAUL SITE PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-A2-1.1

JOB NO: 000000



PROFILE

SCALE: 1"= 10'

0' 10' 20'

REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION A2 PROVIDE UPSTREAM FISH PASSAGE
TRAP AND HAUL PROFILE

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-A2-1.2

JOB NO: 000000

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SCOTT DAM DOWNSTREAM FISH PASSAGE PLAN

SCALE: 1"= 30'

0' 30' 60'

N

OPTION DESCRIPTION:

OPTION B1 CONSISTS OF A FLOATING COLLECTOR OR TOWER WITH MULTIPLE ENTRANCES LOCATED ON THE RIGHT ABUTMENT OF THE DAM. THE COLLECTOR WOULD SCREEN FISH OUT OF THE FLOW INTO A HOLDING AND BYPASS SYSTEM. THE FLOW WOULD BE ROUTED TO THE EXISTING LOW LEVEL OUTLET.

KEY OPTION COMPONENTS:

A NEW INTAKE TOWER TIED TO EXISTING LOW LEVEL INTAKE. PROVIDE MULTIPLE INTAKE PORTS TO ALLOW FOR RESERVOIR LEVEL FLUCTUATION.

B OPTIONAL LOCATION FOR FLOATING CORNER COLLECTOR WITH HOLDING TANK FOR COLLECTED FISH.

C DAM ACCESS TO COLLECT AND TRANSPORT DOWNSTREAM FISH MIGRANTS.

D MAINTAIN EXISTING LOW LEVEL OUTLET AND VALVE HOUSE.

E MAINTAIN EXISTING SPILLWAY GATES AND OPERATION.

F MAINTAIN EXISTING RESERVOIR OPERATION AND WATER STORAGE.

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REV	DATE	BY	DESCRIPTION
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WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION B1 PROVIDE DOWNSTREAM FISH PASSAGE
CORNER COLLECTOR PLAN

DESIGNED D. NELSON

DRAWN J. LAHMON

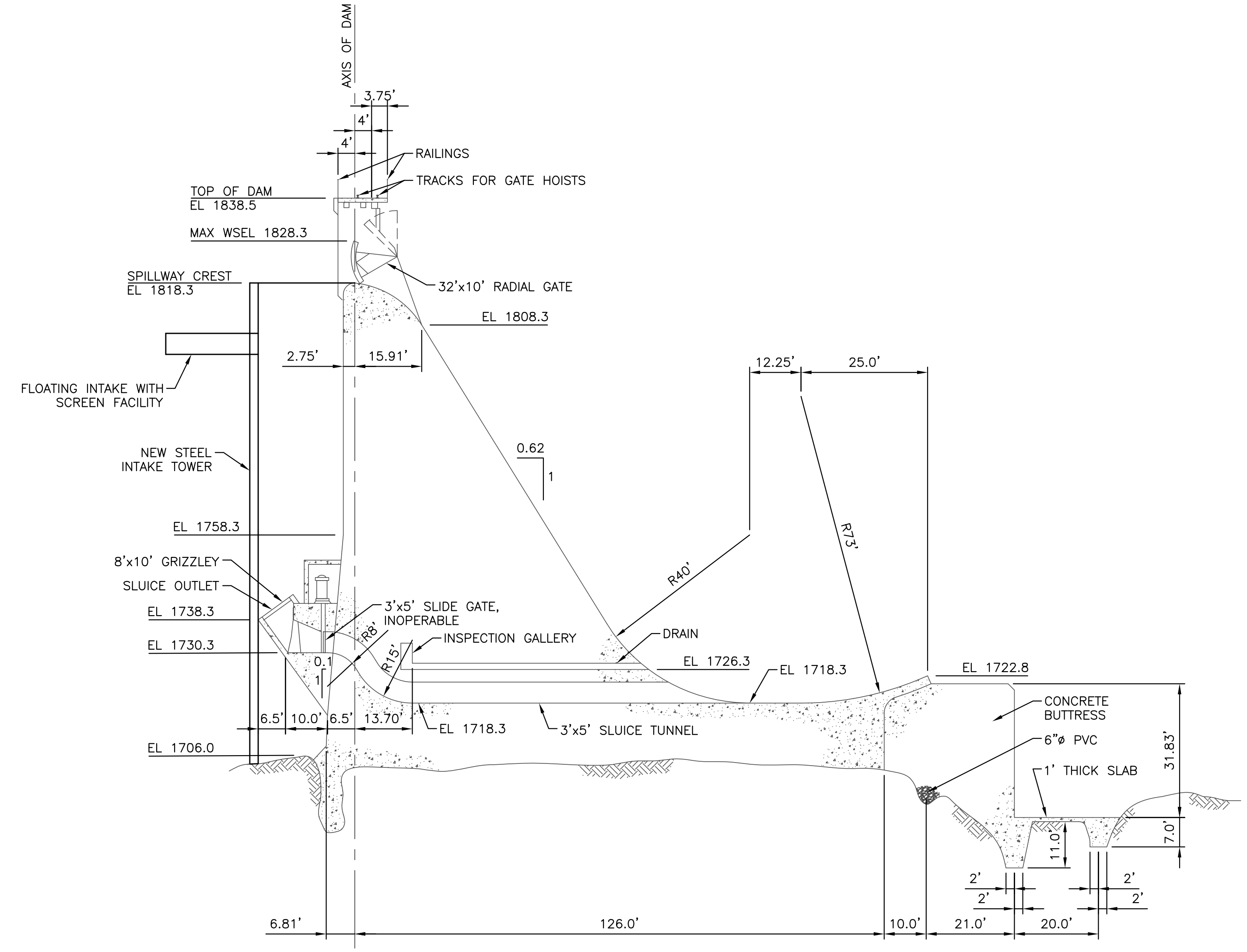
CHECKED M. McMILLEN

ISSUED DATE 08/29/16

DRAWING

SD-B1-1.1

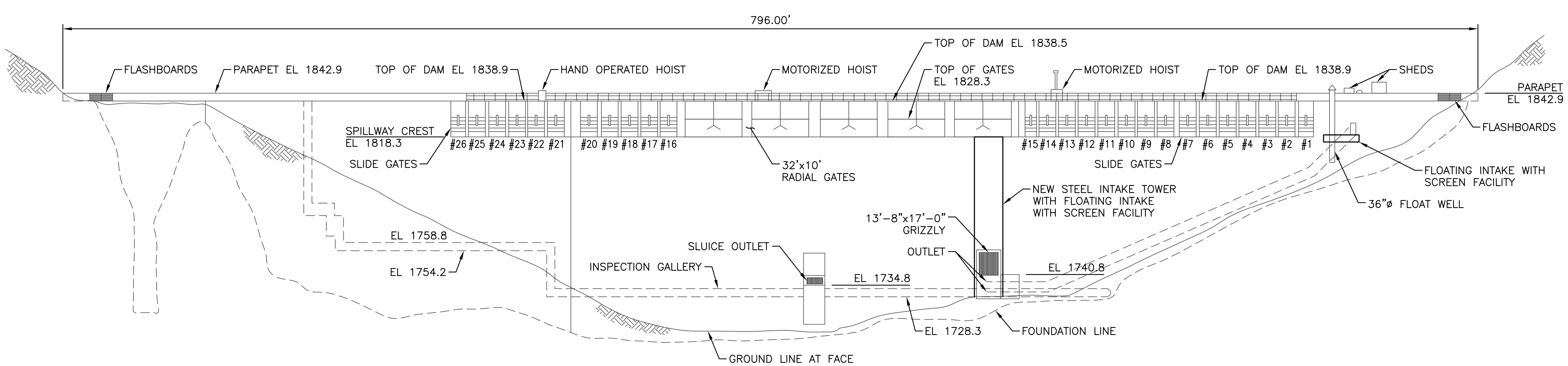
JOB NO: 000000



MAXIMUM SECTION

SCALE: 1"= 20'

0' 20' 40'



ELEVATION

SCALE: 1"= 40'

0' 40' 80'

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REV	DATE	BY	DESCRIPTION
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WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION B1 PROVIDE DOWNSTREAM FISH PASSAGE
CORNER COLLECTOR SECTIONS

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-B1-1.2

JOB NO: 000000

OPTION DESCRIPTION:

OPTION B2 CONSISTS OF A FLOATING SURFACE COLLECTOR WITH A GUIDANCE NET. DOWNSTREAM FISH MIGRANTS ARE GUIDED TO THE FLOATING SURFACE COLLECTOR ENTRANCES. THE COLLECTOR CONSISTS OF A VERTICAL PLATE SCREEN, HOLDING RACEWAYS, LOADING HOPPER, AND PUMPBACK SYSTEM TO RETURN THE SCREENED WATER BACK TO THE RESERVOIR. FISH ARE TRANSPORTED TO THE DAM FOR LOADING AND TRUCK TRANSPORT TO THE TAILRACE FOR RELEASE.

KEY OPTION COMPONENTS:

- A GUIDANCE NET EXTENDING FROM RESERVOIR ABUTMENTS TO THE SURFACE COLLECTOR.
- B EXISTING LOG BOOM IMPROVED TO MAXIMIZE DEBRIS REMOVAL.
- C FLOATING SURFACE COLLECTOR.
- D FLOATING DOCK SYSTEM WITH JIB CRANE ON TOP OF DAM TO RAISE FISH TRANSPORT TANK TO TOP OF DAM.
- E TRUCK ACCESS FOR LOADING TRANSPORT TANK AND DRIVING TO DOWNSTREAM FISH RELEASE LOCATION.
- F MAINTAIN EXISTING LOW LEVEL OUTLET AND VALVE HOUSE.
- G MAINTAIN EXISTING SPILLWAY GATES AND OPERATION.
- H MAINTAIN EXISTING RESERVOIR OPERATION AND WATER STORAGE.

SCOTT DAM DOWNSTREAM FISH PASSAGE PLAN

SCALE: 1"= 30'

0' 30' 60'

N

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WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION B2 PROVIDE DOWNSTREAM FISH PASSAGE
FLOATING SURFACE COLLECTOR PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING SD-B2-1

JOB NO: 000000

SCOTT DAM TRIBUTARY COLLECTOR PLAN

SCALE: 1"= 1000'

0' 1000' 2000'

N

OPTION DESCRIPTION:

OPTION B3 CONSISTS OF INSTALLING A TRIBUTARY COLLECTOR AT THE UPSTREAM END OF THE RESERVOIR.

KEY OPTION COMPONENTS:

A TRIBUTARY COLLECTOR INSTALLED NEAR EEL RIVER CONFLUENCE WITH LAKE PILLSBURY. LOCATION OF THE COLLECTOR WILL BE ADJUSTED BASED ON THE RESERVOIR ELEVATION. GUIDANCE NETS MAY BE REQUIRED TO OPTIMIZE OUT MIGRANT COLLECTION.

B MAINTAIN EXISTING SCOTT DAM FACILITIES INCLUDING THE DAM, LOW LEVEL VALVE HOUSE, SPILLWAY, AND DEBRIS BOOM.

C MAINTAIN EXISTING RESERVOIR OPERATION AND STORAGE.

D OPTIONAL TRIBUTARY COLLECTOR FOR SECONDARY TRIBUTARY SYSTEM (RICE CREEK)

REV	DATE	BY	DESCRIPTION
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WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION B3 TRIBUTARY COLLECTOR PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-B3-1

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JOB NO: 000000

OPTION DESCRIPTION:

OPTION C CONSISTS OF PARTIAL REMOVAL OF THE DAM FROM THE TOP OF THE DAM DOWN TO THE SPILLWAY CREST. THE STORAGE CAPACITY OF THE RESERVOIR WOULD BE ELIMINATED WITH THIS OPTION. THE LOW LEVEL OUTLET OPERATION WOULD BE MAINTAINED.

KEY OPTION COMPONENTS:

A LOWER DAM TO SPILLWAY CREST. TURN SPILLWAY TO UNGATED OVERFLOW SPILLWAY.

B PROVIDE LOWER SECTION IN CENTER OF SPILLWAY TO FOCUS DOWNSTREAM FISH PASSAGE DURING JUVENILE FISH OUT MIGRATION.

C MAINTAIN EXISTING LOW LEVEL INTAKE AND VALVE HOUSE TO LOWER RESERVOIR LEVEL BELOW SPILLWAY CREST AND TO DRAIN RESERVOIR.

D RESERVOIR OPERATION WOULD BE MODIFIED TO ELIMINATE WATER STORAGE. RIVER FLOWS WOULD PASS OVER THE MODIFIED SPILLWAY.

SCOTT DAM PARTIAL DECOMMISSIONING PLAN

SCALE: 1"= 30'

0' 30' 60'

N

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION C PARTIAL DECOMMISSIONING PLAN

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-C-1

JOB NO: 000000

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OPTION DESCRIPTION:

OPTION D CONSISTS OF COMPLETE DAM REMOVAL AND RE-ESTABLISHING THE NATURAL RIVER CHANNEL THROUGH THE RESERVOIR. THE EXISTING SEDIMENT WILL BE MAINTAINED IN PLACE TO THE MAXIMUM EXTENT POSSIBLE.

KEY OPTION COMPONENTS:

A REMOVE THE EXISTING DAM ENTIRELY FROM THE DAM FOUNDATION TO THE DAM CREST.

B REMOVE THE VALVE HOUSE AND LOW LEVEL OUTLETS.

C RESTORE THE NATURAL RIVER CHANNEL THROUGH THE RESERVOIR. MAINTAIN SEDIMENT IN PLACE WITHIN THE RESERVOIR AREA. REGRADE, STABILIZE, AND REPLANT THE NEW RIVER CHANNEL TO PROVIDE STABLE OVERBANK AREAS AND MAIN RIVER CHANNEL.

D MODIFY THE EXISTING RIVER CHANNEL TO RESTORE THE NATURAL RIVER CHANNEL.

SCOTT DAM FULL DECOMMISSIONING PLAN

SCALE: 1"= 30'

0' 30' 60'

N

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REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION D FULL DECOMMISSIONING
WITHOUT SEDIMENT REMOVAL

DESIGNED D. NELSON

DRAWN J. LAHMON

CHECKED M. McMILLEN

ISSUED DATE 08/29/16

DRAWING

SD-D-1

JOB NO: 000000

OPTION DESCRIPTION:

OPTION E CONSISTS OF COMPLETE DAM REMOVAL AND RE–ESTABLISHING THE NATURAL RIVER CHANNEL THROUGH THE RESERVOIR. THE SEDIMENT WILL BE REMOVED AND DISPOSED OF AT AN OFF–SITE LOCATION.

KEY OPTION COMPONENTS:

A REMOVE THE EXISTING DAM ENTIRELY FROM THE DAM FOUNDATION TO THE DAM CREST.

B REMOVE THE VALVE HOUSE AND LOW LEVEL OUTLETS.

C REMOVE THE SEDIMENT FROM THE RESERVOIR AREA AND RESTORE THE ORIGINAL RIVER CHANNEL TO THE ORIGINAL ALIGNMENT AND GRADE. REGRADE, STABILIZE, AND REPLANT THE NEW RIVER CHANNEL TO PROVIDE STABLE CHANNEL AND OUTERBANK AREAS.

D MODIFY THE EXISTING RIVER CHANNEL TO THE NATURAL CHANNEL.

SCOTT DAM FULL DECOMMISSIONING PLAN

SCALE: 1"= 30'

0' 30' 60'

REV	DATE	BY	DESCRIPTION
A	08/29/16	MDM	DRAFT FEASIBILITY REPORT

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

POTTER VALLEY HYDROELECTRIC PROJECT FEASIBILITY STUDY

SCOTT DAM
OPTION E FULL DECOMMISSIONING
WITH SEDIMENT REMOVAL

DESIGNED D. NELSON
DRAWN J. LAHMON
CHECKED M. McMILLEN
ISSUED DATE 08/29/16

DRAWING
SD-E-1

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