7.0 FISH PASSAGE PLANNING AND EVALUATION

One of the study elements contained in this section is the Anadromous Fish Passage Modeling. The Habitat Modeling Group, established to guide this study element, will continue working in 2004 to investigate the reintroduction of anadromous salmonids in the Project area and the upper basin. The tasks PacifiCorp and stakeholders commit to completing in 2004 correspond with modeling issues, and finding solutions to the issues identified in previous anadromous fish reintroduction reviews. A description of the remaining tasks and a time frame for completing each is presented in Section 7.10.2.1.

7.1 DESCRIPTION AND PURPOSE

The Klamath Hydroelectric Project (Project) does not have fish passage facilities at each of the Project's developments. Upstream and downstream passage of fish over or around Iron Gate dam and Copco No. 1 and 2 dams currently is not provided. Successful upstream passage potentially could open up, expand, or reestablish the use of spawning and rearing habitat for many species, especially anadromous fish that historically occurred above Iron Gate dam.

Upstream fish passage facilities on the Upper Klamath River currently consist of fish ladders at J.C. Boyle, Keno, and Link River dams. The purpose of these passage facilities is to allow the passage of resident fish to the Upper Klamath River (and Upper Klamath Lake) and also provide spawning access to certain tributaries. The fish species targeted for use of the facilities when they were built was rainbow trout. The J.C. Boyle facility is the only one with downstream passage facilities (screens and a bypass are located at the diversion intake).

The Iron Gate fish hatchery was built in 1961 by Pacific Power and Light (PacifiCorp's predecessor) as mitigation for the loss of spawning areas in the Klamath River and its tributaries between the Iron Gate Development and the Copco Developments. The FERC license stipulates specific production goals from the hatchery for fall Chinook, coho, and steelhead (see Table 7.1-1). This facility is funded largely by PacifiCorp (80 percent) and is operated by the CDFG, which funds the remaining cost (20 percent).

Project facilities exclude native fish from historic habitats, and restrict and entrain some downstream migrants into Project facilities. PacifiCorp has an obligation in the FERC relicensing to assess the adequacy of existing fish passage facilities and to evaluate the need for additional facilities. The primary purpose of this study is to assist the development of a strategy for re-introduction of anadromous fish and determine the relative technical/biological contribution of a wide array of Project fish passage options to support the overall goal of fish and ecosystem restoration.

Table 7.1-1. Iron Gate fish hatchery production goals and constraints.

Species	Egg Allotment	Stocking Goals and Constraints			
		Type	Number	Minimum Release Size	Target Release Dates[1]
Fall Chinook	10,000,000	Smolt	4,920,000[2]	90/lb	June 1 - 15
		Yearling	1,080,000[3]		October 15 - November 15
Coho	500,000[4]	Yearling	75,000	10-20/lb	March 15 - May 1
Steelhead	1,000,000	Yearling	200,000	6 inches[5]	March 15 - May 1

1 If unusual circumstances dictate, releases may deviate from the target release dates on approval from the regional manager.

2 In years when yearlings are not reared at the Fall Creek ponds, the smolt production will be 5,100,000.

3 Approximately 900,000 yearlings will be reared at Iron Gate fish hatchery and 180,000 will be reared at the Fall Creek ponds and released from Iron Gate fish hatchery. If the Fall Creek ponds are not operated, the production goal will be 900,000 yearlings.

4 A large number of coho eggs must be taken to meet the hatchery production goal because of reduced egg survival caused by soft-shell disease.

5 By September 1, steelhead numbers in the hatchery will be reduced as necessary to meet but not exceed the production goal.

7.1.1 Previous Reviews of Anadromous Fish Introduction to the Upper Klamath Basin

The feasibility of re-introducing salmon and steelhead trout to the Upper Klamath basin above Iron Gate dam has been evaluated on three previous occasions. The purpose of the reviews was to assess whether re-establishment of sustainable runs of anadromous fish in the Upper Klamath basin could be achieved by constructing fish passage facilities. Therefore, the current lack of fish passage at Copco and Iron Gate dams was not a factor in determining feasibility (Factor 1 and 2 in Fortune et al. 1966). A summary of these reviews is presented below.

7.1.1.1 Fortune et al. 1966

The first study, completed in 1966 (Fortune et al., 1966), was directed by an inter-agency committee consisting of representatives from the U.S. Bureau of Sport Fisheries and Wildlife, U.S. Bureau of Commercial Fisheries, CDFG, Fish Commission of Oregon, and Oregon State Game Commission. In addition, an attorney from Klamath Falls and a representative from Pacific Power and Light Company were members of the Steering Committee. This is the most comprehensive of the reviews, and the later reviews rely heavily on the information presented in the Fortune et al. (1966) report. The evaluation included a useful historical account of fish occurrence in the Upper Klamath basin based on published accounts, newspaper articles, and personal interviews with longtime local residents. The investigators also surveyed and documented habitat conditions in the Klamath River basin upstream of Iron Gate dam as they existed in 1965.

After evaluating the information contained in the Fortune et al. (1966) report, the Steering Committee advised against pursuing a program to re-establish anadromous fish runs to the Upper Klamath basin. That conclusion was based on the following considerations as quoted from the committee's report:

1. Problems related to downstream passage of fry and juvenile fish at impoundments and lakes are serious. In the judgment of the Committee, losses resulting from residualism, predation, diversions and failure of downstream migrants to negotiate the impoundment would prevent the establishment and maintenance of adequate runs.

2. Losses of upstream-migrating adults at fishways and in forebays or lakes would also be inevitable.

3. The re-establishment of anadromous fish would depend on obtaining stocks of fish whose migrating, spawning, and incubation requirements fit within the very narrow limits afforded by conditions in the Upper Klamath basin. There are insufficient stocks of fish in the Klamath to implement an effective transplant and no assurance that present Klamath stocks would adapt to the narrow requirements of the upper basin. Experience elsewhere has demonstrated it is very unlikely that suitable stocks outside the basin could be found.

4. While perhaps no single factor in itself precludes the possibility of establishing anadromous fish in the Upper Klamath basin, the interaction of all factors would prevent establishment of self-sustaining runs capable of perpetuating themselves at a useful level.

Fortune et al. (1966) also reviewed information regarding the historical presence of anadromous fish in the Upper Klamath basin. The conclusions for salmon and steelhead trout are as follows:

1. <u>Fall Chinook salmon:</u> Fall Chinook salmon occurred in the upper basin around the turn of the 20^{th} century (1900). There was a popular sport fishery targeting fall Chinook in the autumn months at Klamath Falls and downstream near Keno. These runs were first curtailed around 1889-1902 when log crib dams were constructed at Klamathon (below Iron Gate) by the Klamath River Improvement and Lumber Company. These dams had no or inadequate fish ladders. Starting in 1910, the Bureau of Fisheries installed fish collection racks at Klamathon, which further curtailed upstream migration. Completion of Copco dam in 1917 permanently blocked fish passage to areas upstream.

2. <u>Spring Chinook salmon</u>: Spring Chinook salmon were believed to have occurred historically above Upper Klamath Lake based on accounts from Native Americans interviewed by Spier (1930 – cited in Fortune et al. 1966). However, the spring Chinook salmon runs had disappeared "before white man came to the area." These fish were reported to have entered the Williamson/Sprague rivers in May and June and they also were reported to be smaller than the Chinook salmon that arrived in the fall.

3. <u>Steelhead trout</u>: The evidence reviewed by Fortune et al. (1966) indicated that steelhead trout were present in the Upper Klamath River up to, and including, Spencer Creek. However, there was no conclusive evidence that steelhead trout ever existed above Upper Klamath Lake. Referring to the question of steelhead runs above the lake, Fortune et al. (1966) concluded, "Though it is possible that steelhead trout did migrate to the upper basin, no conclusive evidence of such runs can be derived from the reports examined." There was abundant documentation of large rainbow trout observed in and above Upper Klamath Lake, but at the time there was no clear means to differentiate sea run steelhead trout from the large adfluvial redband rainbow trout that resided in Upper Klamath Lake and Lake Ewauna and spawned in the tributaries to Upper Klamath Lake.

7.1.1.2 Klamath River Basin Fisheries Task Force, 1992

The Klamath River Basin Conservation Area Restoration Program was authorized by Congress in 1986 to formulate a 20-year program to restore anadromous fish populations in the Klamath River basin, including the Trinity River. The Klamath River Basin Fisheries Task Force , completed the "Upper Klamath River Basin Amendment to the Long Range Plan" in 1992. This amendment contained an evaluation of the feasibility of restoring anadromous fish to the Upper Klamath basin. The three recommendations of the task force were:

1. The task force should not support attempts to restore anadromous fish above Iron Gate dam at this time.

2. Only native Klamath broodstock should ever be employed in reintroduction efforts.

3. Continue efforts to conserve gene resources in the lower basin to preserve diverse life history strategies that might someday help to restore upper basin runs.

The reasons given for not supporting re-introduction included the following:

1. Disease Introduction. No viral diseases are known to infect native fish of the Upper Klamath basin. If salmonids were brought in from other basins, or even allowed to pass upstream from Iron Gate dam, there is a strong possibility of introducing infectious hematopoietic necrosis (IHN) to the Upper Klamath basin, where native fish populations, including redband trout, have no natural resistance.

2. Genetic Risks. If out-of-basin stocks are used for re-introduction into the Upper Klamath basin, they could stray and spawn with lower river stocks. Such interbreeding could lower the fitness of the locally adapted downriver stocks.

3. Suitable Stocks. Because the stocks that were genetically adapted to the Upper Klamath basin have been extirpated, it is uncertain whether the genotypes present in stocks downstream of Iron Gate dam would be suited to the Upper Klamath basin.

4. Habitat Quality. Water quality in the Upper Klamath Lake may have deteriorated since Fortune et al. (1966) assessed potential migratory problems for anadromous fish. High water temperatures and pH and low dissolved oxygen would be lethal to salmonids attempting to migrate through the lake after June 1. Water quality problems originating in the lake could continue to pose problems for outmigrating smolts downstream of the lake.

5. Passage Conditions. Even with provisions for downstream passage facilities at the dams, the added stress of passing the dams and through the reservoirs, combined with passage problems through Upper Klamath Lake, could limit the success of attempts to re-introduce anadromous salmonids to the Upper Klamath basin.

The task force evaluation concludes with the following statement:

> "While the dream of restoring salmon and steelhead remains alluring, consideration of re-introduction of these fish above Iron Gate dam should be left to the future."

7.1.1.3 ODFW, Klamath River Basin Fish Management Plan, 1997

The ODFW addressed the topic of salmon and steelhead reintroduction in its 1997 Klamath River Basin Fish Management Plan. The report restates the four problems associated with reintroduction noted by the 1966 Fortune et al. report (see above) and identifies the following two additional factors:

1. Introduction of Klamath River salmon and steelhead from California, the logical choices, would risk importation of viral diseases that could cause harm to existing native trout.

2. Successful reintroduction of salmon and steelhead would present direct competition for food and habitat with existing native fish fauna.

The Oregon management plan also summarizes the results of an experimental program in 1970-1974 whereby surplus adult steelhead trout from the Iron Gate fish hatchery were trapped and released into the Oregon reaches of the Klamath River. An evaluation of the program (Hanel and Stout, 1974) concluded that few anglers were attracted to the potential sport fishery, many of the fish moved downstream into California waters, and the steelhead spawned at the same time and in the same areas as resident trout, many of which were larger that the steelhead. As a result of poor angler use and, in particular, the potential for interbreeding with the native redband trout, the program was discontinued.

The ODFW review concludes with the following statement:

"Because of existing habitat problems, loss of native stocks, risk of disease introduction and potential competition with remaining native redband trout, it does not appear feasible, or prudent, to attempt re-establishment of anadromous salmon or steelhead to the upper Klamath basin in Oregon, now or in the near future."

7.2 OBJECTIVES

The objectives to be addressed by this study are as follows:

- Evaluate the existing fish passage facilities and needs for their improvement for resident and anadromous fish.

- Assist in the development of a strategy for restoring the full compliment of historic native anadromous fish, including Chinook salmon, coho, steelhead, and lamprey to areas blocked by Project facilities.

- Develop conceptual engineering plans for potential new fish passage facilities.

- Develop and evaluate the relative contribution and the engineering and biological feasibility of various options and scenarios for fish passage, and rank relative effectiveness of fish passage options to include structural facilities as well as non-structural options, and dam removal.

- Evaluate the Iron Gate fish hatchery, which provides the current mitigation for the loss of spawning areas between Iron Gate dam and Copco dam and Project impacts to anadromous salmonids.

- Assess the effects and effectiveness of the wide array of fish passage options on the full compliment of historic native anadromous fish, including lamprey and resident fish.

- Review and summarize information related to the upstream passage of adult rainbow trout at J.C. Boyle dam.

- Characterize resident fish entrainment and turbine-induced mortality at J.C. Boyle, Copco, and Iron Gate Developments.

7.3 RELICENSING RELEVANCE AND USE IN DECISIONMAKING

Several of the Project dams do not contain upstream or downstream fish passage facilities. The lack of upstream passage facilities at Iron Gate and Copco dams precludes the reestablishment of anadromous fish to the upper Klamath River basin. With the Project's relicensing, there is an opportunity to rectify fish passage and, to some degree, water quality and habitat conditions affected by the Project. The Project relicensing, therefore, includes an evaluation of restoring native fish populations to historic areas in the basin above Iron Gate dam. This is an important stated goal for the fisheries resource agencies, affected tribes, and many of the nongovernment organizations (NGOs). While recognizing that many of the habitat and water quality problems in the basin upstream of Iron Gate dam are not related to the Project, stakeholders requested that PacifiCorp evaluate a future scenario where habitat and water quality are restored as a result of basin-wide initiatives.

The conclusions and options from this and other fisheries technical studies will assist in providing the support and rationale needed by the NOAA Fisheries and USFWS in developing their prescriptions for fish passage facilities under Section 18 of the Federal Power Act (FPA). The conclusions also will be used to respond to the most current legislation in Oregon that addresses fish passage for anadromous fish and game fish and the state of California's Fish and Game code.

7.4 METHODS AND GEOGRAPHIC SCOPE

In general, the overall fish passage task includes scientific investigation, conceptual engineering design, facility evaluations, and anadromous fish production/passage modeling. In support of the above objectives, three major topics are covered in this section:

1. Engineering Analysis of Existing and Potential New Facilities
2. Evaluation of the Iron Gate Hatchery
3. Biological Modeling of Fish Passage Options

In addition to these three primary topics, this section of the FTR addresses:

- Review of Adult Trout Passage at J.C. Boyle Dam
- Characterization of Resident Fish Entrainment and Turbine-Induced Mortality

These last two topics, while not specifically outlined in the Fish Passage Study Plan (No. 1.10), were discussed with the Fish Passage Work Group and Aquatics Work Group. They are included in this section of the FTR because they pertain to fish passage at project facilities. To facilitate continuity, each of these five topics are presented separately with their specific methods sections followed by results and discussion.

The general geographic scope of this study is related to the location of the Project facilities. For most tasks the study area contains six river reaches and four reservoirs on the mainstem Klamath River, extending from RM 282.3 at Upper Klamath Lake/Agency Lake in Oregon to the Klamath River downstream of Iron Gate dam at RM 190.1 in California. Upper Klamath Lake/Agency Lake and the Klamath River downstream of Iron Gate dam represent the upper and lower bounds of the study area. Fisheries descriptions and assessments presented in the following text address the 64.2-mile-long segment of the Klamath River and important tributaries (Spencer, Shovel, and Fall creeks) between Link River dam at RM 254.3 and Iron Gate dam at RM 190.1. This segment consists of 28.9 miles of river reaches and 35.3 miles of reservoirs.

The ongoing modeling efforts will include a geographic scope based on historic, current, and potential habitat of modeled species. The modeling effort geographic scope is much larger and includes tributaries to Upper Klamath Lake downstream through the Project, including the mainstem Klamath River, extending to the Pacific Ocean.

Upstream and downstream fish passage will be reviewed at Keno dam, J.C. Boyle dam, Copco No. 1 dam, Copco No. 2 dam, Fall Creek dam, and Iron Gate dam. If anadromous fish passage is required at Link River dam, it will be the responsibility of the U.S. Bureau of Reclamation (USBR), as owner of the dam, to provide the appropriate facilities for upstream passage. The USBR already is taking responsibility to provide improved fish passage at Link River dam. The USBR currently is scheduled to construct a new fish ladder that will replace the existing sub-standard fish ladder, starting in the summer of 2004. The new ladder (vertical slot with baffles) was designed with input from resource agencies (ODFW, USFWS) and has been approved by the USFWS. Although it was designed to target federally listed suckers, experience suggests that it is expected to also effectively pass anadromous fish due its relatively low gradient, low velocities (maximum of 5.0 ft/s), and ability to allow passage at any flow depth. The ODFW staff believes that the new ladder will allow resident redband trout to more effectively migrate above the dam.

7.5 RELATIONSHIP TO REGULATORY REQUIREMENTS AND PLANS

The conclusions and options that come out of the fish passage studies can be used with other information to assist the resource agencies and tribes in making recommendations to the FERC for fish passage facilities, hatchery improvements, or other alternative PM&E measures. The following list contains federal, state, and tribal references to goals and objectives for fisheries protection and enhancement:

- CDFG Upper Klamath Wild Trout Management Plan
- ODFW Klamath River Basin Fish Management Plan
- USFWS and NMFS (now NOAA Fisheries) ESA requirements

- Klamath River Basin Fisheries Task Force's Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program.
- Klamath River Wild and Scenic River Plan (U.S. Bureau of Land Management)
- U.S. Forest Service Klamath River Restoration Plan
- Tribal natural resource goals, objectives, and cultural values

In addition, the NOAA Fisheries and USFWS have authority to prescribe fishways under Section 18 of the FPA for the FERC license. The outcome of the fish passage studies provides these agencies with the needed information through which they can justify prescribing passage facilities or, alternatively, reserving authority to do so in the future.

7.6 TECHNICAL WORK GROUP COLLABORATION

A Fish Passage Work Group (FPWG) was established and is composed of agency, tribal, NGOs, and other interested parties. This FPWG helped develop and assess information on resident and anadromous fish passage issues and identify, from a biological and technical perspective, preferred fish passage options for consideration. As part of the FPWG, the following three subgroups were established to address specific topics associated with the fish passage evaluation and planning work:

1. Engineering Subgroup
2. Habitat/Modeling Subgroup
3. Hatchery Subgroup

7.7 ENGINEERING ANALYSIS OF FISH PASSAGE FACILITIES

7.7.1 Methods

The process of identifying and evaluating fish passage options necessarily requires a stepwise approach to select reasonable candidates for a more detailed analysis. To accomplish this, fish passage options were identified at a conceptual level then various options were modeled (see Section 7.10) .In identifying upstream and downstream fish passage options, conceptual drawings were prepared for each Project development. Information also was prepared on the operational considerations (Project operations and facility operations/maintenance), pros and cons, biological efficiency, lamprey considerations, and estimated costs by option. A summary matrix was constructed to describe general acceptance or non-acceptance of Project options by the regulatory agencies (NOAA Fisheries, USFWS, ODFW, and CDFG).

Key engineering feasibility issues include the following:

1. Determine whether the J.C. Boyle and Keno fishways conform with defined fish passage criteria for both resident fish species (for which the facilities were originally built) and anadromous species.

2. Evaluate the engineering feasibility of new or modified upstream and downstream fish passage options and behavioral devices for PacifiCorp facilities in the Project area.

The Link River dam fishway was not included in this study because the USBR is addressing upstream passage at the dam through ESA obligations. It is anticipated that a new fishway at the Link River dam will be constructed in 2004.

PacifiCorp identified the latest regulations and standards for fish passage set by the ODFW, CDFG, USFWS, and NOAA Fisheries, and prepared a list of proposed fish passage criteria for the design of new or modified upstream and downstream passage facilities. In cases where the standards of the state and federal agencies differ, the more stringent standard was applied. Site-specific information was collected related to engineering design and construction requirements at potential fish passage facility locations.

An evaluation was conducted to determine the engineering feasibility of providing improved fish passage at the Project's developments. The evaluation included a review of available information, a field reconnaissance, and selection of appropriate fish passage technologies. Using this information, conceptual facilities and planning-level cost estimates were developed to assist in the selection of recommended fish passage options.

7.7.1.1 Information Review and Field Reconnaissance

A literature and information review was conducted to gather data for the engineering evaluation. The primary reference was an assessment of fish passage conditions on the Upper Klamath River, prepared by FishPro in July 2000. Other related reports, texts, and studies also were collected and reviewed.

Record drawings and engineering data were obtained to provide information specific to the design, construction, and operation of the existing developments. This information included the layout and configuration of each development, dimensions of structures, and related hydraulic capacities. Where available, information for nearby facilities currently under construction was obtained.

A field reconnaissance of the eight PacifiCorp developments was conducted in September 2001. The facilities were inspected by members of the Fish Passage Engineering Subgroup including representatives from PacifiCorp, CH2M HILL, ODFW, CDFG, NOAA Fisheries, and USFWS.

The orientation and configuration of each development was confirmed with the record drawings. Measurements were taken to describe the streamflow, headwater and tailwater elevations, and other hydraulic characteristics. Proposed locations of new facilities were investigated.

The hydropower developments were reviewed to assess existing upstream and downstream fish passage conditions. Where fish passage facilities currently exist, an evaluation was made to determine their conformance with the established engineering criteria. The need for modifications to the existing facilities or the need for new facilities was determined at this time. The relevant findings from the existing facilities review, information review, and field reconnaissance were summarized for each fish passage facility.

7.7.1.2 Criteria Development

Fisheries engineering design criteria were developed to assist in the evaluation of existing fish passage facilities and the development of conceptual design options. The criteria were obtained from a variety of sources including current published guidance from federal and state fisheries resource agencies, project data, fisheries engineering reports, and texts. Input from members of the Fish Passage Engineering Subgroup was relied upon to establish design criteria where published information was lacking or inconclusive. In cases where the standards of the state and federal agencies differed, the more stringent standard was applied.

7.7.1.3 Technology Selection

Potential technologies for upstream and downstream fish passage were identified by the Engineering Subgroup. The group considered the merits and drawbacks of the engineering, physical, and biological feasibility of each fish passage technology. General effectiveness and historical use in the western United States also was considered.

A summary matrix of potential upstream and downstream fish passage facilities was developed. The matrix includes a general description of each technology and a summary of specific issues identified by the Engineering Subgroup.

7.7.1.4 Conceptual Facility Development

Where fish passage facilities were out of compliance with the established criteria or where facilities did not exist, conceptual facilities were proposed by the Engineering Subgroup. The facilities were developed for each site in conformance with the identified design criteria and technological guidelines. They also were selected for their ability to provide adequate fish passage while maintaining the operational intent of the hydropower development.

A summary of each conceptual facility was prepared including a general description of basic facility elements, facility sizing estimates, and capacity estimates. General arrangement drawings were developed to describe the location of proposed facilities in relation to the existing facilities. The relative merits and drawbacks of each option were identified in a summary matrix.

Planning-level cost estimates were prepared for each conceptual fish passage option. The costs included an estimate of capital project cost and an estimated present worth of operations and maintenance costs. Several of the proposed projects would use water that otherwise would be used for power generation, and several projects would create additional head losses. These water and head losses have been quantified in an estimated present worth of energy production cost.

7.7.1.5 Potentially Modified Facilities—J.C. Boyle and Keno Fishway

As-built drawings of the existing fishway facilities at Keno and J.C. Boyle dams were evaluated and compared to established fish passage design criteria for both resident and anadromous species. If criteria conflicts were determined for existing fishways, then potential methods for achieving adequate passage, as well as the same operational intent, were explored and the engineering feasibility of the method evaluated.

A field study was conducted to measure parameters relating to the established fish passage criteria where such information could not be obtained from existing drawings or reports. One field trip was conducted during late summer of 2001 to observe conditions at low flows. Data collection included the following:

- Upstream water surface elevation (at fishway exit)
- Downstream water surface elevation (at fishway entrance)
- Water surface elevation at intermediate locations within the fishway where there is ready access
- Existing channel bottom elevation at fishway exit
- Existing channel bottom elevation at fishway entrance
- Description of surface currents in the vicinity of the fishway entrance and exit, with particular attention to strong current patterns such as eddies, dead zones, and hydraulic jumps
- Description of stream channel characteristics (shape, length, width, meanders) upstream and downstream of the facility
- Observation of debris and bedload conditions

Results of the drawing review and field study were used to determine headwater and tailwater rating curves, calculate pool turbulence factors, describe surface currents at fishway entrances and exits, and describe stream channel conditions, including attraction flow at fishway entrances.

Using the collected field data, a hydraulic analysis was completed for each fishway to estimate passage conditions under a range of flows and water depths at each dam. Results of the field conditions were also used to extrapolate expected conditions throughout the entire range of anticipated fishway use.

7.7.1.6 Potential New Facilities—Iron Gate, Fall Creek, Copco No. 1 and Copco No. 2, East Side, and West Side

A site reconnaissance was conducted with the Engineering Subgroup at each proposed passage facility. Before the field visits, available information was collected and reviewed for each site, including general stream course; elevation of channel bed; channel length and width; and channel meander and structural features. Relevant site conditions observed during field visits include stream channel flow characteristics (such as water depth and width, if possible to measure); debris and bed load characteristics; location and type of bedrock; vegetation; drainage ways; soil mass movement and erosion; existing fills and excavation; and existing roads and ditches.

A preliminary assessment was conducted for each proposed facility to identify all relevant methods capable of achieving fish passage objectives that conform to established fish passage criteria. Conceptual design plans were developed that identify facility size and configuration as needed to meet defined fish criteria. Stream channel information collected during the field surveys was used to determine the likely locations of passage entrances and exits. For selected facility options drawings were prepared that include a plan and section view of the passage structure and a site layout showing structure location and orientation, site access, and any necessary support buildings or structures. A planning-level cost estimate also was developed for each option for comparative purposes.

The Engineering Subgroup prepared an initial list of options for fish passage facilities that included a brief description of each technology and comments from the NOAA Fisheries, USFWS, CDFG, and ODFW. Technical memorandums (see March 2003 Fish Passage Meeting Handouts) for each dam then were prepared that described existing facilities (where applicable) as well as proposed new facility options. Planning level cost estimates for each option facility were included.

7.8 RESULTS AND DISCUSSION

The purpose of this section is to briefly document existing fish passage facilities at the Klamath River Hydroelectric Project and to present proposed fish passage alternatives for further consideration. Both upstream and downstream fish passage alternatives were developed according to applicable design criteria and input from the regulatory agencies. Figures developed for each alternative show the general arrangement of each proposed facility. Estimates of project capital costs, present worth operations and maintenance costs, and present worth energy costs were also calculated for each alternative.

7.8.1 Fish Passage Facility Design Criteria

PacifiCorp owns and operates the Klamath Hydroelectric Project, which includes eight developments in the Klamath River basin. The eight developments are East Side, West Side, Keno, J.C. Boyle, Copco No. 1, Copco No. 2, Iron Gate, and Fall Creek. Improved fish passage facilities may be required at these structures as a result of the on-going FERC re-licensing process. The Engineering Subgroup was tasked with investigating the feasibility of providing upstream and downstream fish passage at these hydroelectric developments. This section documents the fisheries engineering design criteria used during the development of conceptual fish passage alternatives for each site.

7.8.1.1 Background

The criteria documented herein were compiled from a variety of sources including current published guidance from federal and state fisheries resource agencies, Project data, fisheries engineering reports, and texts. Input from members of the Engineering Subgroup was relied upon to establish design criteria where such published information was lacking or inconclusive.

7.8.1.2 Design Criteria

Tables 7.8-1 and 7.8-2 list references used for this study, and provide a brief explanation of how each reference applies to the development of the conceptual alternatives.

Table 7.8-1. Resource agency design guidelines.

Reference	Applicable to
National Marine Fisheries Service (NOAA Fisheries), Southwest Region, January 1997, Fish Screening Criteria for anadromous Salmonids, File Report	Design of fish screens
Oregon Department of Fish and Wildlife (ODFW), March 2001, Fish Screening Criteria for Water Diversions, File Report	Design of fish screens
California Department of Fish and Game (CDFG), June 2000, Fish Screening Criteria, File Report.	Design of fish screens

Table 7.8-2. Other published design criteria.

Reference	Applicable to
Bell, M.C. 1991. Fisheries Handbook of Engineering Requirements and Biological Criteria, U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.	Design of all fish passage facilities
Mefford, B., Glickman and Campbell. 2001. Link River Dam Fishway Replacement Feasibility Study, U.S. Bureau of Reclamation (USBR), Klamath Area Office, Oregon.	Design of fish ladders for suckers
FishPro. July 2000. Fish Passage Conditions on the Upper Klamath River: Prepared for The Karuk Tribe and PacifiCorp, Oregon and California.	Design of all fish passage facilities
Clay, C. H. 1995. Design of Fishways and Other Fish Facilities, Second Edition, Lewis Publishers, Ann Arbor and Boca Raton.	Design of all fish passage facilities

The above criteria provide guidance with respect to the layout, orientation, sizing and hydraulic parameters for the design of fish passage facilities.

The current accepted criteria used in the design of upstream and downstream fish passage facilities are provided in Appendix 7A.

7.8.2 Link River Dam—East Side Facilities

7.8.2.1 Existing Fish Passage Facilities

Link River dam is owned by the USBR and provides diversion capabilities from Upper Klamath Lake to PacifiCorp's East Side Development. Currently, the East Side Development has neither fish screens on the power canal nor a tailrace barrier on the powerhouse. An existing fish ladder on the left abutment of the dam provides some upstream fish passage. The ladder is a pool- and weir-type fish ladder with a vertical slot entrance. The flow is adjusted manually with stop logs. This ladder was designed and built to pass trout; however, other migrating fish species such as suckers have been observed to use the ladder. As owners of the Link River dam, USBR is responsible for operations of the ladder.

The USBR has recently completed construction of a new fish screen for the A-Canal, which diverts water for irrigation from Upper Klamath Lake, 1,900 feet upstream from Link River dam. The A-Canal screen bypass flow can be pumped back into Upper Klamath Lake or diverted downstream of Link River dam. The fish screen criteria approved by the USFWS and ODFW for the A-Canal screens, namely the 2.0-mm clear spacing, should be suitable for suckers, anadromous fish, and resident trout species in Upper Klamath Lake.

Fish Ladder

PacifiCorp operates the dam in accordance with USBR operations rules, which, in recent years, have been modified annually in accordance with the Klamath Project Biological Opinion (BO) prepared by the USFWS. The USBR currently is designing a new fish ladder for Link River dam, to be installed at the right abutment next to the West Side power canal (Keno canal) in 2004. This new ladder is being designed specifically to facilitate upstream passage of suckers; however, resident trout also will benefit from this new fish ladder. The existing left bank fish ladder will remain in service and may be improved at some future time. If anadromous fish are reintroduced in this area, the proposed USBR fish ladder should be suitable for salmon, steelhead, and Pacific lamprey. However, some modifications to the ladder may be required to accommodate all species.

7.8.2.2 Conceptual Downstream Fish Passage Facilities

A fish screen may be required to provide downstream fish passage. The following presents a discussion of such downstream passage technologies.

Fish Screen

The capacity of the East Side power canal is 1,200 cfs. A steel trashrack with 2.75-inch bar spacing is located at the flowline intake structure. The conceptual construction cost for a canal screen was developed by scaling the cost of the A-Canal screen, and through comparison with cost curves from similar projects. Annual operations and maintenance costs were developed to account for additional operational requirements, debris handling, equipment maintenance, etc,. associated with the facility. An estimate of additional bypass flows unavailable for generation and headloss through the structure was used to develop energy costs.

A conventional fish screen meeting NOAA criteria for the East Side Development is estimated to cost approximately $15 million. The present worth cost for operating and maintaining the screen is estimated to be approximately $646,000. Water cost for this screen, in the form of bypass flow, is anticipated to be approximately 20 cfs. The present worth of the associated energy costs is estimated to be approximately $66,000. Figure 7.8-1 presents the proposed conventional fish screen facility for the East Side power canal. The location and position of the screen is shown relative to the existing Link River dam and the proposed A-Canal gravity bypass pipe outfall.

High-speed fish screens also can be considered at this site. High-speed screens have an approach velocity approximately four times that of conventional screens. Although the high-speed screen potentially could have only 25 percent of the screen area, the construction cost is estimated to be 40 percent of the conventional screen cost, or approximately $6.12 million. The present worth and O&M cost of the high-speed screen is estimated to be approximately $517,000. Water cost for the high-speed screen would be the same as the conventional screen, or approximately 20 cfs. The present worth of the associated energy costs is estimated to be approximately $66,000. Figure 7.8-2 presents the fish screen as it would appear in a high-speed configuration. Table 7.8-3 summarizes the conceptual downstream fish passage facilities.

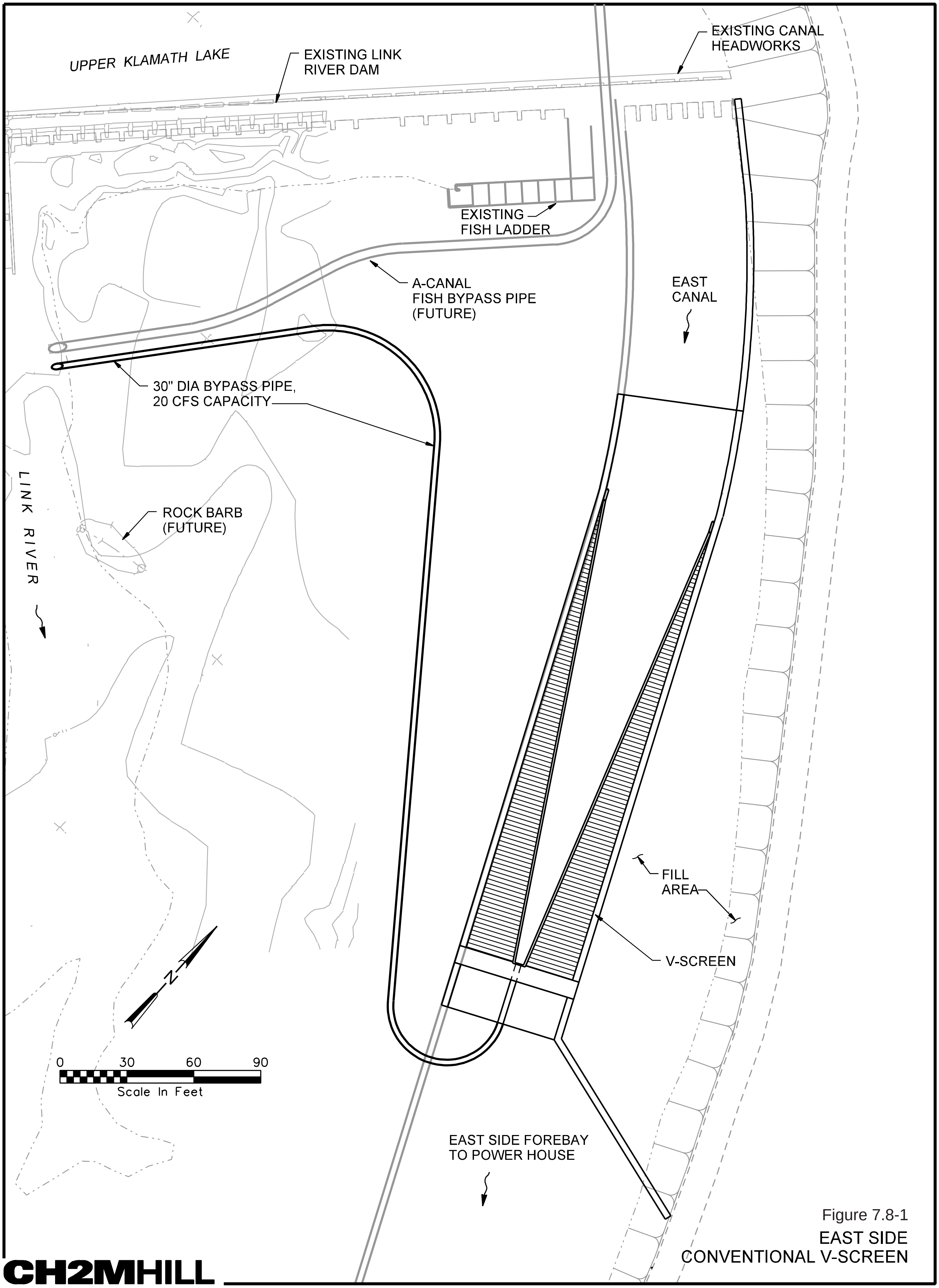

Figure 7.8-1
EAST SIDE
CONVENTIONAL V-SCREEN

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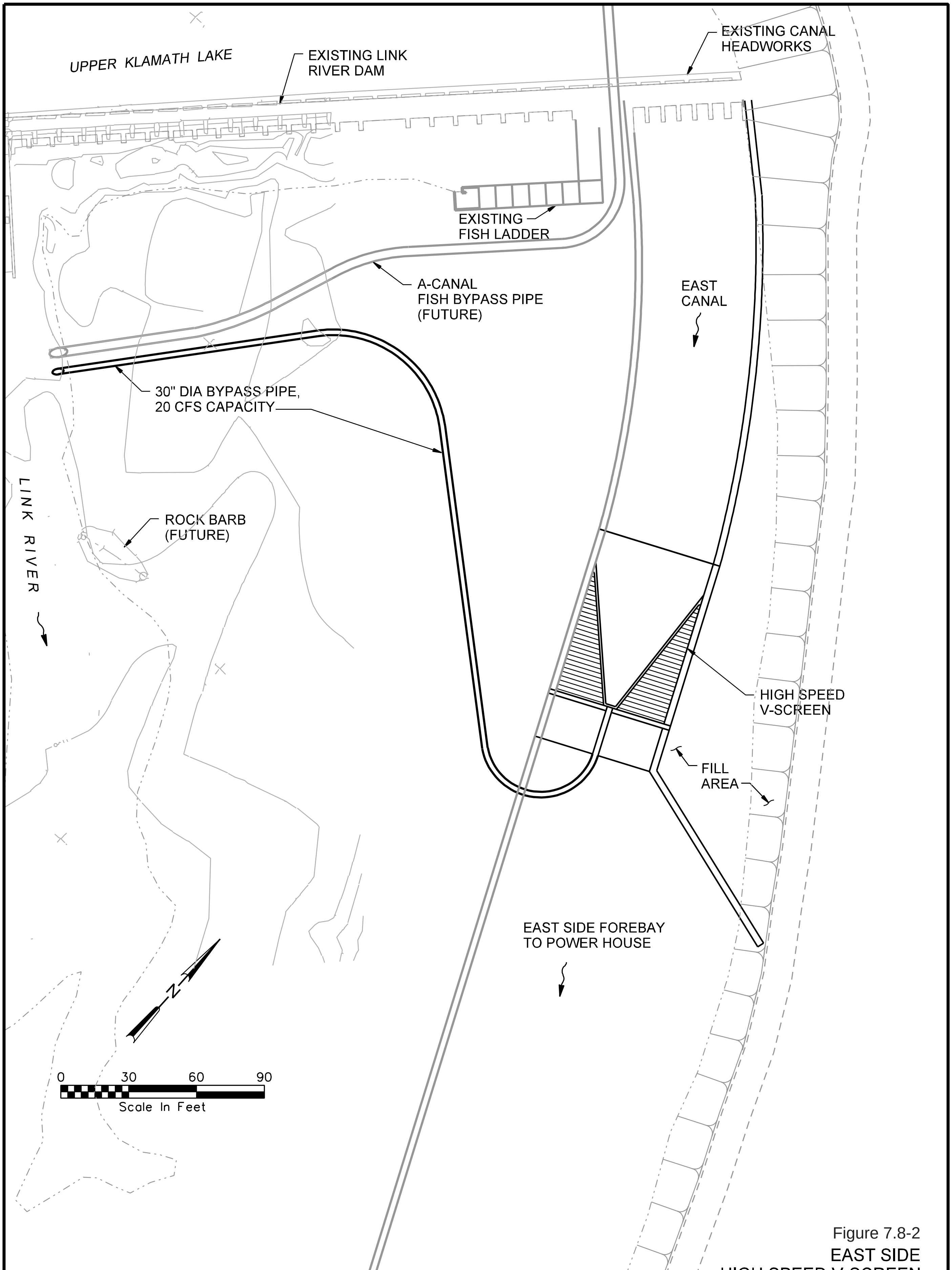

Figure 7.8-2
EAST SIDE
HIGH SPEED V-SCREEN

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Table 7.8-3. Conceptual East Side downstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Conventional V-Screen	7.8-1	Proven technology that meets current agency guidelines for downstream fish protection.	At 1,200 cfs, this is a large and costly structure.	$15,000,000	$646,000	$66,000
High-Speed V-Screen	7.8-2	This is a much smaller structure, with an associated reduced cost.	Does not meet agency approach velocity criteria so would be viewed as an “experimental technology.”	$6,120,000	$517,000	$66,000

[1] Present worth costs are calculated using a real discount rate of 6.6 percent for a period of 30 years.
[2] Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

7.8.2.3 Conceptual Upstream Fish Passage Facilities

A tailrace barrier could enhance upstream fish passage by preventing fish from being delayed, injured, or killed by swimming into the powerhouse tailrace. The following presents a discussion of such a facility.

Tailrace Barrier

The tailrace barrier would be an adult diffuse-type tailrace barrier such as a picket barrier. The estimated project cost for a tailrace barrier of this size is approximately $3.06 million. This estimate was made through comparison of costs curves from similar projects.. Present worth O&M costs are estimated to be $323,000. Present worth energy costs are estimated to be approximately $22,000. Table 7.8-4 provides a summary of this upstream fish passage concept.

7.8.3 Link River Dam—West Side Facilities

7.8.3.1 Existing Fish Passage Facilities

Link River Dam is owned by the USBR and provides the diversion capabilities from Upper Klamath Lake to PacifiCorp's West Side Development. Currently, the West Side Development has neither fish screens on the power canal nor a tailrace barrier at the powerhouse. An existing fish ladder on the left abutment of the dam provides some upstream fish passage.

7.8.3.2 Conceptual Downstream Fish Passage Facilities

A fish screen at this development would enhance downstream fish passage by eliminating fish entrainment related to continuous operations. The following presents a discussion downstream fish passage facilities.

Fish Screen

The capacity of the West Side power canal is 250 cfs. The cost of a conventional inclined V-screen canal screen was derived through comparison with other cost curves. A conventional fish screen meeting NOAA Fisheries criteria for the West Side Development is estimated to cost approximately $2.04 million. This cost was developed using cost curves from similar projects. Annual operations and maintenance costs were developed to account for additional operational requirements, debris handling, equipment maintenance, etc., associated with the facility. The present worth cost of operating and maintaining the conventional screen is estimated to be approximately $646,000. Water cost for the screen, in the form of bypass flow, will be approximately 20 cfs. The present worth of the associated energy costs is approximately $16,500. Figure 7.8-3 presents the proposed conventional fish screen facility for the West Side power canal. The general arrangements of the proposed USBR fish ladder and the A-Canal gravity bypass outfall also are shown in Figure 7.8-3.

Table 7.8-4. Conceptual East Side upstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Tailrace Barrier	N/A	Precludes adults from being falsely attracted to the powerhouse tailrace, being delayed or being injured.	A large structure is needed to meet agency approach velocity criteria of 1.0 fps.	$3,060000	$323,000	$22,000

[1] Present worth costs are calculated using a real discount rate of 6.6 percent for a period of 30 years.
[2] Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

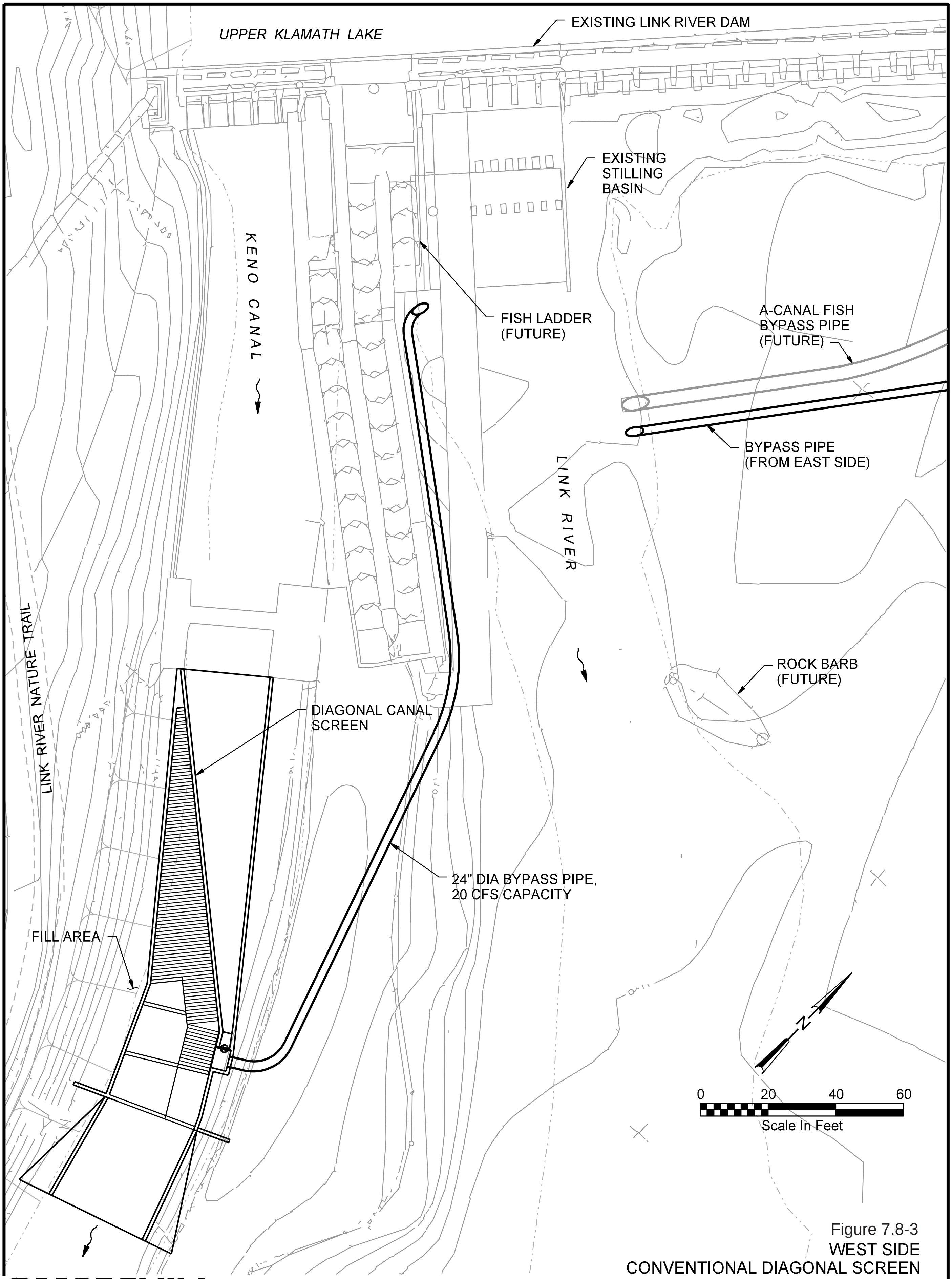

Figure 7.8-3
WEST SIDE
CONVENTIONAL DIAGONAL SCREEN

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High-speed fish screens also can be considered at this site. High speed screens have an approach velocity approximately four times that of conventional screens. Although the high-speed screen potentially could be only 25 percent of the screen area cost, the construction cost is estimated to be 40 percent of the conventional screen cost, or approximately $869,000. The O&M present worth cost is estimated to be approximately $517,000. Water cost for the high-speed screen would be the same as the conventional screen, or approximately 20 cfs. The present worth energy cost would be $16,500. Figure 7.8-4 presents the fish screen as it would appear in a high-speed configuration. Table 7.8-5 summarizes the conceptual downstream fish passage facilities for the West Side Development.

7.8.3.3 Conceptual Upstream Fish Passage Facilities

A tailrace barrier could enhance upstream fish passage by preventing fish from being delayed, injured or killed by swimming into the powerhouse tailrace. The following presents a discussion of such a facility.

Tailrace Barrier

The tailrace barrier would be an adult diffuse-type tailrace barrier such as a picket barrier. The estimated project cost for a tailrace barrier is approximately $740,000. Present worth O&M costs are estimated to be $323,000. Present worth energy costs are estimated to be approximately $5,490. Table 7.8-6 provides a summary of this upstream fish passage concept.

7.8.4 Keno Dam

7.8.4.1 Existing Fish Passage Facilities

The original construction of the Keno Development included a fish ladder on the left abutment of the dam. Currently, no powerhouse and no downstream fish passage facilities exist. A summary of the existing facilities is presented below.

Spillway

All water released from Keno Dam goes through the spillway radial gates, with the exception of flows from the fish ladder, auxiliary water supply (AWS) system, and sluice conduit. The six radial gates are all the same size, approximately 40 feet wide by 16 feet high. Bays 1, 2, and 3 spill into the left abutment stilling basin with an invert elevation of 4,052 feet. On the September 19, 2001, field trip, the flow in the river was 750 cfs. The water was approximately 9.1 feet deep in the left abutment stilling basin.

PacifiCorp normally releases 250 cfs as a minimum flow from the dam, 150 cfs from the ladder and AWS, and an additional 100 cfs from the 36-inch-diameter sluice pipe, which discharges into the stilling basin adjacent to the ladder. Based on this information, it is estimated that approximately 500 cfs were being discharged through the spillway gates during the site visit on September 19, 2001.

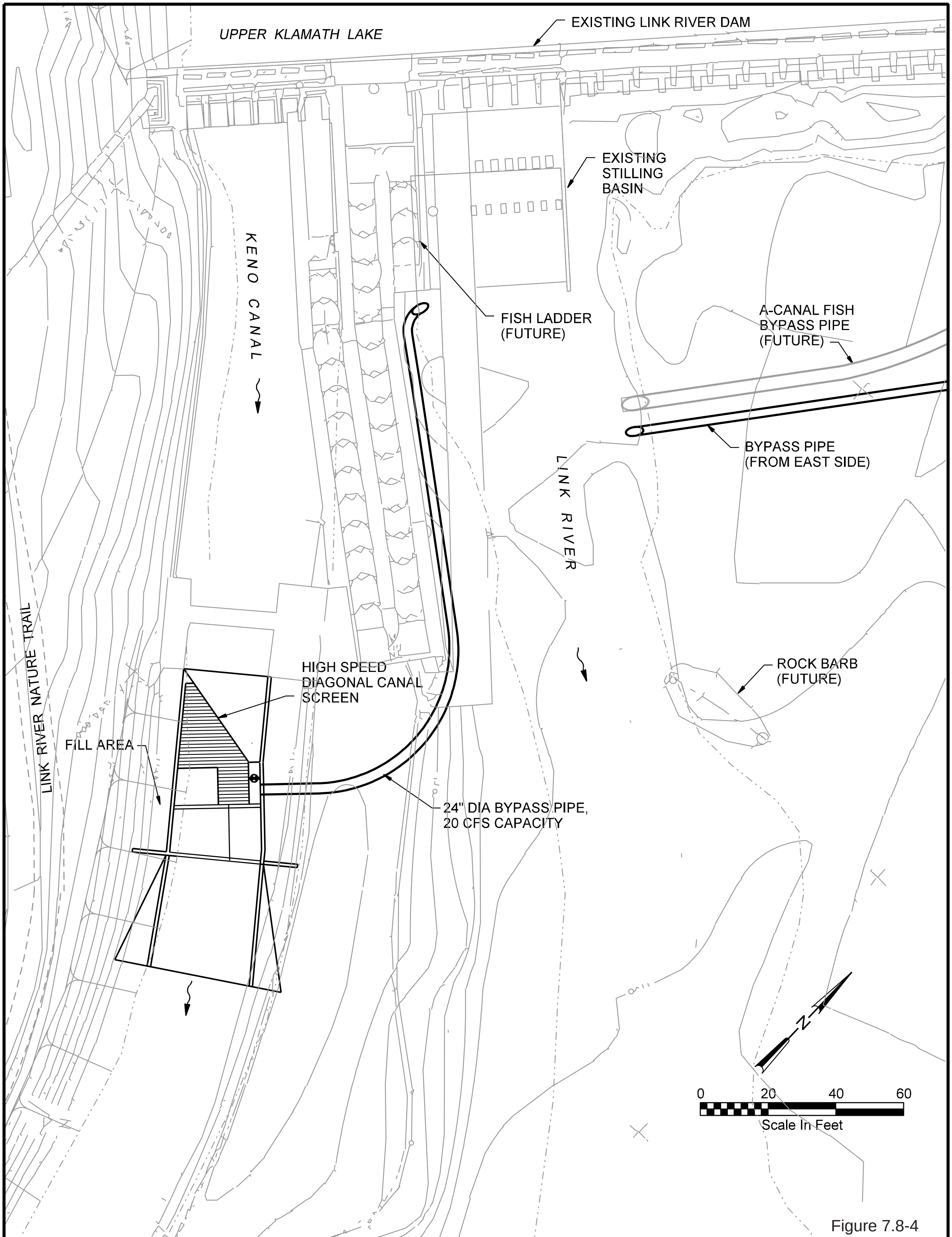

Figure 7.8-4
WEST SIDE
HIGH SPEED DIAGONAL SCREEN

CH2MHILL

Table 7.8-5. Conceptual West Side downstream fish passage facilities.

Facility Being Considered	**Figure No.**	**Pros**	**Cons**	**Estimated Project Capital Cost**	**Present Worth of Estimated O&M Costs[1]**	**Present Worth of Estimated Energy Costs[1,2]**
Conventional Diagonal Screen	7.8-3	Proven technology that meets current agency guidelines for downstream fish protection.	High cost for a small hydro development.	$2,040,000	$646,000	$16,500
High–Speed Diagonal Screen	7.8-4	This is a much smaller structure, with an associated reduced cost.	Does not meet agency approach velocity criteria so would be viewed as an “experimental technology.”	$869,000	$517,000	$16,500

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

Table 7.8-6. Conceptual West Side upstream fish passage facilities.

Facility Being Considered	**Figure No.**	**Pros**	**Cons**	**Estimated Project Capital Cost**	**Present Worth of Estimated O&M Costs[1]**	**Present Worth of Estimated Energy Costs[1,2]**
Tailrace Barrier	N/A	Precludes adults from being falsely attracted to the power house tailrace, being delayed or being injured.	A large structure is needed to meet agency approach velocity criteria of 1.0 fps.	$740,000	$323,000	$5,490

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

Fish Ladder

The existing fish ladder at Keno dam is a pool and weir-type ladder with an AWS. The fish ladder is made up of an entrance bay with AWS diffuser; 24 numbered pools formed by fixed concrete weirs; and four automated weir gates, which form pools 25, 26, 27 and 28. Pool 28 is the exit pool of the ladder.

On the September 19, 2001, field trip, the lake level was approximately 4,085.6 feet and the tailwater level at the fishway entrance was approximately 4,061.0 feet, yielding a gross head of approximately 24.6 feet.

Pools 1 through 24 are generally 10 feet 6 inches long, including the 6-inch concrete weirs. The width of the pools is a consistent 6 feet. The weirs are 4 feet high, 6 inches thick, and 3 feet inches wide. Each of the fixed weirs has a 15-inch-high by 10-inch-wide orifice flush with the floor and centered in the weir.

Flow in the ladder is estimated to be 4.9 cfs through the orifice and 5.6 cfs over the 3-foot-wide weir when the head from pool to pool is 0.7 foot. The total flow under this condition would be approximately 10.5 cfs. At 1.0 foot of head, the total flow would be approximately 15.2 cfs. The slope of the ladder is 1V:10.5H, which is slightly flatter than the current criteria for trout of 1V:10H, but much steeper than for the current criteria for suckers of 1V:22H. The large pool volume and relatively low flow produces a turbulence factor of 1.6 foot-pounds per second per cubic foot (ft-lb/s/ft^3) of pool volume for the case with 0.7-foot drop per pool. For 1.0-foot drop, the turbulence factor is 3.2 ft-lb/s/ft^3. Both of these values are below the recommended value of less than 4.0 ft-lb/s/ft^3.

Automated weirs 25 through 28 have a small 3-inch-diameter drain hole in the center of the weir at the floor. Most fish using the ladder will have to jump over the last four metal weirs to gain access to the reservoir.

The AWS system provides additional flow to the ladder entrance bay. The 30-inch-diameter supply line is controlled by a valve upstream of the diffuser pipe. Flow from this system goes through a 5-foot-high by 28-foot-long wall diffuser grating. With a normal wall diffuser criteria of 1.0 fps gross, the system should be able to deliver 140 cfs. Normally, the delivery system would be limited to 70 cfs, which would imply that the diffuser criteria was 0.5 fps. The depth in the entrance bay at the time of the site visit was 6.8 feet. The entrance width is 3 to 6 inches with an area of approximately 23.8 ft^2. The low differential across the entrance indicates that the ladder plus AWS flow was only 40 or 50 cfs. The 1- to 2-fps entrance velocity is consistent with entrance criteria for suckers. The 36-inch sluice conduit, which discharges into the spillway stilling basin, potentially could convey 100 cfs.

In summary, the 150 cfs ladder plus AWS flow discussed in the field seems too high. The ladder flow is likely about 10 to 15 cfs and the AWS is about 40 to 50 cfs. The estimate of 100 cfs for the sluice conduit seems reasonable. If the AWS system is pushed to 85 cfs to get a total instream flow of 200 cfs, this may produce less than desirable fish ladder entrance conditions for suckers.

7.8.4.2 Conceptual Downstream Fish Passage Facilities

The effectiveness of the existing spillway for downstream fish passage was discussed during the September 2001 field trip . Minor modifications to the spillway may improve downstream fish passage.

Spillway Modifications

Concern was expressed during the September 2001 field trip that the small openings of the 40-foot-wide radial gates might not be fish friendly. However, it is not clear how much of a problem this would be for downstream migrating fish. A 1-foot opening in a single gate would yield about 1,100 cfs. So, it appears that there may be a fish passage problem for river flows greater than the ladder/AWS flow up to approximately 1,400 cfs. Retrofitting a top spill feature to a radial gate was discussed. A 3-foot-deep by 20-foot-wide top spill gate may be added to the existing gate for approximately $125,000 and would improve downstream fish passage. An additional benefit would be the ability to sluice floating debris through the top spill gate. The concept is summarized in Table 7.8-7.

7.8.4.3 Conceptual Upstream Fish Passage Facilities

There are two levels of potential modifications to the existing fish ladder at Keno dam. The first level would be minor modifications that may be required to improve upstream passage for salmon or trout. The second level would be a major reconstruction of the ladder to meet the recommended slope for suckers.

Modify Existing Fish Ladder

The details of potential minor modifications to the existing ladder have not been explored fully with the Engineering Subgroup. Options to be discussed include the following:

- Doubling the number of weirs
- Switching to vertical slot weirs
- Adding larger orifices to the upper pools
- Modifying the entrance
- Operational adjustments

It is estimated that these minor adjustments would cost between $250,000 and $1 million. Figure 7.8-5 presents a plan view of improvements to the existing fish ladder at Keno dam.

Sucker Fish Ladder

The proposed USBR fish ladder for Link River dam was designed specifically to facilitate upstream passage for suckers and could be used as a model for the Keno dam site. Resident trout would benefit from a fish ladder designed to pass adult suckers. If anadromous fish are reintroduced in this area, the proposed fish ladder should be suitable for salmon, steelhead, and Pacific lamprey. However, some modifications may be required.

Table 7.8-7. Conceptual Keno dam downstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Spillway Modifications	N/A	May facilitate downstream passage in a specific band of river flow when small radial gate openings are called for.	Benefit of proposed modification is uncertain as it has not been demonstrated that downstream passage through the spillway gates is harmful to fish.	$125,000	N/A	N/A

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

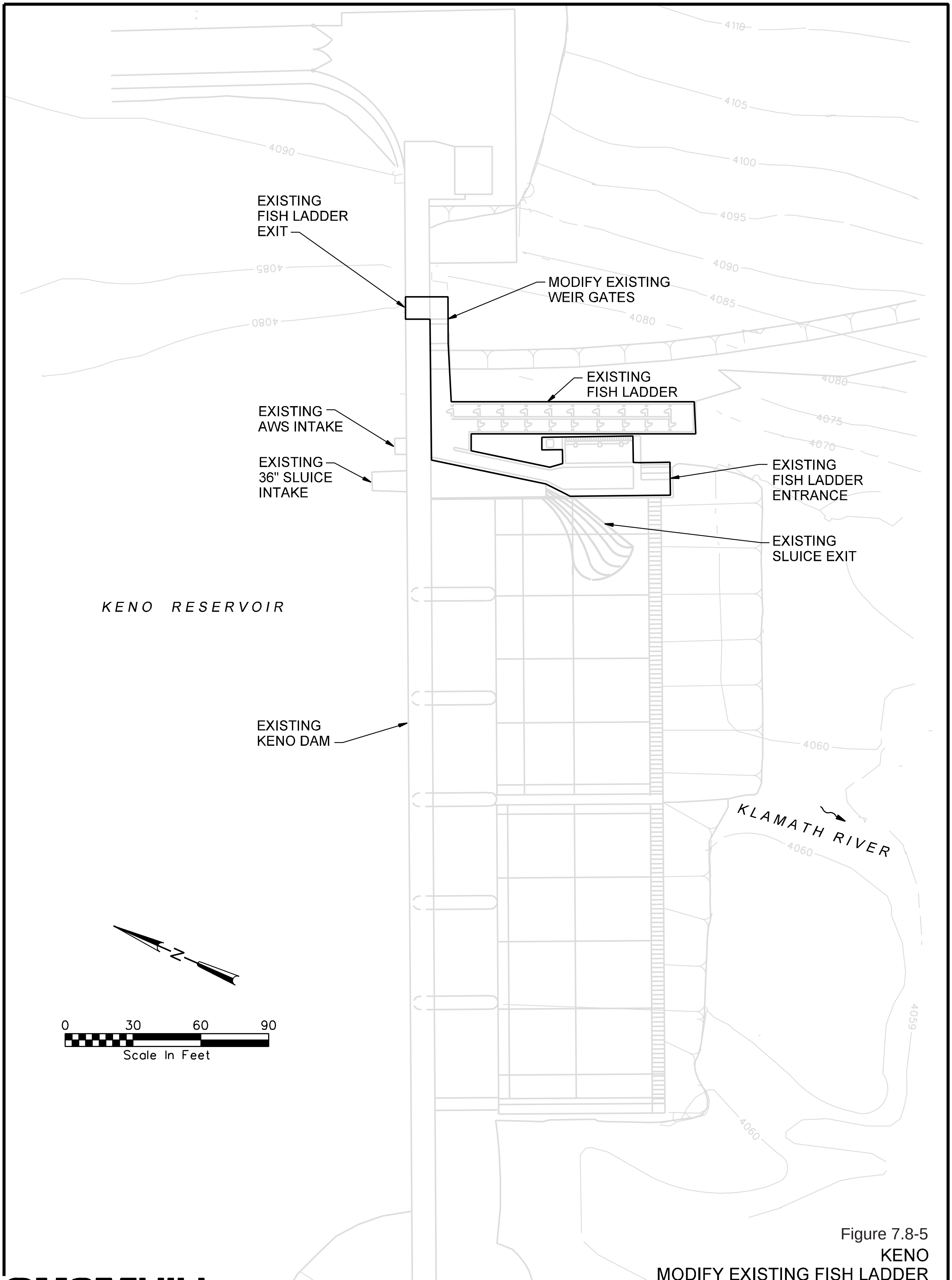

Figure 7.8-5
KENO
MODIFY EXISTING FISH LADDER

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To meet the recommended slope for sucker passage of 1V:22H, most of the existing Keno dam fish ladder would have to be removed and a new fish ladder constructed. It may be possible to retain the AWS and entrance pool of the existing fish ladder and then lengthen the remainder of the fish ladder. Major reconstruction of the fish ladder at Keno may cost approximately $2.24 million. Figure 7.8-6 presents a plan view of a new fish ladder configured for suckers. Table 7.8-8 summarizes conceptual upstream fish passage facilities.

7.8.5 J.C. Boyle Dam

7.8.5.1 Existing Fish Passage Facilities

The original construction of the J.C. Boyle Development included fish screens on the power intake tower, a fish ladder at the dam, but no tailrace barrier at the powerhouse. A description of the existing fish screens and fish ladder is presented below.

Fish Screens

The initial design of the power intake for the J.C. Boyle Development included four Rex traveling band screens. PacifiCorp has maintained these screens in good working order. In 1988, a new building was added to the intake to protect the screens. The existing screens do not meet current criteria for fish screens. They are 11 feet 2 inches wide and 29 feet 6 inches high at a low forebay level of 3,788.0 feet. This screen height assumes 6 inches of the bottom of the screen is ineffective because of the normal seal arrangement. The gross approach area for each of the four screens is 329.4 $ft^2$for a total gross area of 1,318.0 ft^2. The resulting approach velocity with an intake flow of 3,000 cfs is 2.3 fps, which is almost six times the modern criteria of 0.4 fps.

The existing screen bypass system, although consistent with the design one normally would expect for traveling band screens, does not meet current design criteria. The flow provided for the existing bypass fish return is estimated at 20 cfs.

Fish Ladder

The existing fish ladder at J.C. Boyle dam is a pool and weir type ladder, with an AWS system. Design drawings and the FishPro (1992) report do not present a clear picture of the design of this fish ladder. FishPro (1992) reports 57 pools in the ladder, but, according to the drawings and as verified through field reconnaissance, there are 63 pools. The pools are generally 8 feet 6 inches long, including the 6-inch weirs. The width of the pools is a consistent 6 feet. The weirs are 3 feet 6 inches high, 6 inches thick, and 6 feet wide. Each weir has a 4-inch square orifice flush with the floor and centered in the weir. Pools 60 through 63 and the exit pool are controlled by 6-foot automated weir gates, which, at full pool elevation of 3,793.0 feet, provide a 1-foot drop from pool to pool. At the low forebay elevation of 3,788.0 feet, the weir gates are fully down.

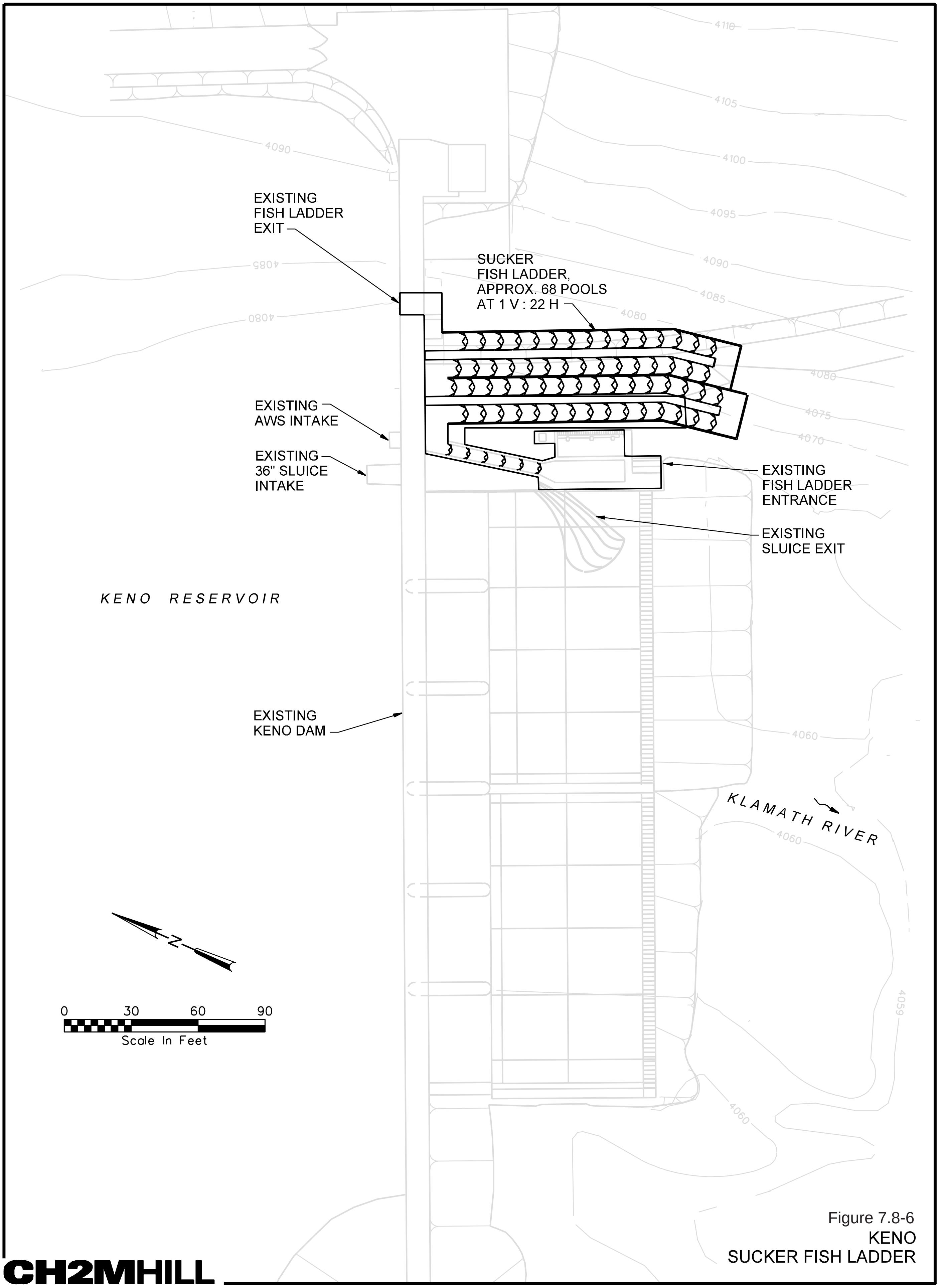

Figure 7.8-6
KENO
SUCKER FISH LADDER

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Table 7.8-8. Conceptual Keno dam upstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Modify Existing Fish Ladder	7.8-5	Would improve passage for trout and potentially reintroduced anadromous fish.	None.	$1,000,000	N/A	N/A
Sucker Fish Ladder	7.8-6	Would provide more favorable passage for adult suckers.	High cost.	$2,240,000	N/A	N/A

[1] Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

[2] Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

The tailwater elevation at the fish ladder entrance on the day of the field visit on September 19, 2001, was 3,732.8 feet. This elevation is more than 3 feet above the value listed in the design drawings, so it needs to be verified with a field survey. A shift in the tailwater elevation may have occurred over the years as a result of vegetation growth along the outlet channel to the river. With a forebay range from 3,793.0 to 3,788.0 feet, the fish ladder operates over a gross head range of 60.2 to 55.2 feet. At full pool, there would be about a 1-foot drop across each weir. This approximate 1-foot drop also would exist at the low forebay level because the automated weirs are set up to supply a constant flow. This 1-foot drop does not conform with the design criteria for resident trout of 6- to 9-inch drops between pools.

Flow in the fish ladder is estimated to be 0.6 cfs through the 4-inch square orifices, and 20 cfs over the 6-foot-wide weirs. The slope of the ladder is 1V:8.5H, which is steeper than both the current criteria for trout at 1V:10H, and the current criteria for suckers at 1V:22H. The pool volume of the existing ladder is 192 cubic feet (4-foot average depth, 6 by 8 feet in plan). With an approximate ladder flow of 21 cfs, the turbulence factor for the typical pool would be 6.8 $ft\text{-}lb/s/ft^3$, which is 1.7 times the modern recommended value of less than 4.0 $ft\text{-}lb/s/ft^3$.

Summary of Existing Facilities

The existing fish screens and ladder at the J.C. Boyle Development met existing design criteria when constructed in 1957. Both facilities appear to be in good condition and maintained to meet the original design criteria. However, neither of these facilities meets current fish passage criteria for the state and federal fisheries resource agencies as related to resident and anadromous fish.

7.8.5.2 Conceptual Downstream Fish Passage Facilities

Fish screens or a gulper may be required to facilitate downstream fish passage. A discussion of such facilities is presented below.

Fish Screens

The J.C. Boyle intake has a design flow of 3,000 cfs. This is similar in size to the Rocky Reach Surface Collector Prototype on the Columbia River near Wenatchee, Washington. For a conventional fish screen design with an approach velocity (V_n) of 0.4 fps, this would result in 6,250 $ft^2$of required fish screen area. The system for J.C. Boyle would be similar to Rocky Reach in that it would need to be built in the lake. The normal lake fluctuation of 5.5 feet is also similar to Rocky Reach. However, the reservoir is shallow in front of the existing power intake, so some excavation would be required.

Primary screens would screen most of the flow with a 200 cfs bypass. The 200 cfs bypass would pass through secondary screens yielding a final bypass flow of 20 cfs to be discharged to the river below the dam. As a result, the water cost for this technology would be similar to the existing fish screen bypass of 20 cfs. Both conventional and high-speed fish screens could be considered at this site.

Based on the 3,000 cfs capacity, and using the fish screen cost curve, the construction cost for such a facility would be approximately $14.5 million. However, the cost could be 50 percent higher because of the shallow lake conditions, resulting in an estimated Project cost of approximately $21.7 million. Present worth O&M costs are estimated to be approximately

$646,000. Associated water costs would be approximately 20 cfs, resulting in a present worth energy loss of approximately $147,000. The conceptual layout for a conventional V-screen is presented in Figures 7.8-7 and 7.8-8.

A high-speed screen may be considered at this site. The estimated Project cost is approximately $8.84 million. Present worth O&M costs are estimated to be approximately $517,000. Associated water costs would be approximately 20 cfs, resulting in a present worth energy loss of approximately $147,000.The conceptual layout for a high-speed V-screen is presented in Figure 7.8-9.

Gulper System

The gulper system is a surface collector technology, which has been used successfully at the Puget Sound Energy Baker River Project for years. In recent planning studies for Round Butte and Cougar Lake in Oregon, gulpers have been proposed. In concept, the gulper is a 200-cfs floating surface collector with guide nets placed in a reservoir to provide downstream migrating fish a passage option preferable to deep turbine intakes. The estimated Project cost for a gulper system for J.C. Boyle would be approximately $6.29 million. Present worth O&M costs are estimated to be $620,000.

The gulper would take in 200 cfs from the surface of the lake and bypass 20 cfs with the fish into the bypass pipe for delivery to the river below the dam. Pumps internal to the floating gulper return 180 cfs back to the reservoir. The water cost for this alternative would be the same as a positive barrier screen or approximately 20 cfs. Present worth energy costs would be similar to the screens, resulting in an estimated present worth energy cost of $163,000. The conceptual layout of a J.C. Boyle gulper is presented in Figure 7.8-10. Table 7.8-9 summarizes the conceptual downstream fish passage facilities.

7.8.5.3 Conceptual Upstream Fish Passage Facilities

A fish ladder or fish lock with aerial tramway may improve upstream fish passage at the J.C. Boyle Development. A discussion of such facilities is presented below.

Fish Ladder

If a new fish ladder were required at J.C. Boyle, it would have to provide passage over the 60.2 feet of gross head as described earlier. A new ladder for anadromous fish would cost approximately $9 million. Near-surface water temperatures in the J.C. Boyle Reservoir may at times exceed optimal conditions for fish passage. Special water temperature facilities for summer operation may bring the total construction cost for a ladder to approximately $9.9 million. Present worth O&M costs are estimated to be approximately $517,000 and $1.81 million depending on the design (increased costs would be associated with designing to the holding facility). In addition, the ladders would require a total flow of 120 cfs (40 cfs for the ladder and 80 cfs for the AWS). This results in a present worth energy cost of approximately $3.77 million and $4.51 million, depending on the design.

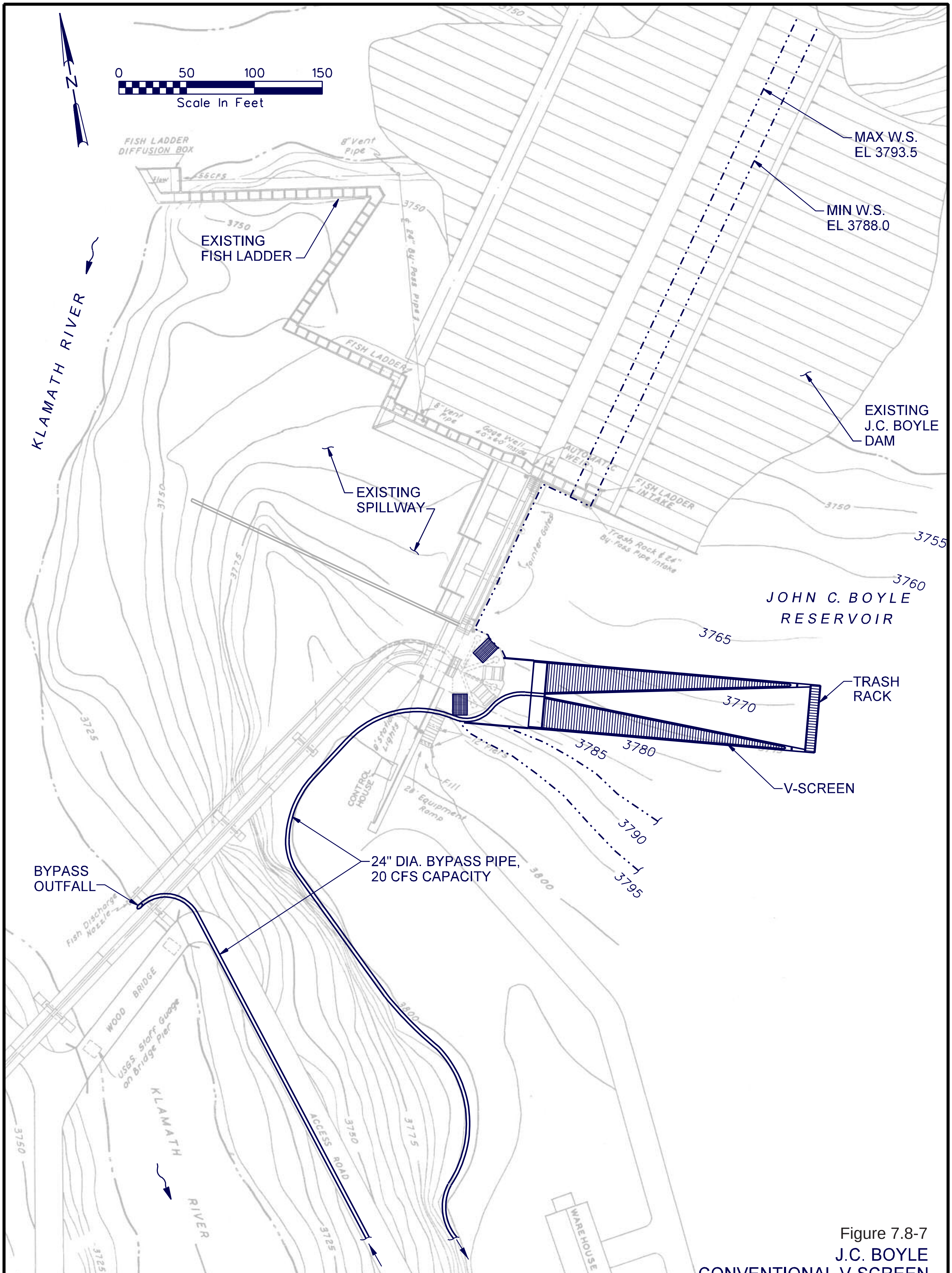

Figure 7.8-7
J.C. BOYLE
CONVENTIONAL V-SCREEN

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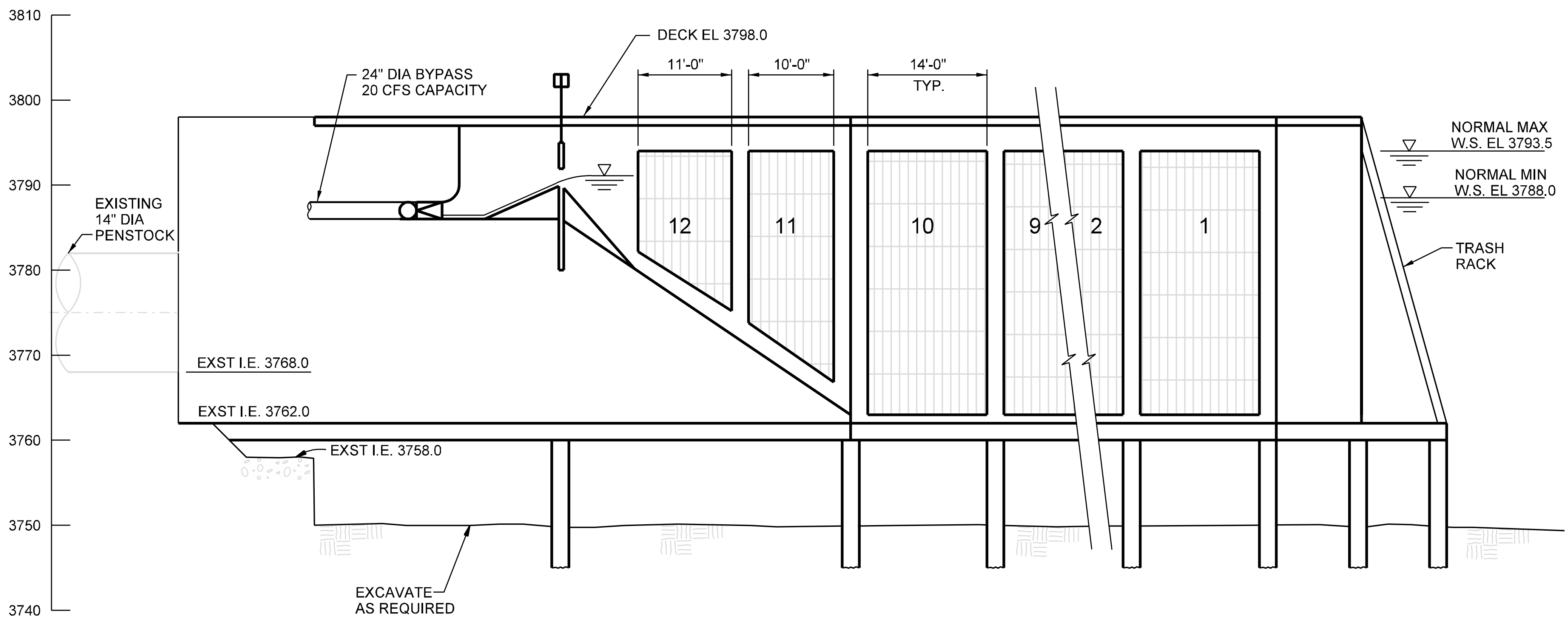

SECTION
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Figure 7.8-8
J.C. BOYLE
CONVENTIONAL V-SCREEN SECTION

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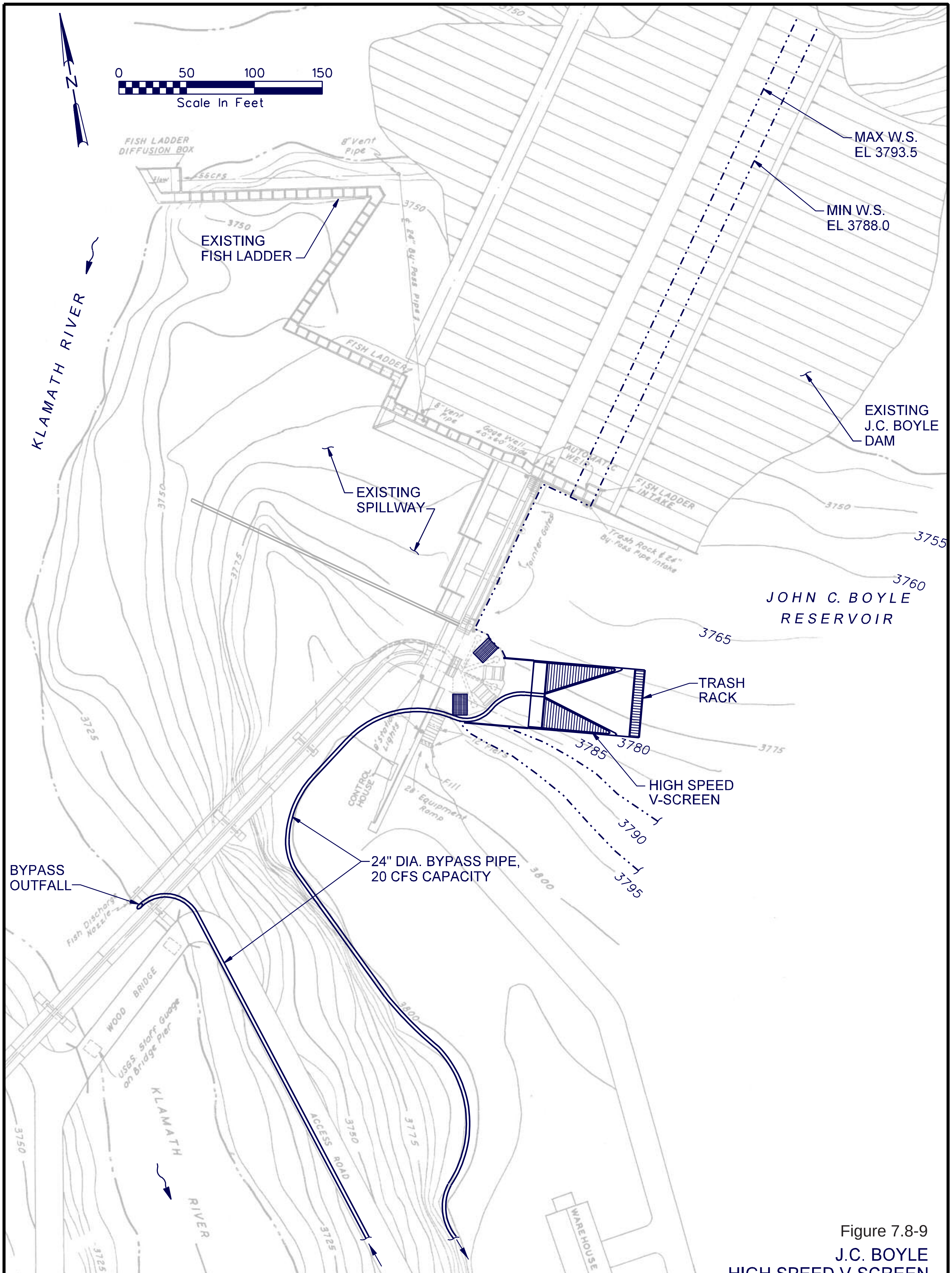

Figure 7.8-9
J.C. BOYLE
HIGH SPEED V-SCREEN

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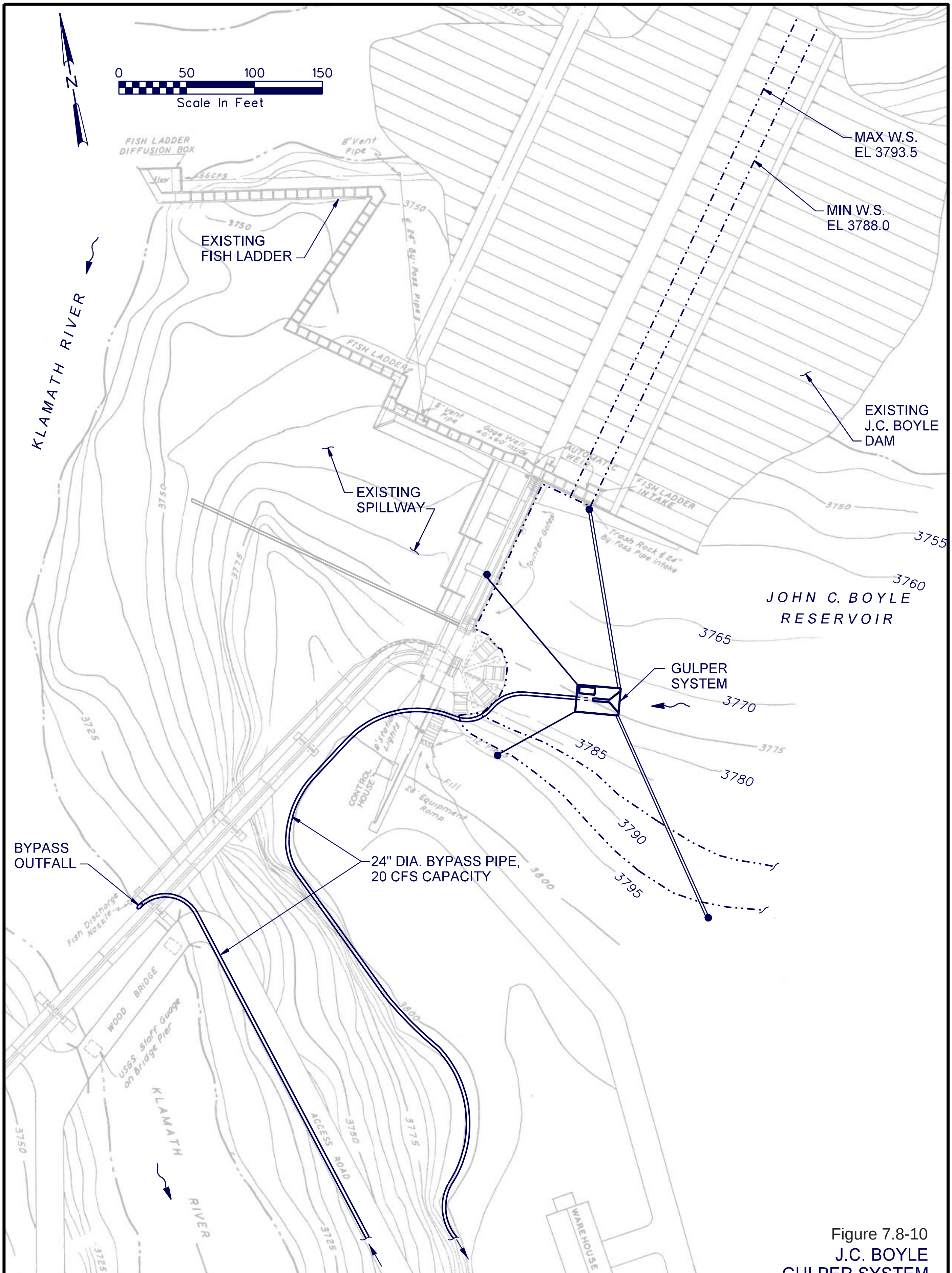

Figure 7.8-10
J.C. BOYLE
GULPER SYSTEM

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Table 7.8-9. J.C. Conceptual Boyle downstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Conventional V-Screen	7.8-7 and 7.8-8	Full screening for the intake meets agency criteria.	Very large screen, may require extensive forebay excavation.	$21,700,000	$646,000	$147,000
High-Speed V-Screen	7.8-9	Smaller size and cost with full screening.	Does not meet agency approach velocity criteria (experimental).	$8,840,000	$517,000	$147,000
Gulper System	7.8-10	Smaller size and cost.	Only partial screening of intake flow. Viewed as experimental.	$6,290,000	$620,000	$163,000

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

Based on the unit cost of the proposed Link River dam sucker ladder, it is estimated that a sucker ladder at J.C. Boyle would cost approximately $2 million. However, it is anticipated that there would be a low chance of suckers successfully passing the 60-foot incline at the J.C. Boyle dam.. Because of this high cost and anticipated low success rate, the sucker ladder was dropped from further consideration.

For any new fish ladder at J.C. Boyle, careful consideration would have to be given to environmental conditions. Forebay water quality, in particular high temperatures, could be a problem for some fish during the warm summer months.

It is difficult to speculate why the existing fish ladder had relatively good initial performance. Approximately $1.25 million in repairs was estimated to improve the existing ladder for resident fish passage. Conceptual fish ladder facilities are presented in Figures 7.8-11 and 7.8-12.

Fish Lock with Aerial Tramway

A fish lock with aerial tramway would provide upstream passage for suckers, as well as other species of concern. This alternative for sucker passage is based primarily on the results of research by the USBR and USFWS at Pyramid Lake. At that project, suckers rejected a 45-foot-high ladder, but responded well to a fish lock. It is estimated that such a facility would cost approximately $9 million. Present worth O&M costs are estimated to be approximately $1.81 million. The associated water costs would result in a present worth energy loss of approximately $764,000. This concept is presented in Figure 7.8-13.

Tailrace Barrier

A tailrace barrier for 3,000 cfs of powerhouse discharge is estimated to cost approximately $7.92 million. Present worth O&M costs would be approximately $323,000. Present worth energy losses are estimated to be approximately $49,100. Table 7.8-10 provides a summary of upstream fish passage facilities.

7.8.6 Copco No.1 Dam

7.8.6.1 Existing Fish Passage Facilities

The original construction of the Copco No.1 Development did not include provisions for fish passage.

7.8.6.2 Conceptual Downstream Fish Passage Facilities

A fish screen or gulper may be required to facilitate downstream fish passage. The following is a discussion of potential fish passage facilities that may be required.

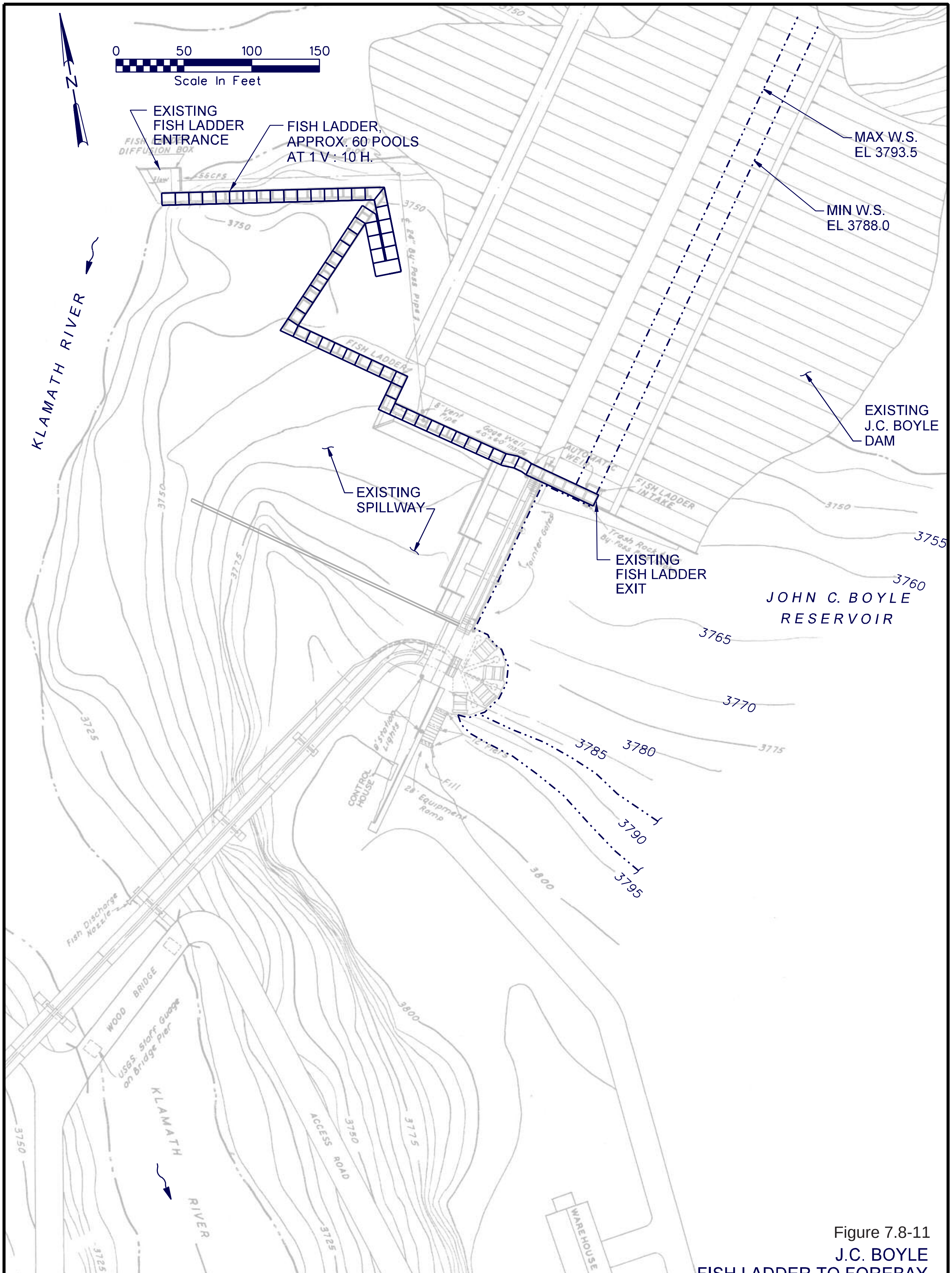

Figure 7.8-11
J.C. BOYLE
FISH LADDER TO FOREBAY

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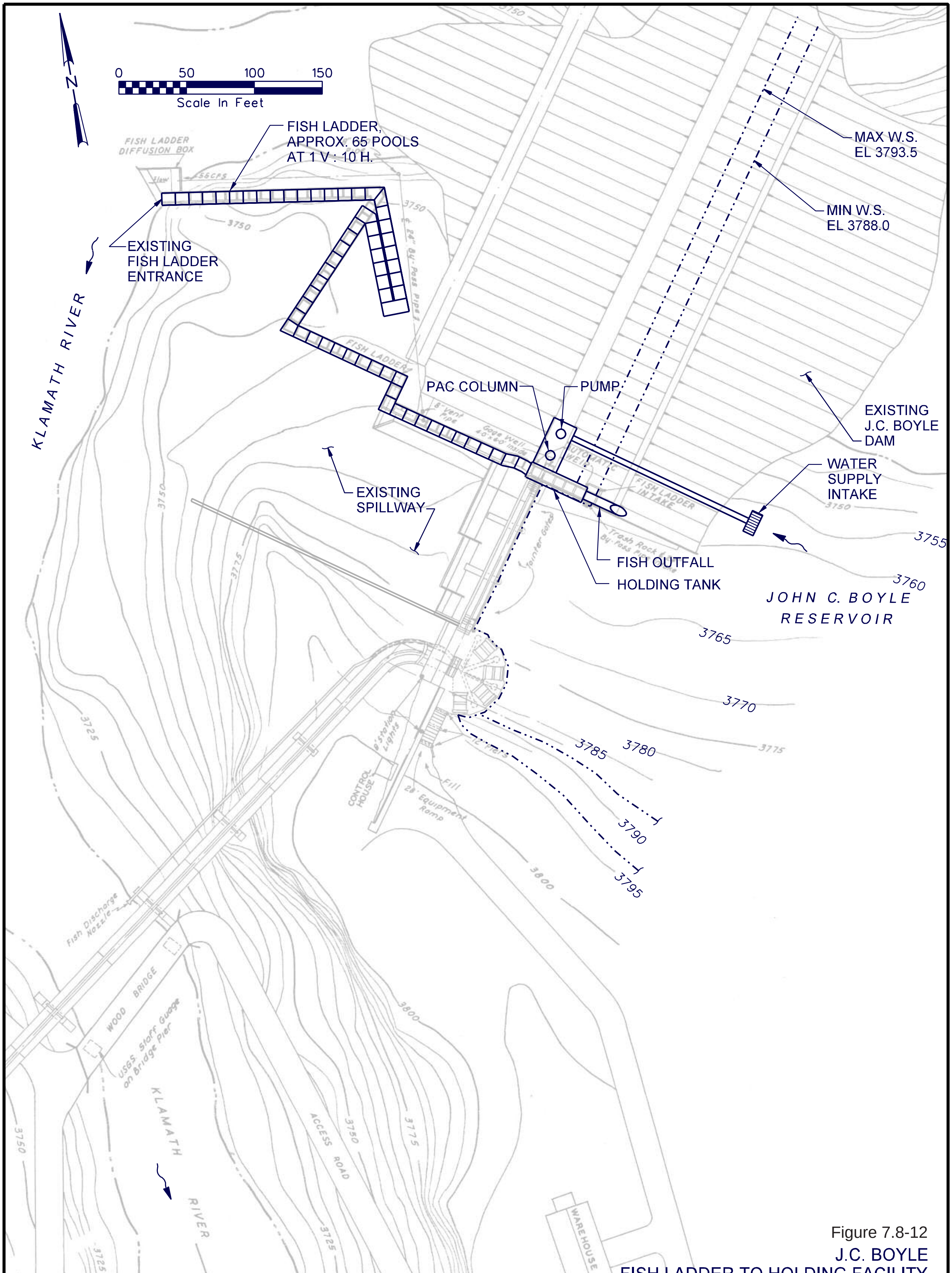

Figure 7.8-12
J.C. BOYLE
FISH LADDER TO HOLDING FACILITY

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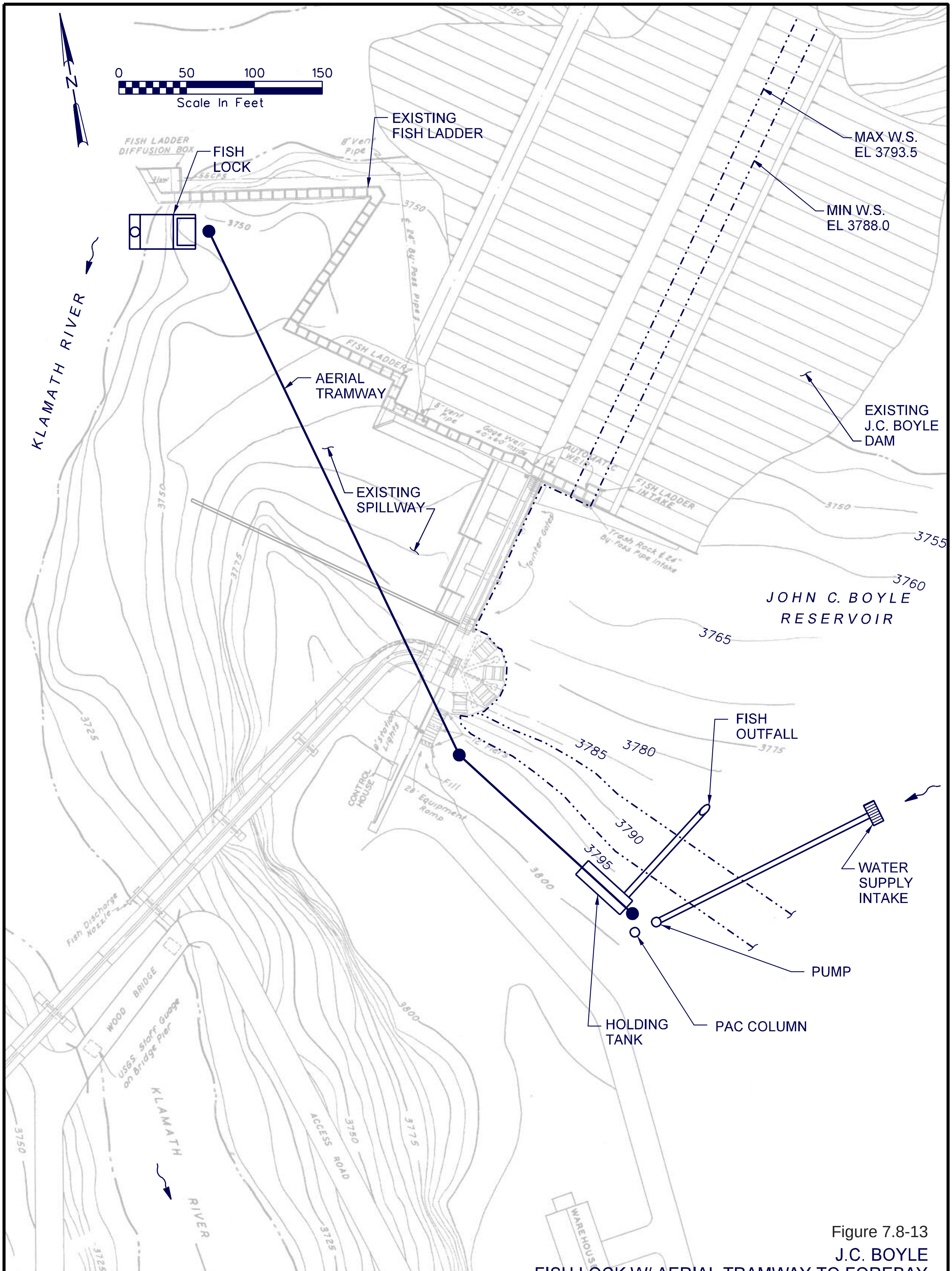

Figure 7.8-13
J.C. BOYLE
FISH LOCK W/ AERIAL TRAMWAY TO FOREBAY

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Table 7.8-10. Conceptual J.C. Conceptual Boyle upstream fish.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Fish Ladder to Forebay	7.8-11	Would improve passage for trout, salmon and lamprey.	High costs.	$9,000,000	$517,000	$3,770,000
Fish Ladder to Holding Facility	7.8-12	Would improve passage for trout, salmon and lamprey. Would provide better water quality in ladder.	Higher costs.	$9,900,000	$1,810,000	$4,510,000
Modify Existing Fish Ladder	N/A	Low cost. May meet trout criteria.	Does not meet salmon or sucker criteria.	$1,250,000	N/A	N/A
Fish Lock with Aerial Tramway	7.8-13	Provides for upstream passage for all fish and includes water temperature control.	Higher operating costs and relatively “new” technology to the West Coast.	$9,000,000	$1,810,000	$764,000
Tailrace Barrier	N/A	Protects fish form delay and injury.	High cost without demonstrated need.	$7,920,000	$323,000	$49,100

[1] Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

[2] Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

NA = Not Applicable

Fish Screen

The Copco No. 1 power intakes are located near the surface of Copco reservoir on the right abutment of the Copco No.1 dam. Access to this site is constrained. The rated hydraulic capacity of Copco No. 1 is 3,200 cfs. The two side-by-side trashracks are approximately 44 feet wide by 12.5 feet wide and have a bar spacing of 3 inches. Because of the intake size and limited site constraints, it is estimated that conventional fish screens designed for a 0.4 fps approach velocity for the Copco No. 1 intakes would cost 50 percent more than the value from the cost curve. The estimated Project cost for these screens with a bypass to the tailrace would be approximately $23.4 million. The present worth cost of operating and maintaining the screens is estimated to be approximately $646,000. The bypass flow for the screens would be approximately 20 cfs. The present worth of associated energy costs would be approximately $1.18 million.

Both conventional and high-speed fish screens could be considered at this site. High-speed screens may cost 40 percent of the cost for conventional screens, and as a result would cost approximately $9.61 million. O&M and energy costs would be similar to those of a conventional screen.

The proposed fish screen bypass would penetrate the dam and then transport the downstream migrants to either a selected outfall point on the river at the Copco No. 1 tailrace, the Copco No. 2 tailwater, or a fish facility for truck transport to the Klamath River below Iron Gate dam. Though extremely long by normal bypass standards, a piped bypass from Copco No.1 to the river below Iron Gate dam is possible. The conceptual layout for a conventional screens and bypasses is presented in Figures 7.8-14, 7.8-15, 7.8-16, 7.8-17, and 7.8-19. The conceptual layout for a high-speed screen is presented in Figure 7.8-20.

Trap and Haul to Below Iron Gate

A trap and haul system would trap juveniles in a fish screen collector and truck them to below the Iron Gate dam. The Project cost is estimated to be approximately $24.9 million, including the construction of a fish screen. O&M and energy present worth costs are estimated to be approximately $3.26 million and $1.18 million, respectively. This option is presented in Figure 7.8-18.

Gulper System

The gulper system is a surface collector technology, which has been used successfully at the Puget Sound Energy, Baker River Project for years. In recent planning studies for Round Butte and Cougar Lake in Oregon, gulpers have been proposed. In concept, the gulper is a 200-cfs floating surface collector with guide nets placed in a reservoir to provide downstream migrating fish a passage option preferable to deep turbine intakes. The gulper system may be practical in the Copco No. 1 forebay. The Project cost for a gulper system for Copco No. 1 would be approximately $6.43 million. Present worth O&M costs are estimated to be approximately $620,000.

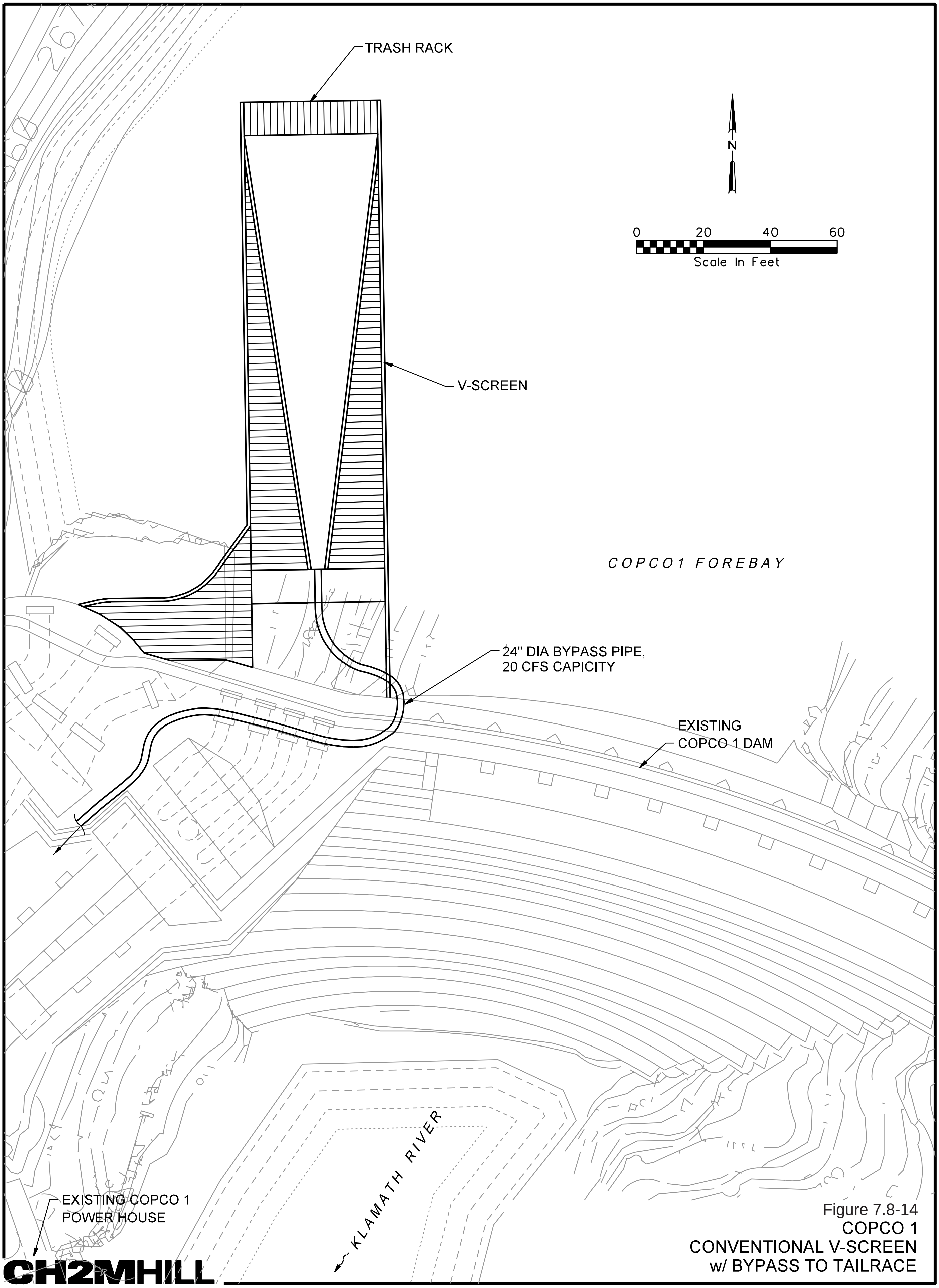

Figure 7.8-14
COPCO 1
CONVENTIONAL V-SCREEN
w/ BYPASS TO TAILRACE

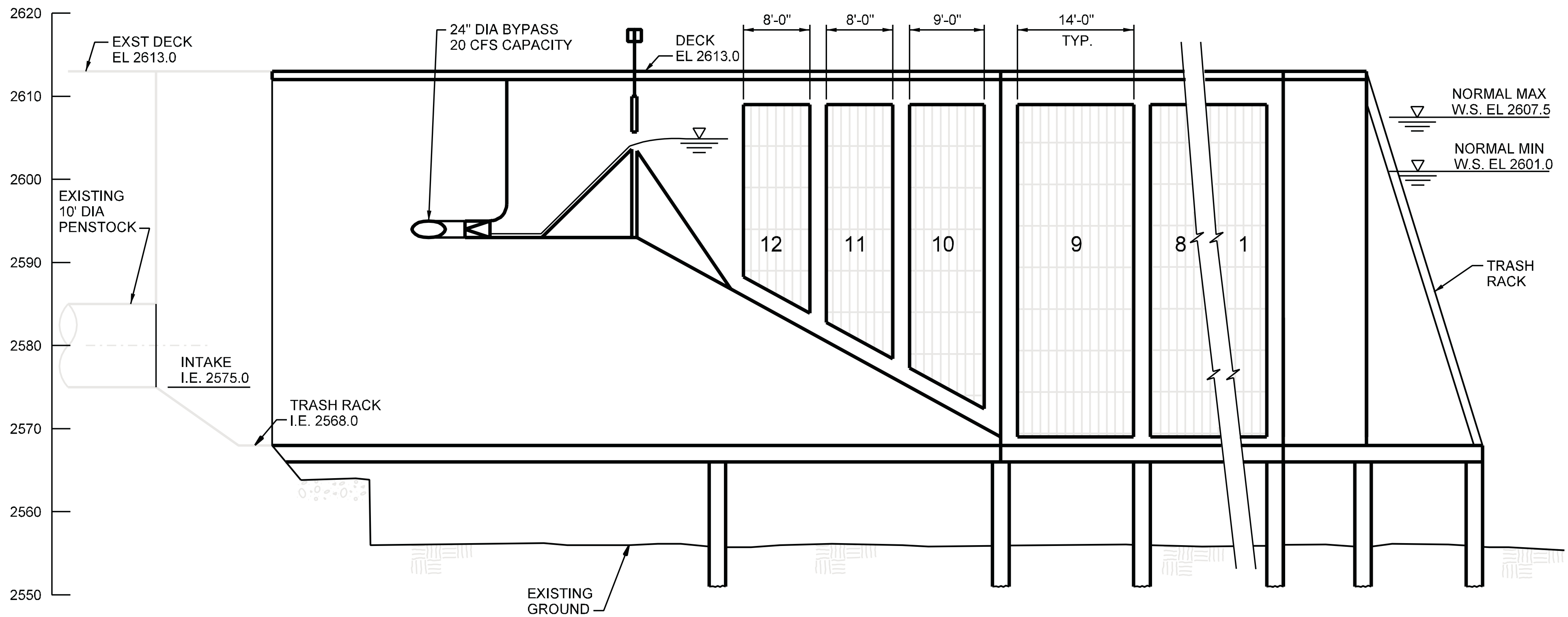

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Figure 7.8-15
COPCO 1
CONVENTIONAL V-SCREEN SECTION

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The gulper would take in 200 cfs from the surface of the lake and bypass the fish with 20 cfs into the bypass pipe for delivery to the river below the dam. Pumps internal to the floating gulper return 180 cfs back to the reservoir. The water cost for this alternative would be the same as the conventional fish screen or approximately 20 cfs. Associated energy costs are estimated to be approximately $1.17 million. The conceptual layout of a gulper is presented in Figure 7.8-21. Table 7.8-11 summarizes the conceptual downstream fish passage facilities.

7.8.6.3 Conceptual Upstream Fish Passage Facilities

A fish lock with aerial tramway, fish ladder, trap and haul operation, or tailrace barrier may be required to facilitate upstream fish passage. A discussion of such facilities is presented below.

Fish Lock with Aerial Tramway

A fish lock with aerial tramway would provide upstream passage for the species of concern. It is estimated that such a facility would cost approximately $12 million. Present worth O&M and energy costs are estimated to be approximately $1.81 million and $764,000, respectively. This concept is presented in Figure 7.8-22.

Fish Ladder

Copco reservoir has a normal maximum pool elevation of 2,607.5 feet and a normal low pool elevation of 2,601.0 feet, for a normal pool range of 5.0 feet. The normal tailwater elevation at the base of the dam is 2,483.0 feet resulting in a total gross head of 124.5 feet. Construction access would be difficult in the steep-walled canyon at the Copco No. 1 site. If a conventional fish ladder for anadromous fish were built from the powerhouse to the forebay, construction costs for the Copco No. 1 fish ladder could be about $18.9 million. Present worth O&M and energy costs are estimated to be approximately $517,000 and $6.01 million, respectively.

Trap and Haul

Trap and haul could work with either a short fish ladder or a fish lock adjacent to the Copco No. 1 powerhouse. The estimated Project cost would be approximately $1.95 million. The cost of roadway improvements is not included in this cost estimate and could vary significantly depending on the desired fish delivery point. Present worth O&M and energy costs are estimated to be1.55 million and $773,000, respectively. Upstream fish passage facilities are summarized in Table 7.8-12.

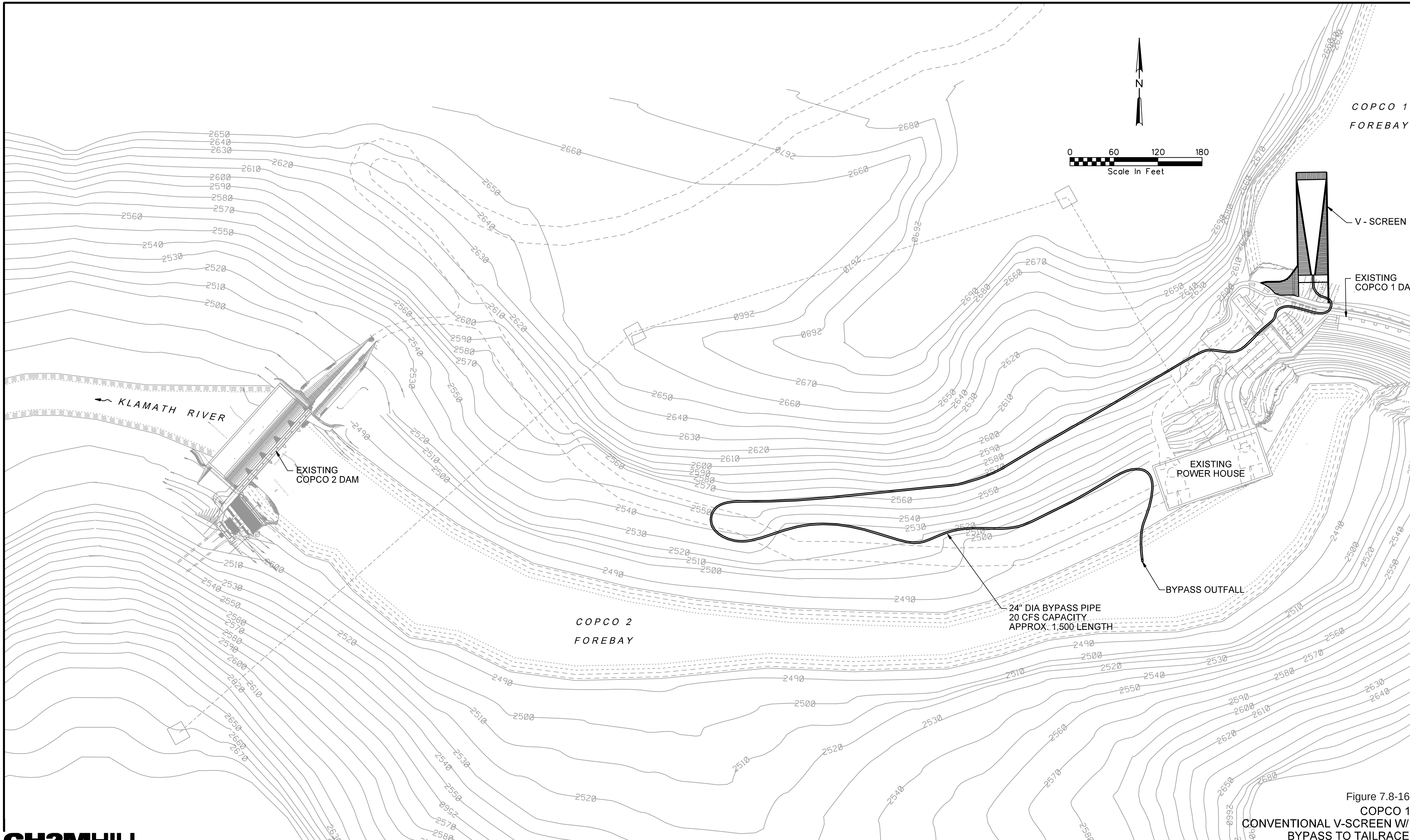

Figure 7.8-16
COPCO 1
CONVENTIONAL V-SCREEN W/
BYPASS TO TAILRACE

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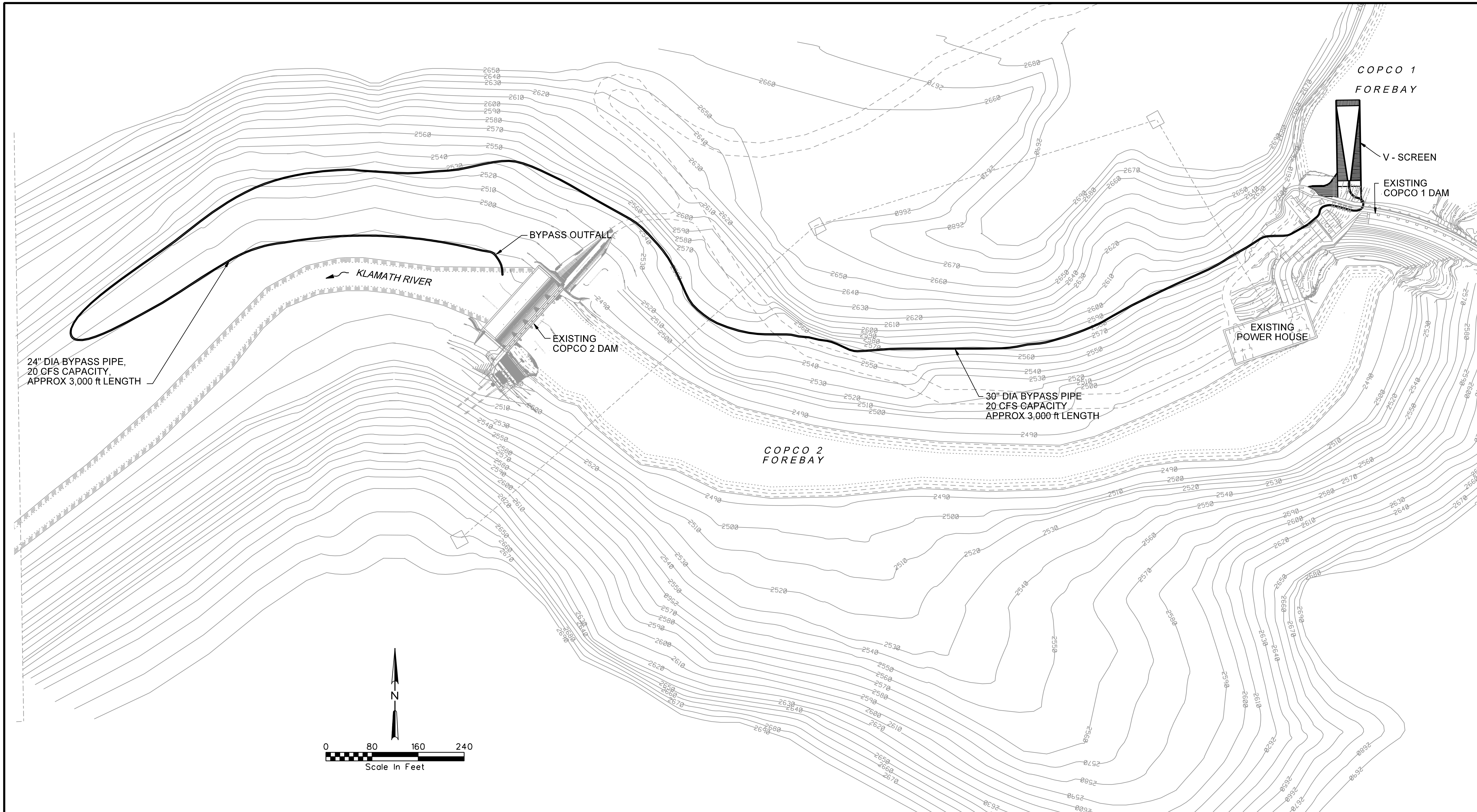

Figure 7.8-17
COPCO 1
CONVENTIONAL V-SCREEN W/
BYPASS TO COPCO 2 TAILWATER

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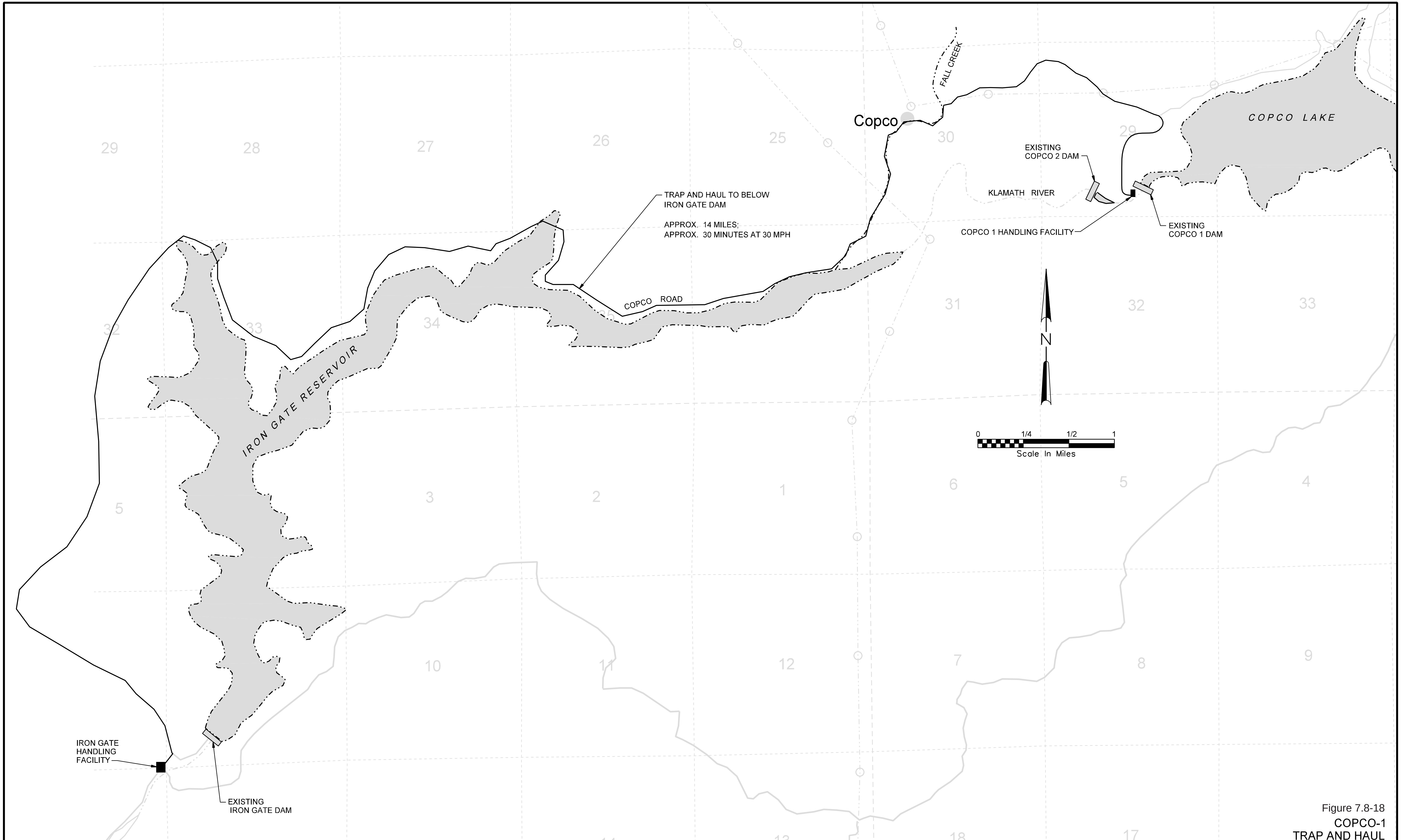

Figure 7.8-18
COPCO-1
TRAP AND HAUL
TO BELOW IRON GATE DAM

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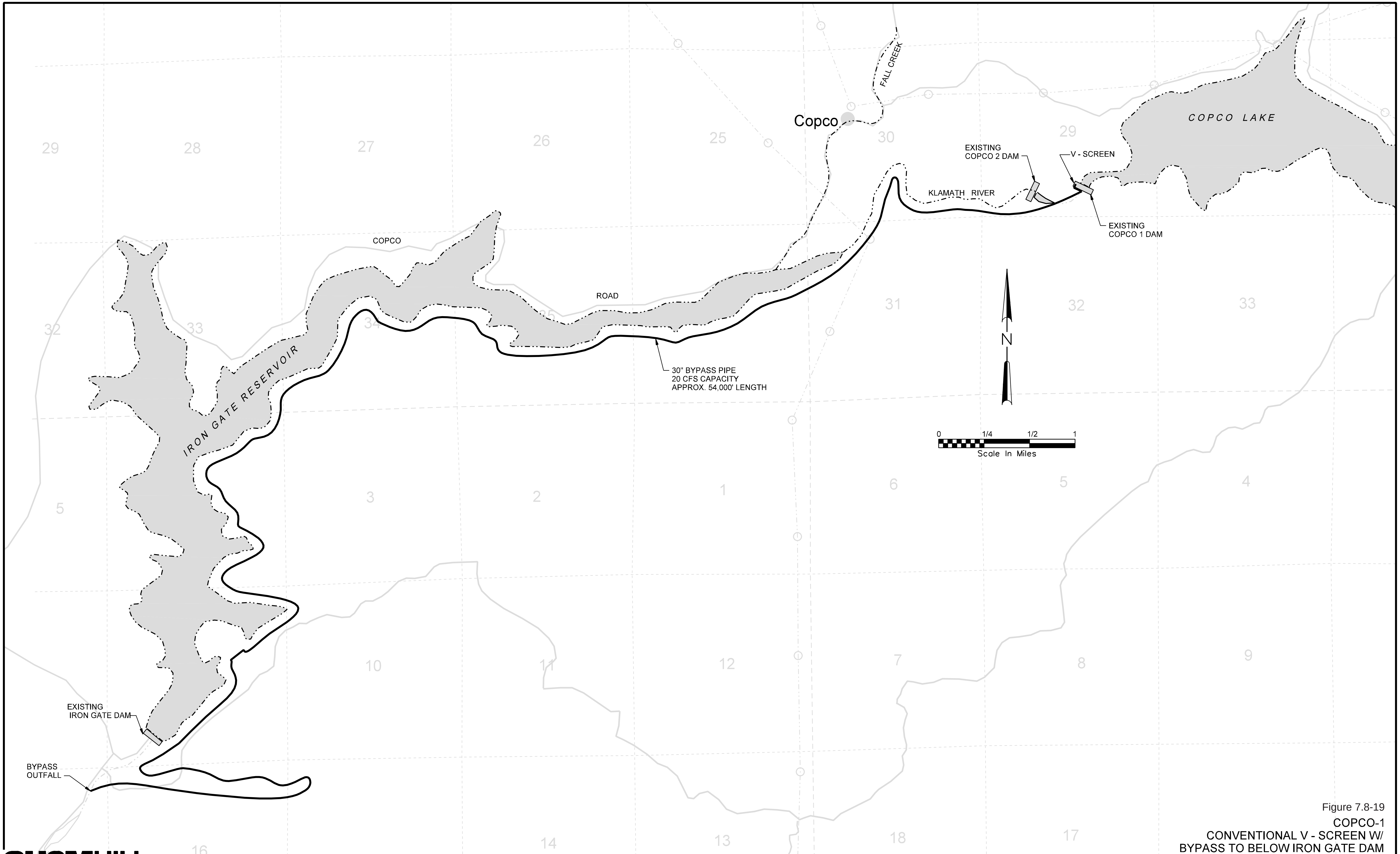

Figure 7.8-19
COPCO-1
CONVENTIONAL V - SCREEN W/
BYPASS TO BELOW IRON GATE DAM

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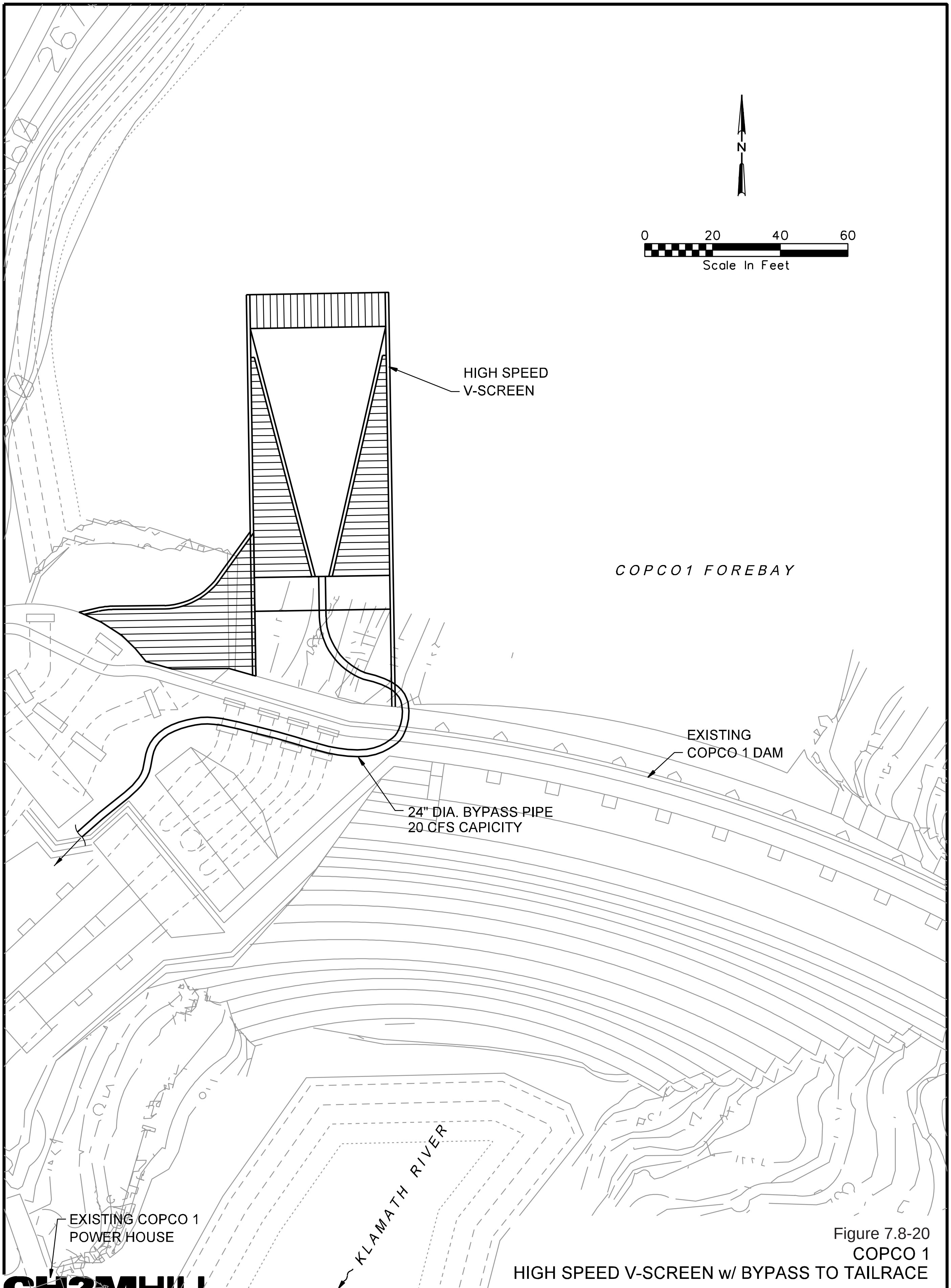

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Figure 7.8-20
COPCO 1
HIGH SPEED V-SCREEN w/ BYPASS TO TAILRACE

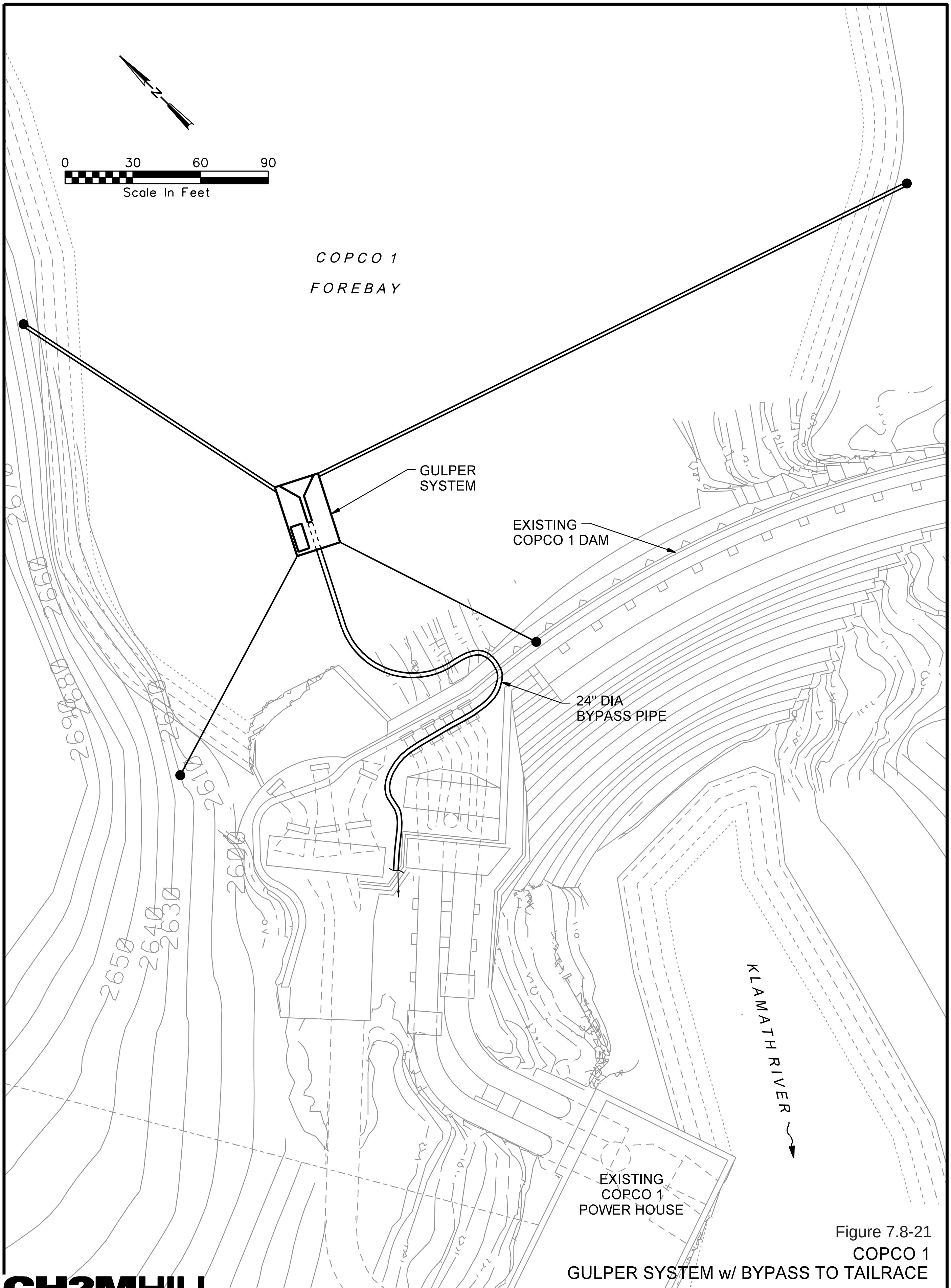

Figure 7.8-21
COPCO 1
GULPER SYSTEM w/ BYPASS TO TAILRACE

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Table 7.8-11. Conceptual Copco No. 1 downstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Conventional V-Screen with Bypass to Copco No. 1 Tailrace	7.8-14 and 7.8-15	Meets agency criteria.	Large size and cost. In-lake construction.	$23,400,000	$646,000	$1,180,000
Conventional V-Screen with Bypass to Copco No. 2 Tailwater	7.8-14	Meets agency criteria.	Large size and cost. In-lake construction.	$24,200,000	$646,000	$1,680,000
Trap and Haul to Below Iron Gate	N/A	Direct passage to below Iron Gate, avoiding two reservoirs and three intakes.	Skips large reach of river.	$24,900,000	$3,260,000	$1,180,000
Conventional V-Screen with Bypass to Below Iron Gate Dam	7.8-14	Meets agency criteria.	Large size and cost. In-lake construction	$42,400,000	$646,000	$2,970,000
High-Speed V-Screen	7.8-16	Low cost and smaller size.	Does not meet agency approach velocity criteria so would be viewed as “experimental technology.”	$9,610,000	$517,000	$1,180,000
Gulper System with Bypass to Tailrace	7.8-17	Low cost and smaller size.	Does not meet agency approach velocity criteria so would be viewed as “experimental technology.”	$6,430,000	$620,000	$1,170,000

[1] Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

[2] Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

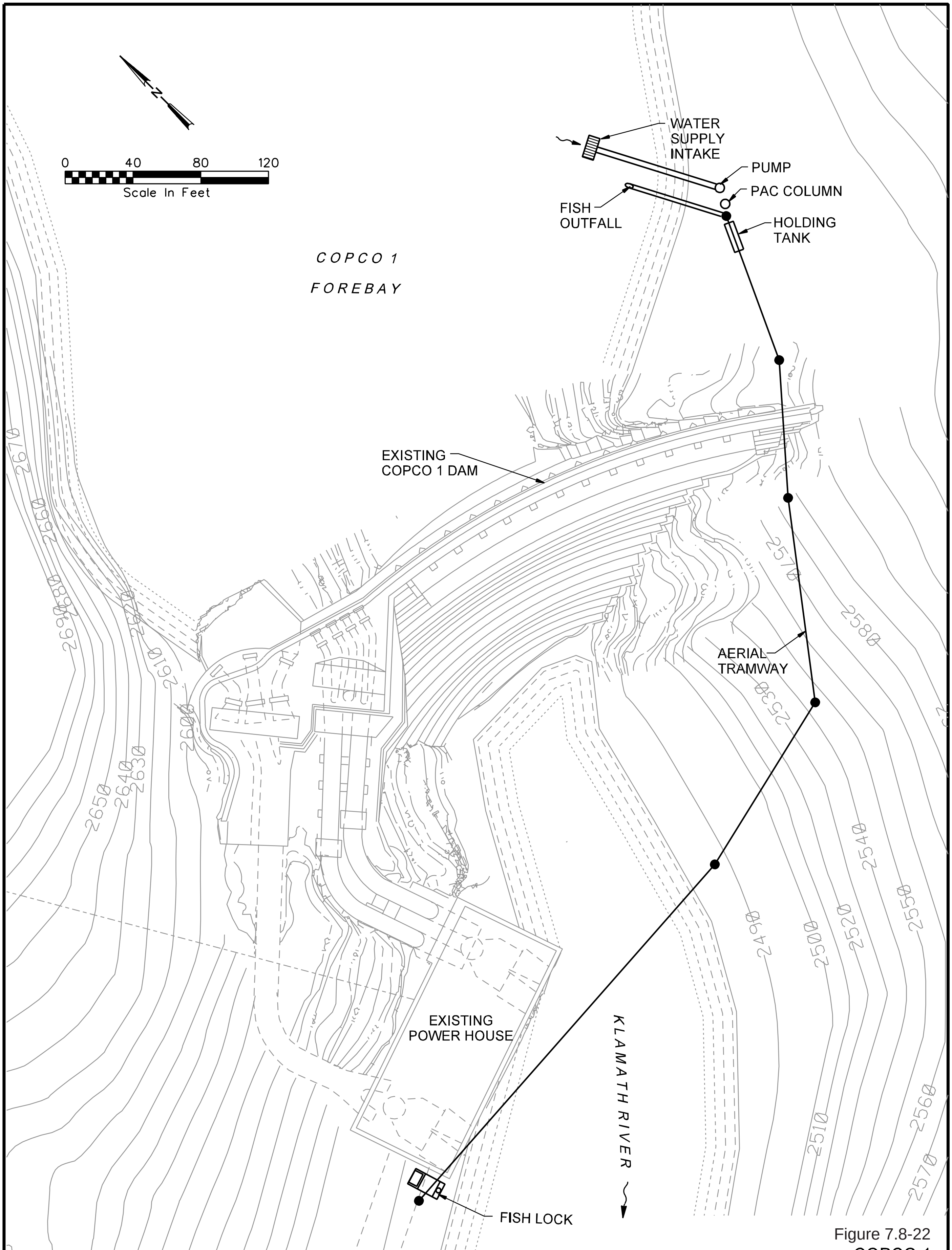

Figure 7.8-22
COPCO 1
FISH LOCK W/ AERIAL TRAMWAY TO FOREBAY

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Table 7.8-12. Conceptual Copco No. 1 upstream fish passage facilities.

Considered Facility	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Fish Lock with Aerial Tramway to Forebay	7.8-18	Provides passage for all fish, well suited for high head dam.	Steep canyon walls and limited access.	$12,000,000	$1,810,000	$764,000
Fish Ladder to Forebay	N/A	Volitional passage and operates continually.	Seep canyon walls, high head, and high cost.	$18,900,000	$517,000	$3,010,000
Trap and Haul to Reservoir	N/A	May be better than high head ladder. Would work best with Copco No. 2 ladder.	Not volitional, has more fish handling.	$1,950,000	$1,550,000	$733,000
Tailrace Barrier	N/A	Precludes adults from being falsely attracted to the power house tailrace, being delayed or being injured.	Limited access to power house.	$9,080,000	$323,000	$58,400

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

Tailrace Barrier

A tailrace barrier for 3,200 cfs of powerhouse discharge may cost approximately $9.08 million. Present worth O&M costs are estimated to be $323,000. Present worth energy costs are estimated to be $58,400. Upstream fish passage facilities are summarized in Table 7.8-12.

7.8.7 Copco No. 2 Dam

7.8.7.1 Existing Fish Passage Facilities

The original construction of the Copco No. 2 Development did not include provisions for fish passage.

7.8.7.2 Conceptual Downstream Fish Passage Facilities

A fish screen may be required to facilitate downstream fish passage at the Copco No. 2 Development. The following presents a discussion of the conceptual facility.

Fish Screens

The Copco No. 2 intake is located on the left bank of the river at the diversion dam. The site is constrained and has limited access. Copco No. 2 has a rated capacity of 3,200 cfs. The trash rack is approximately 37 feet high by 48 feet wide and has 2 inch bar spacing. Because of the large size and limited site constraints, it is estimated that screens for the Copco No. 2 intakes would cost 50 percent more than the value from the cost curve. The estimated Project cost for this facility would be approximately $21.4 million. The present worth cost of operating and maintaining the screens is estimated to be approximately $646,000. The bypass flow would be approximately 20 cfs. The present worth of the associated energy cost would be approximately $800,000. Figures 7.8-23 and 7.8-24 present a conceptual layout for a conventional screen.

Both conventional and high-speed fish screens may be considered at this site. The high-speed screens would cost 40 percent of the Project cost for conventional screens, or approximately $8.62 million. Present worth O&M and energy costs would be approximately $517,000 and $800,000, respectively. Figure 7.8-25 presents a conceptual layout for a high-speed screen.

A gulper system is not considered feasible in the small Copco No. 2 forebay. A summary of proposed downstream fish passage facilities is presented in Table 7.8-13.

7.8.7.3 Conceptual Upstream Fish Passage Facilities

A fish ladder, fish lock, fish lock with aerial tramway, or tailrace barrier may be required to facilitate upstream fish passage. A discussion of such facilities is presented below.

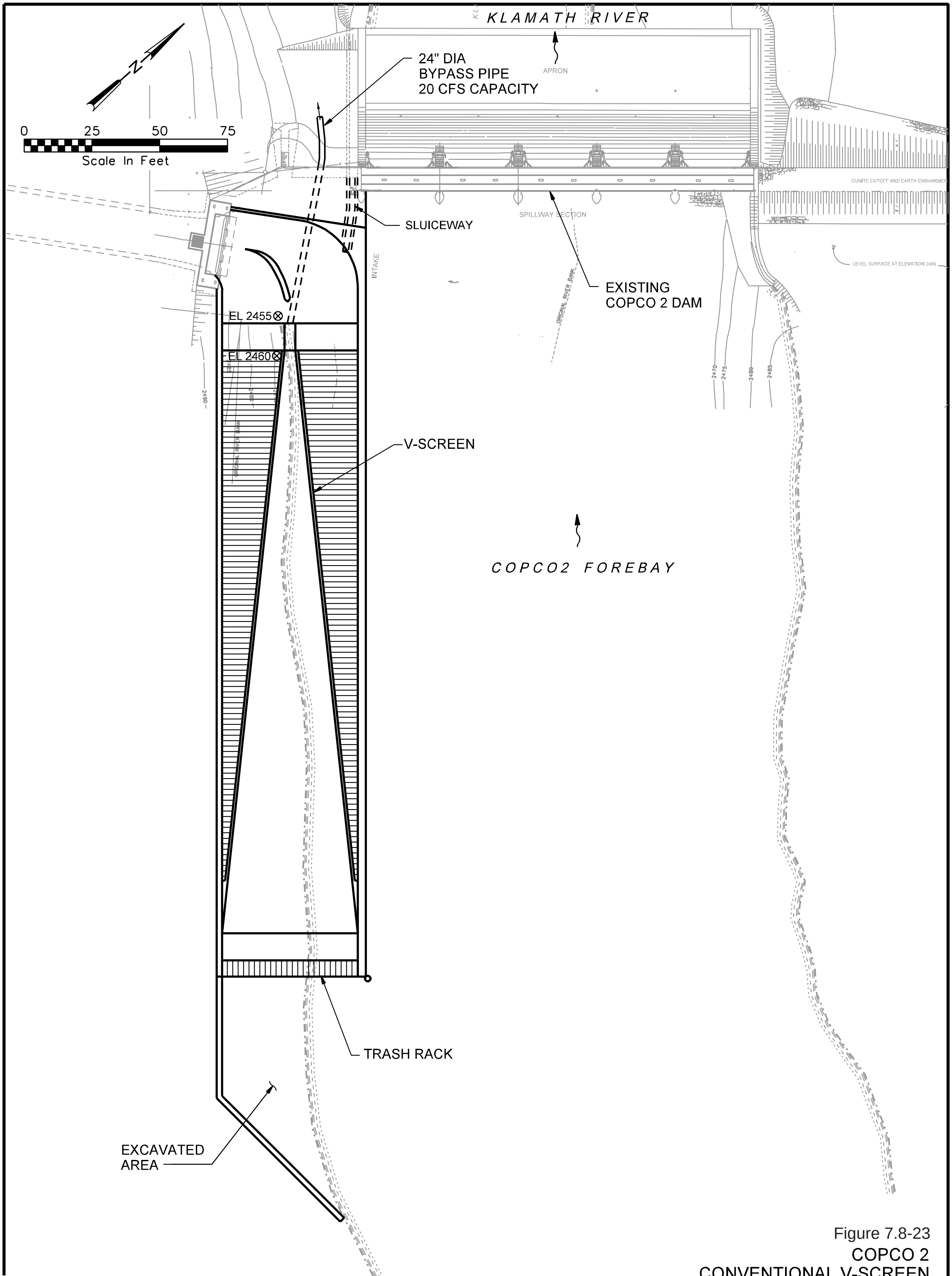

Figure 7.8-23
COPCO 2
CONVENTIONAL V-SCREEN

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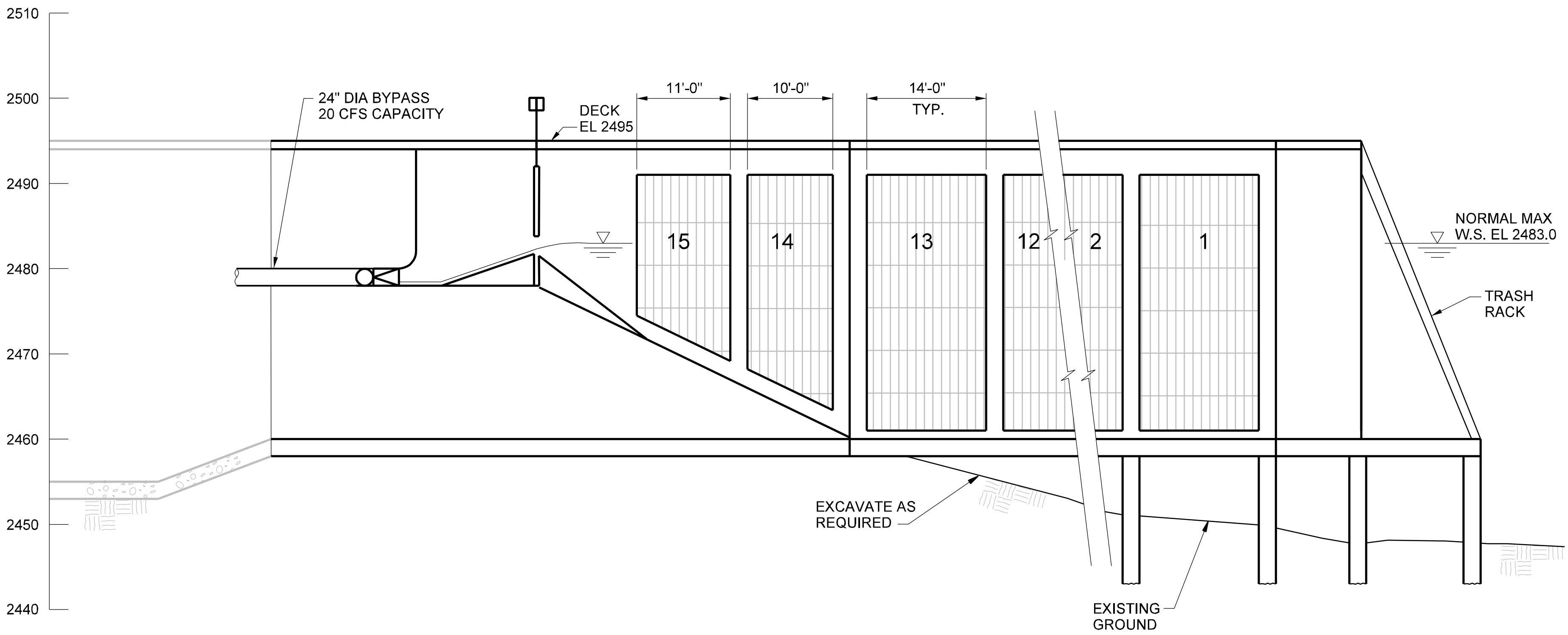

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Figure 7.8-24

COPCO 2

CONVENTIONAL V-SCREEN SECTION

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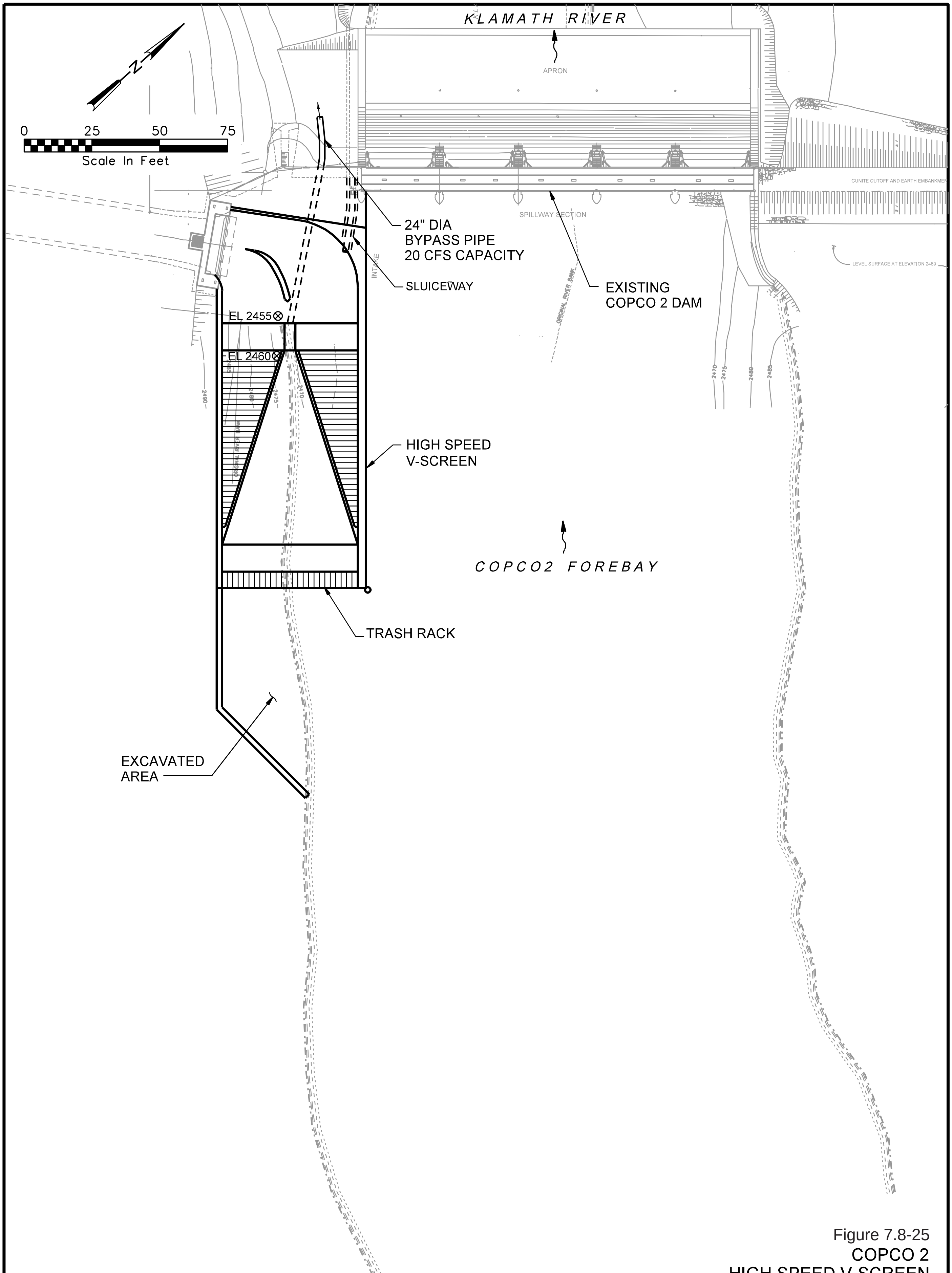

Figure 7.8-25
COPCO 2
HIGH SPEED V-SCREEN

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Table 7.8-13. Conceptual Copco No. 2 downstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Conventional V-Screen	7.8-23 and 7.8-24	Meets agency criteria.	Large screen in a constrained site.	$21,400,000	$646,000	$800,000
High-Speed V-Screen	7.8-25	Smaller screen and lower cost.	Does not meet agency approach velocity criteria and so would be viewed as "experimental technology."	$8,620,000	$517,000	$800,000

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

Fish Ladder

Copco No. 2 has a normal pool level of 2,483.0 feet and a tailwater elevation of 2,461.0 feet, resulting in a total gross head of 22 feet. This head would be well within the feasible range for a conventional vertical slot fishway for anadromous fish. Fish ladder flow would be approximately 35 cfs with an AWS flow of approximately 80 cfs. The Project cost for the Copco No. 2 fish ladder would be approximately $3.3 million, assuming the fish were exited into the Copco No. 2 forebay. Present worth O&M and energy costs are estimated to be approximately $517,000 and $6.81 million, respectively.

If a fish ladder were to start at the exit of a Copco No. 2 fish ladder, and as a consequence not give migrating fish access to the 0.3-mile-long reach of river between Copco No. 2 and Copco No. 1 dams, the fish ladder then would have a total head of 147 feet. The ladder still would have to pass through the steep-walled canyon. The Project cost for this option may be slightly higher than the fish ladder that would start at the Copco No. 1 powerhouse. The Project cost is estimated to be approximately $22.1 million. Fish ladder facilities are presented in Figures 7.8-26 and 7.8-28.

Fish Lock and Fish Lock with Aerial Tramway

Fish locks could provide upstream passage to the Copco No. 1 forebay. It is estimated that such facilities would cost approximately $3.75 million (for the fish lock) and $15 million (for the fish lock with aerial tramway). Present worth O&M costs would be approximately $1.81 million for both options. Present worth energy costs would be $7.54 million (for the fish lock) and $764,000 (for the fish lock with aerial tramway). The fish locks are presented in Figures 7.8-27 and 7.8-29.

Tailrace Barrier

A tailrace barrier at 3,200 cfs powerhouse discharge would cost approximately $8.16 million. Present worth O&M and energy costs are estimated to be $323,000 and $60,400, respectively for each considered design. A summary of considered upstream fish passage facilities is presented in Table 7.8-14.

7.8.8 Iron Gate

7.8.8.1 Existing Fish Passage Facilities

The original construction of the Iron Gate Development included the Iron Gate fish hatchery as mitigation for impacts to the fishery because of the construction of Iron Gate dam. No fish ladder was built to allow for upstream fish passage to the forebay at the dam. The two existing fish ladders, one at the adult collection and holding facility at the base of the dam and the other located at the hatchery outfall, are used to collect brood stock for the hatchery. The powerhouse intake tower in the Iron Gate forebay has a trash rack, but no fish screens. Currently, there is no tailrace barrier at the powerhouse.

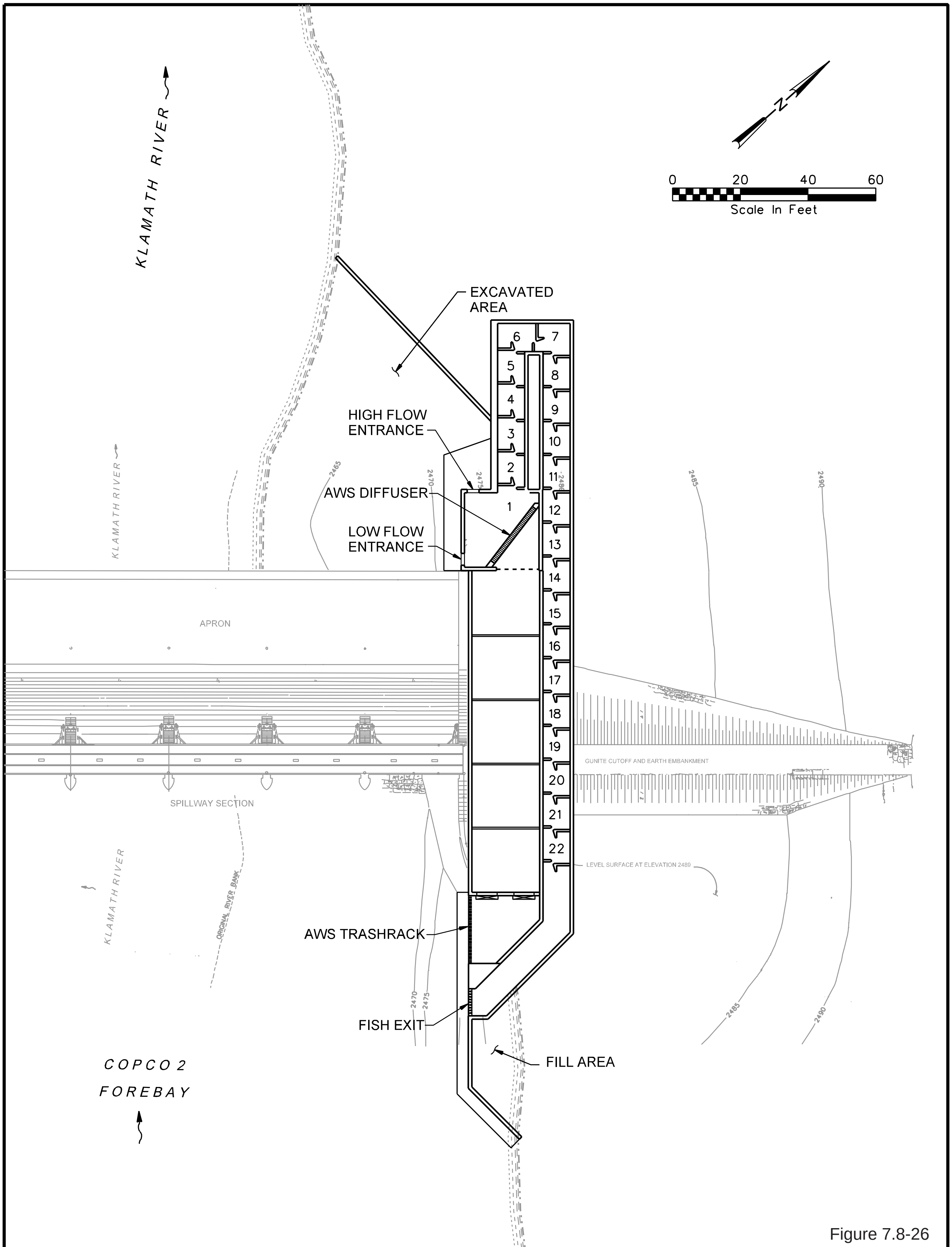

Figure 7.8-26
COPCO 2
FISH LADDER TO FOREBAY

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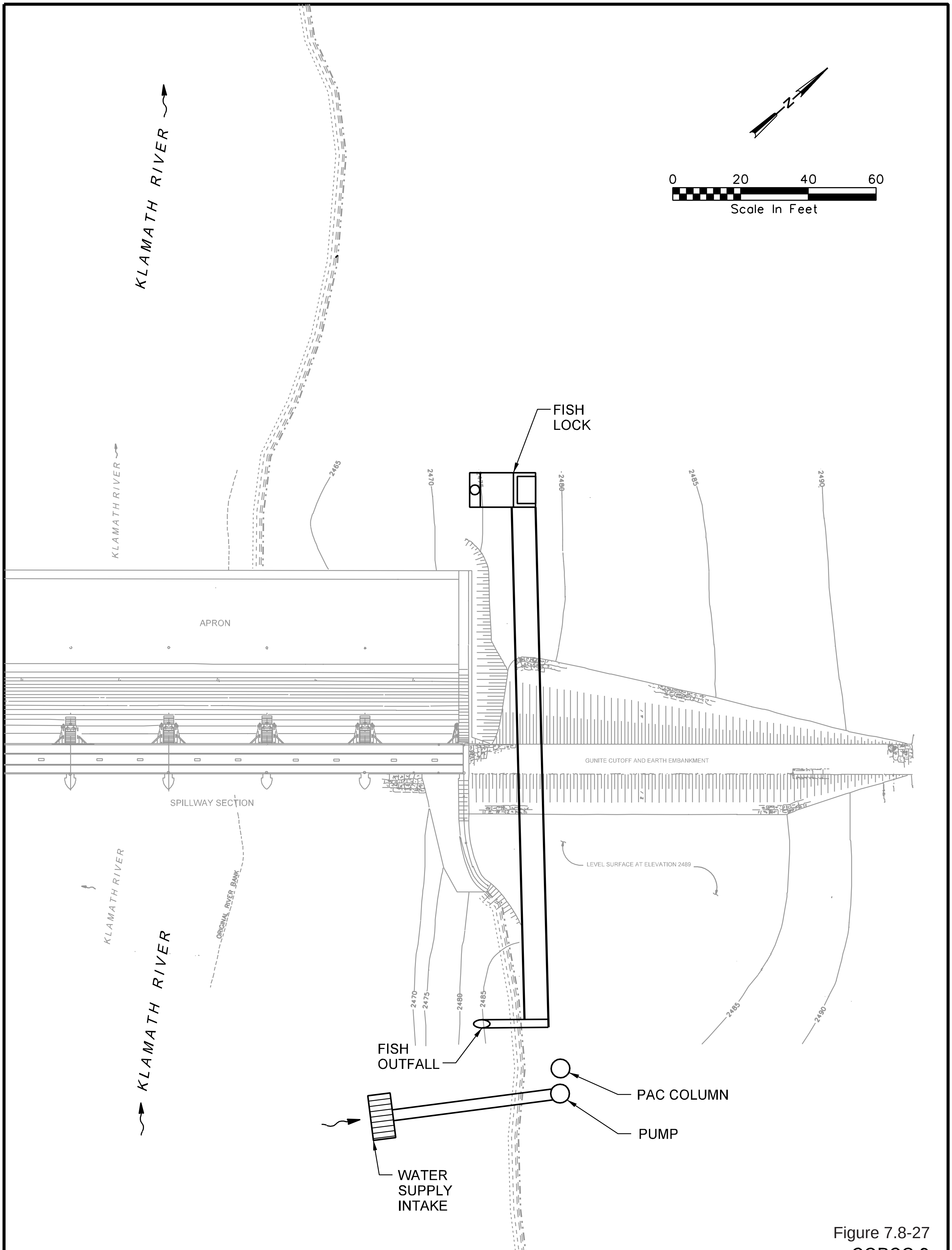

Figure 7.8-27
COPCO 2
FISH LOCK TO FOREBAY

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Table 7.8-14. Conceptual Copco No. 2 upstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	P
Fish Ladder to Forebay	7.8-26	Standard design for volitional passage for salmon and steelhead.	Will need modifications to facili-tate trout and lamprey passage.	$3,300,000	
Fish Lock to Forebay	7.8-27	May provide better passage for lamprey and suckers.	Higher operations cost.	$3,750,000	
Fish Ladder to Copco No. 1 Forebay	7.8-28	Direct passage to Copco No. 1 forebay, with or without water temperature correction.	Skips over 0.3-mile-long reach of river between Copco No. 1 and Copco No. 2.	$22,100,000	
Fish Lock with Aerial Tramway to Copco No. 1 Forebay	7.8-29	Direct passage to Copco No. 1 forebay, with or without water temperature correction.	Skips over 0.3-mile-long reach of river between Copco No. 1 and Copco No. 2.	$15,000,000	
Trap and Haul to Copco No. 1 Reservoir	N/A	Direct passage to Copco No. 1 forebay.	Skips over 0.3-mile-long reach of river between Copco No. 1 and Copco No. 2.	$1,950,000	
Tailrace Barrier	N/A	Precludes adults from being falsely attracted to the powerhouse tailrace, being delayed, or being injured.	High cost.	$8,160,000	

[1] Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

[2] Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

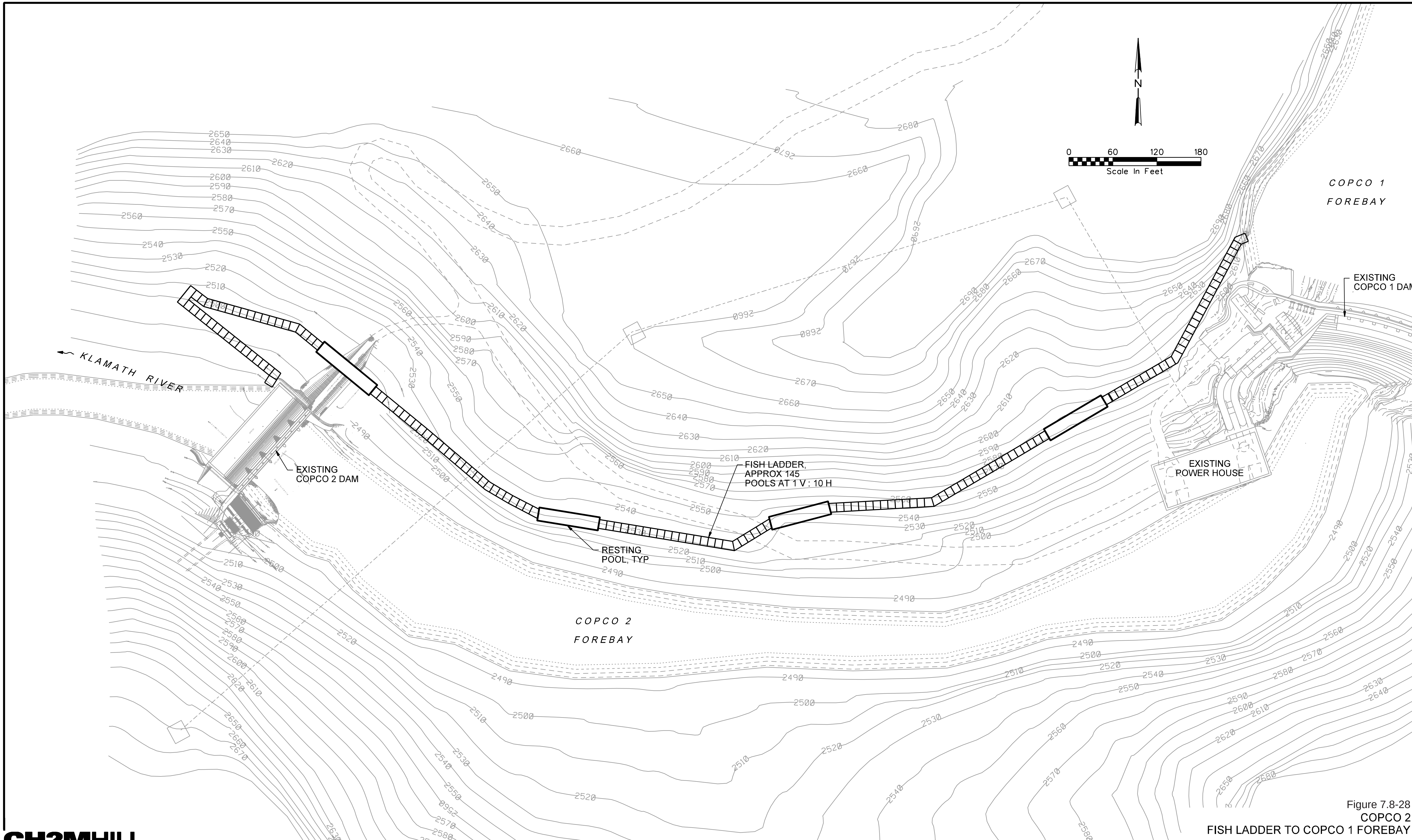

Figure 7.8-28
COPCO 2
FISH LADDER TO COPCO 1 FOREBAY

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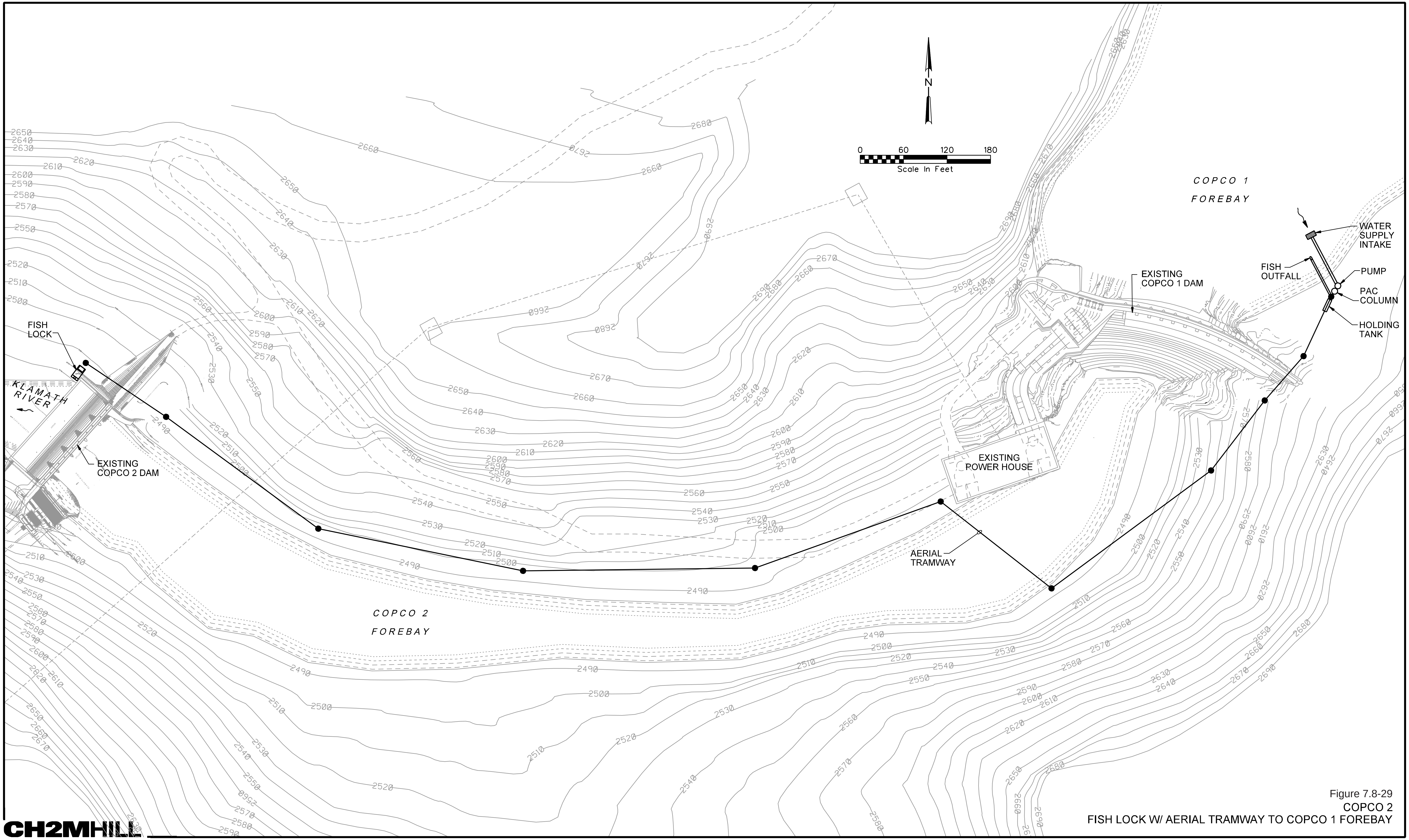

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Figure 7.8-29
COPCO 2
FISH LOCK W/ AERIAL TRAMWAY TO COPCO 1 FOREBAY

copco2_7.dgn 07-APR-2003 13:09:33

Fish Ladder at the Base of Dam

The fish ladder at the base of the dam starts with an entrance pool adjacent to the powerhouse and leads to the adult trapping and holding facilities for the fish hatchery. This is a pool and weir type fish ladder with flow provided from the hatchery water supply system. This supply is drawn from the forebay at a depth of 70 feet. This water supply is oxygenated and is the main source of water for the adult trapping and holding facility. AWS water can be supplied to the entrance pool of the fish ladder by pumps on the tailrace deck of the powerhouse.

Fish Ladder at the Fish Hatchery

The fish ladder at the fish hatchery was designed and constructed by the CDFG because of recurrent false attraction at the hatchery outfall. It has worked so well that in recent years it has attracted the majority of the returning adults. Adults trapped at this site are trucked to the adult holding facilities at the base of the dam. This fish ladder is a pool and weir type with flow provided by the hatchery effluent. The entrance conditions of this ladder can be improved; an extra pool or two could enhance performance.

7.8.8.2 Conceptual Downstream Fish Passage Facilities Being Considered

A fish screen or gulper may be required to facilitate downstream fish passage here. Table 7.8-15 summarizes downstream fish passage facilities.

Fish Screen

The Iron Gate intake has a design flow of 1,735 cfs. The trash rack is 17.5 feet wide by 45 feet long with 4-inch bar spacing. The design flow is about half the size of the Rocky Reach Surface Collector Prototype on the Columbia River near Wenatchee, Washington. A design approach velocity ($V_{n)}$ criteria of 0.4 fps would result in approximately 4,337 $ft^2$of fish screens. The system for Iron Gate would be similar to Rocky Reach in that it would need to be built in the reservoir. The normal pool fluctuation of 8.0 feet is also similar to Rocky Reach.

Using the fish screen cost curve and the 1,735 cfs design capacity, an estimated screening Project cost was developed for Iron Gate of approximately $15.1 million. The present worth of operating and maintaining the screens is estimated to be approximately $646,000. Primary screens would screen most of the flow with a 200 cfs bypass. The 200 cfs bypass would pass through secondary screens, yielding a final bypass flow of 20 cfs to be discharged to the river below the dam. As a result, the water cost for this technology would be approximately 20 cfs. The present worth of the associated energy cost is $1.43 million. Figures 7.8-30 and 7.8-31 present a conventional fish screen.

Both conventional and high-speed fish screens may be considered at this site. The cost of the high-speed screen is estimated to be 40 percent of the cost of the conventional screen, or approximately $4.68 million. Present worth energy and O&M costs are estimated to be $517,000 and $1.43 million, respectively. Figure 7.8-32 presents a high-speed fish screen.

Table 7.8-15. Iron Gate downstream fish passage facilities being considered.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Conventional V-Screen	7.8-30 and 7.8-31	Meets agency criteria.	High cost.	$15,100,000	$646,000	$1,430,000
High-Speed V-Screen	7.8-32	Low cost.	Experimental.	$6,480,000	$517,000	$1,430,000
Gulper System	7.8-33	Low cost.	Only partial screening of intake flow. Viewed as experimental.	$5,970,000	$620,000	$1,450,000

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

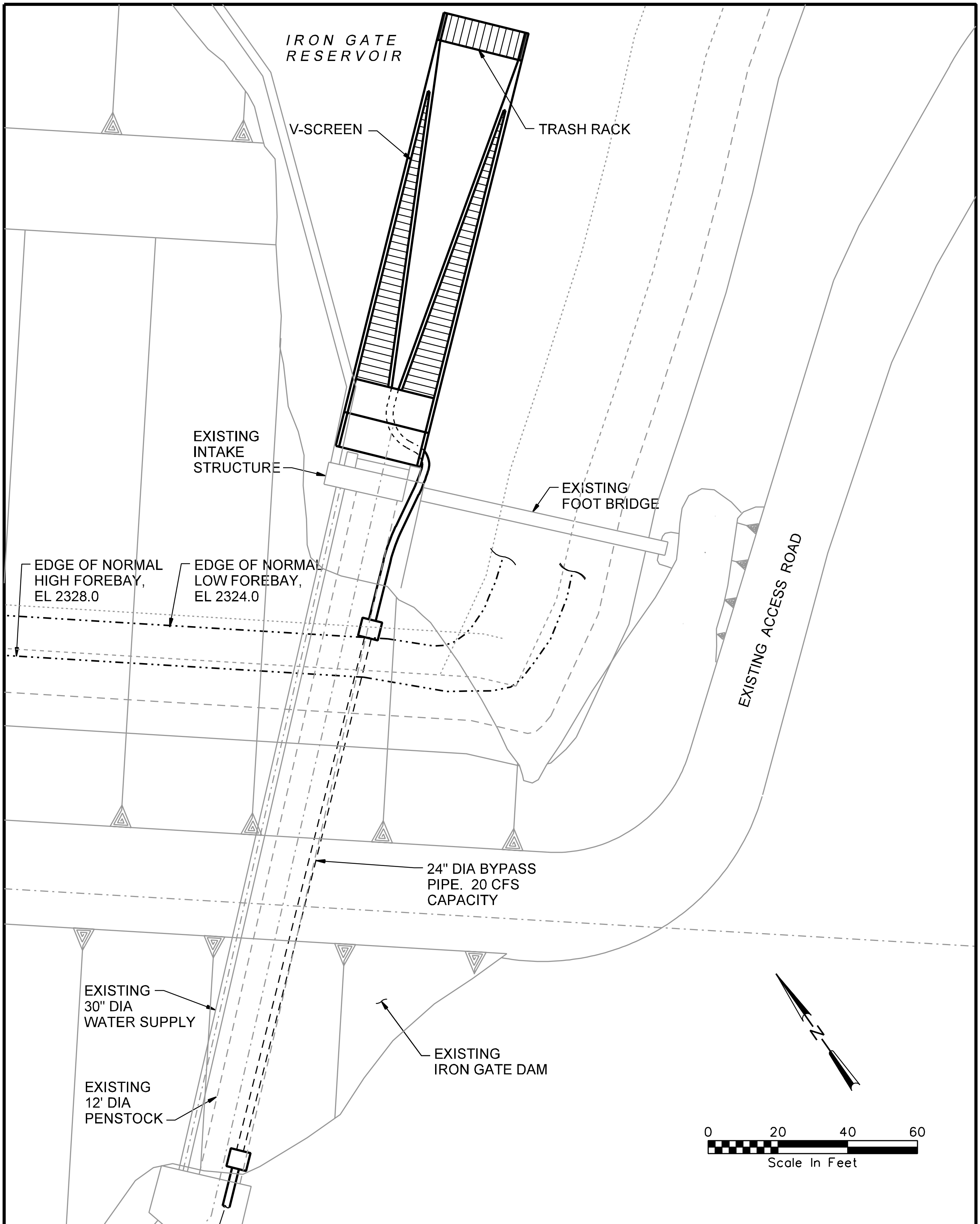

Figure 7.8-30
IRON GATE
CONVENTIONAL V-SCREEN

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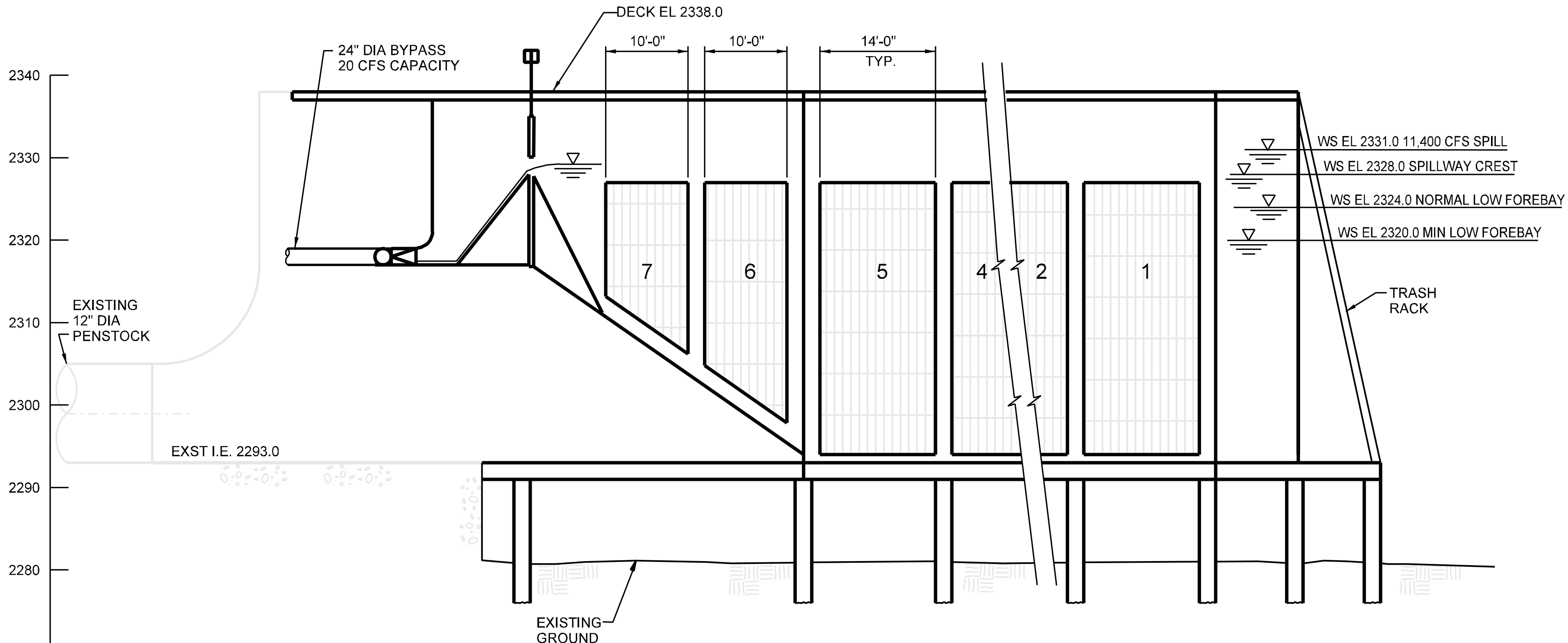

SECTION

SCALE: 1"=20'

Figure 7.8-31
IRON GATE
CONVENTIONAL V-SCREEN SECTION

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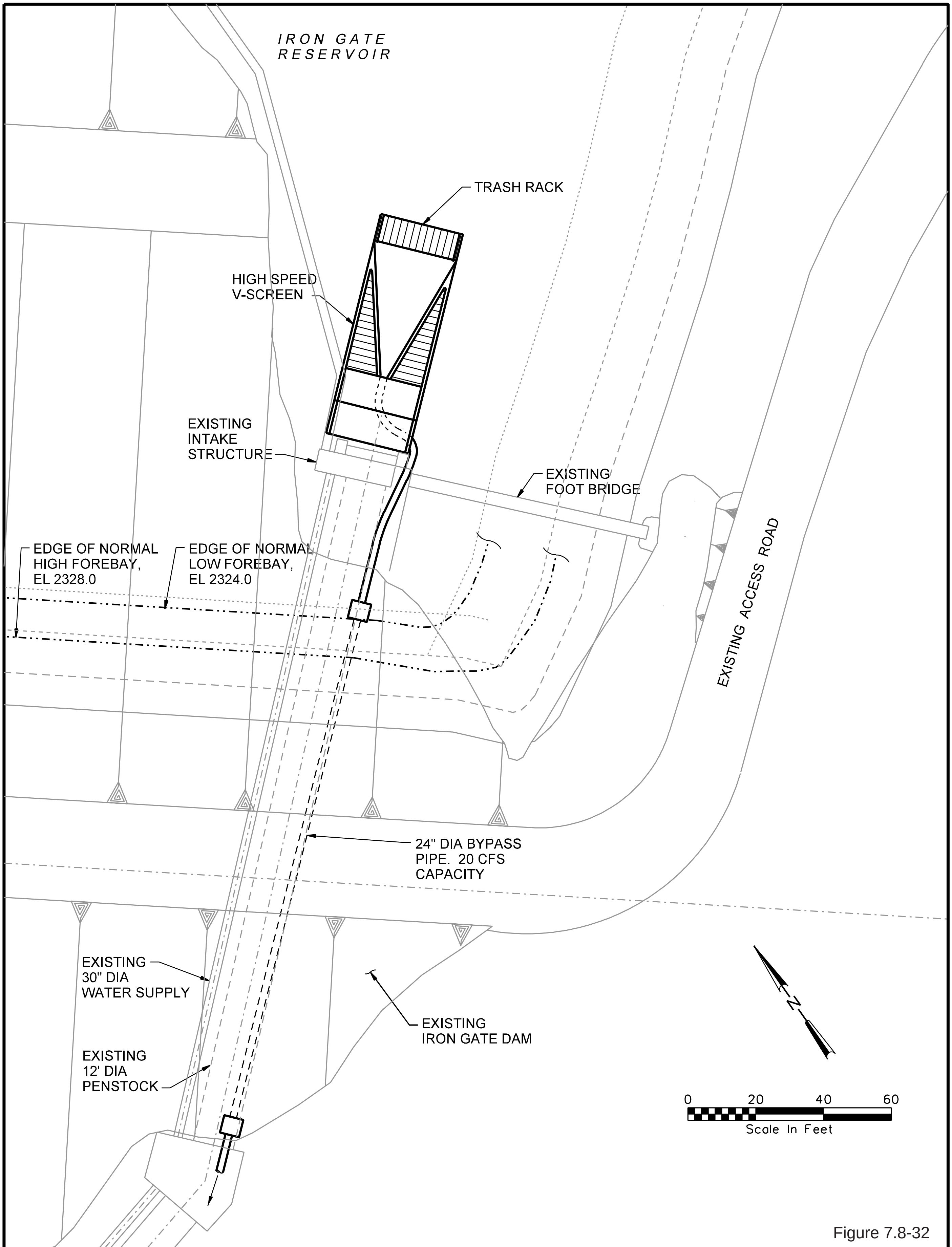

Figure 7.8-32
IRON GATE
HIGH SPEED V-SCREEN

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Gulper

The gulper is a surface collector technology that has been used successfully at the Puget Sound Energy's Baker River Project for years. In recent planning studies for Round Butte and Cougar Lake in Oregon, gulpers have been proposed. In concept, the gulper is a 200-cfs floating surface collector with guide nets placed in a reservoir to provide downstream migrating fish a passage option preferable to deep turbine intakes.

The gulper would take in 200 cfs from the surface of the lake and bypass 20 cfs for delivery of fish to the river below the dam. Pumps internal to the floating gulper return 180 cfs back to the reservoir. The water cost for this alternative would be the same as the positive barrier screen or approximately 20 cfs.

The Project cost for a gulper system for Iron Gate would be approximately $5.97 million. Present worth O&M and energy costs are estimated to be $620,000 and $1.45 million, respectively. Figure 7.8-33 presents a gulper system.

7.8.8.3 Conceptual Upstream Fish Passage Facilities

A fish ladder, fish lock with aerial tramway, trap and haul system, or tailrace barrier may be required to provide upstream fish passage at the Iron Gate Development. Table 7.8-16 summarizes upstream fish passage facilities. The following is a discussion of such facilities.

Fish Ladder

A full-height fish ladder at Iron Gate designed for anadromous fish would be possible, but is not viewed as practical because it is assumed the brood stock collection function for the Iron Gate fish hatchery would need to continue. If the Iron Gate hatchery is to remain, brood stock will continue to be taken at the existing ladders. If a new fish ladder were to start from water surface elevation of 2,188 feet (at the Iron Gate adult facilities) and rise to the forebay at elevation 2,328 feet, the total head on the fish ladder would be approximately 140 feet. If the ladder were to start where the existing power house ladder starts at normal tailwater elevation of 2,171 feet, the gross head would be approximately 157 feet. Near-surface water temperatures in the Iron Gate Reservoir may at times exceed optimal conditions for fish passage. A ladder to the forebay likely would need the water temperature control facilities at the forebay similar to those required for the trap and haul and the tram alternatives.

Based on an approximate construction cost of $100,000 per foot, the 140-foot-long fish ladder, plus the modifications to the existing ladders and sorting facilities, would cost approximately $21 million. The present worth of the O&M is estimated to be approximately $517,000. The new ladder would require approximately 40 cfs to operate, but some of that flow could be used to run the base of the dam facilities. The present worth of the associated water cost is estimated to be approximately $7.72 million. Conceptual fish ladder facilities are presented in Figure 7.8-34.

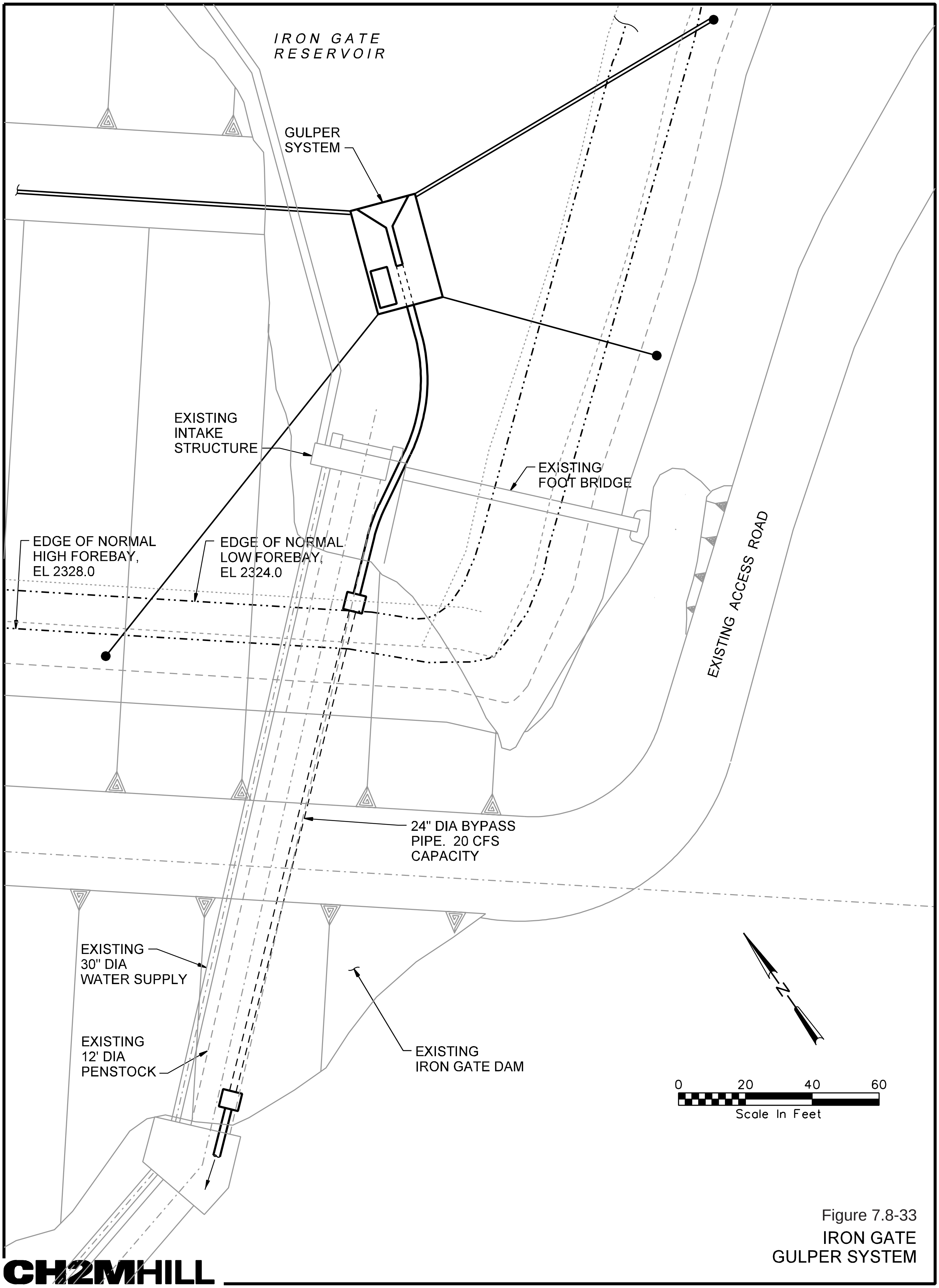

Figure 7.8-33
IRON GATE
GULPER SYSTEM

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Table 7.8-16. Conceptual Iron Gate upstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Fish Ladder to Forebay	7.8-34	Volitional.	Must work with existing hatchery brood stock collection.	$21,000,000	$517,000	$7,720,000
Fish Ladder to Holding Facility	7.8-35	Better control of water temperature.	Not fully volitional. Higher O&M costs.	$21,900,000	$1,810,000	$8,460,000
Fish Lock with Aerial Tramway	7.8-36	Provides upstream passage for all fish. Includes water temperature control.	Higher operating costs. Relatively “new” technology to the West Coast.	$10,500,000	$1,810,000	$764,000
Trap and Haul to Forebay	7.8-37	Lower cost than conventional ladder. Fits well with existing hatchery operations.	Not volitional.	$4,200,000	$1,550,000	$733,000
Trap and Haul to River Mile 204	7.8-37	Eliminates need for upstream passage at Copco No 1 and Copco No. 2. Bypasses poor reservoir water quality.	Bypasses part of the river.	$4,200,000	$1,550,000	$733,000
Tailrace Barrier	N/A	Precludes adults from being falsely attracted to the powerhouse tailrace, being delayed, or being injured.	High cost. No demonstrated need.	$4,590,000	$323,000	$48,900

1 Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

2 Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

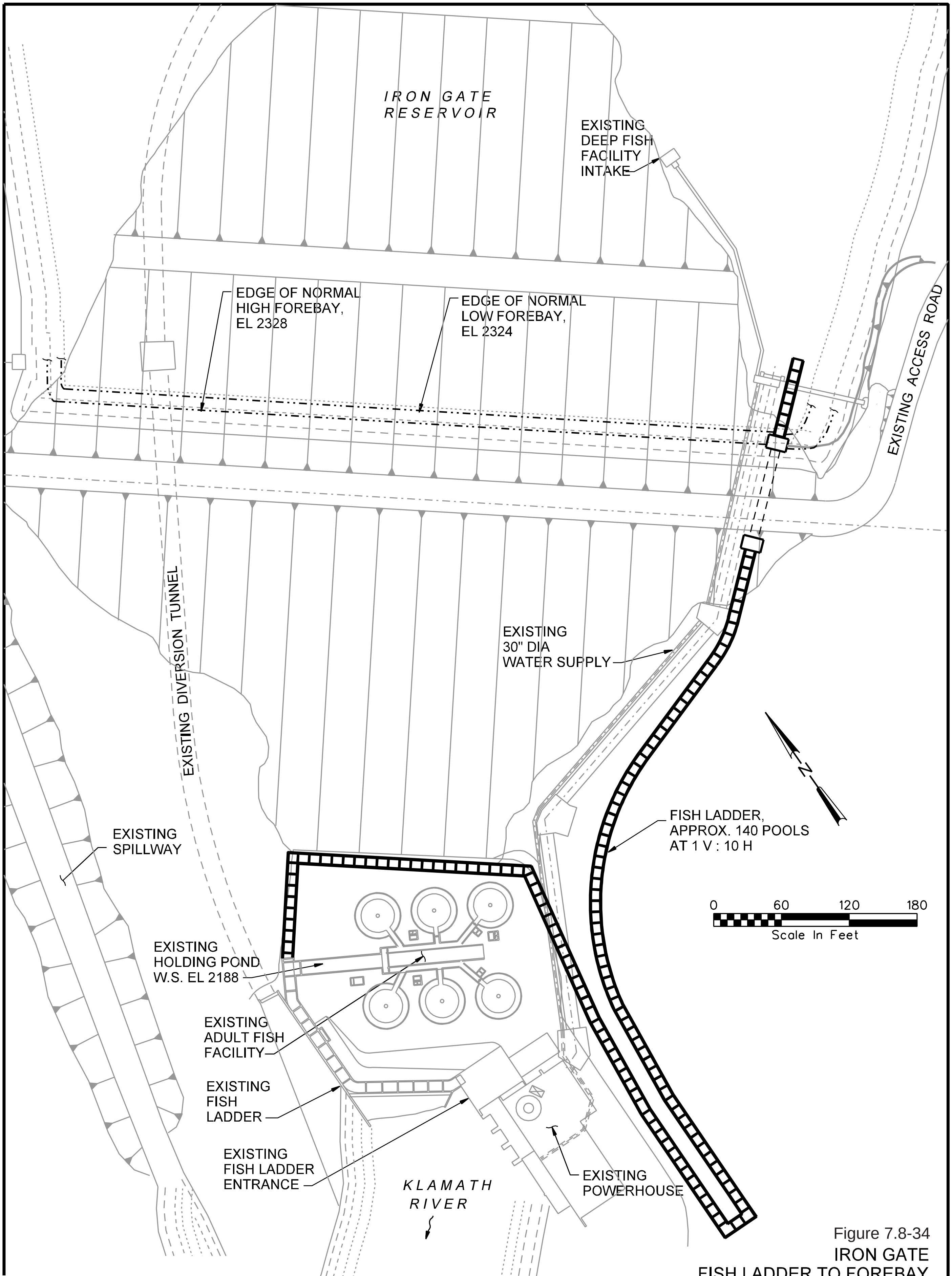

Figure 7.8-34
IRON GATE
FISH LADDER TO FOREBAY

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A fish ladder to a temperature facility also may be considered. Such a facility is estimated to have Project cost of approximately $21.9 million. The present worth of the O&M and energy costs are estimated to be approximately $1.81 million and $8.46 million, respectively**.** A conceptual facility is presented in Figure 7.8-35.

Fish Lock with Aerial Tramway

Any type of fish lock would suffer from the same constraints of the trap and haul, tram, or conventional fish ladder. That is to say, it would have to be designed to accommodate adult collection at the Iron Gate fish hatchery and the forebay temperature problems. An elevated tram, similar to the one originally installed at the Pelton-Round Butte Project, could be implemented at Iron Gate if delivery of fish to the Iron Gate forebay is required. Release facilities for the upstream migrants would be needed for this alternative.

It is estimated that such a facility would cost approximately $10.5 million. The present worth of the O&M and energy costs are estimated to be approximately $1.81 million and $764,000, respectively. A conceptual layout is presented in Figure 7.8-36.

Trap and Haul Adult Passage

The existing two fish ladder systems and some of the hatchery adult handling facilities could be modified to form the basis for a trap and haul system for upstream fish passage at Iron Gate. Fish could be sorted and those fish that the fisheries managers want to pass upstream could be trucked to either the forebay of Iron Gate dam or to the Klamath River upstream of Copco Lake at RM 204. If water quality conditions, especially temperature, remain unchanged, special fish release facilities would be required to allow upstream migrants passage through the forebay.

Capital costs to upgrade the existing fish ladders and adult handling facilities, including providing two modern tanker trucks, could be as high as $4.2 million. Fish handling and sorting facilities would be similar to the Rosa facility on the Yakima River in Washington. The present worth O&M costs for this proposed technology is estimated to be approximately $1.55 million. It does not appear that this technology would have any additional water cost above that currently used to run the existing ladders. However, the system may need to be run for a longer period than the current brood stock facilities. The present worth energy cost is estimated to be approximately $733,000. This method is presented in Figure 7.8-37.

Tailrace Barrier

No tailrace barrier is called for at this time. At $1,700 per cfs, the cost of a tailrace barrier for Iron Gate powerhouse would be approximately $4.59 million.

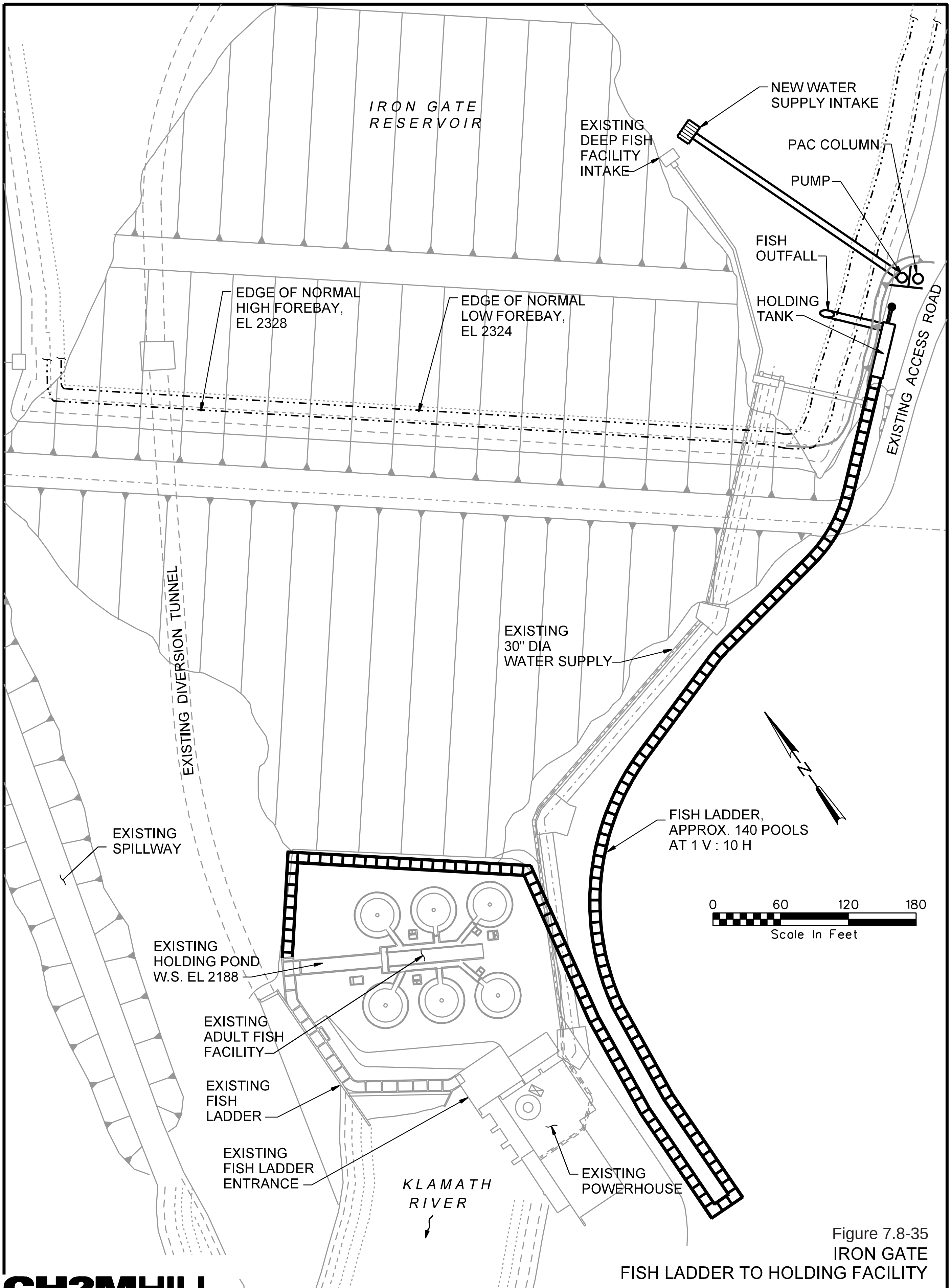

Figure 7.8-35
IRON GATE
FISH LADDER TO HOLDING FACILITY

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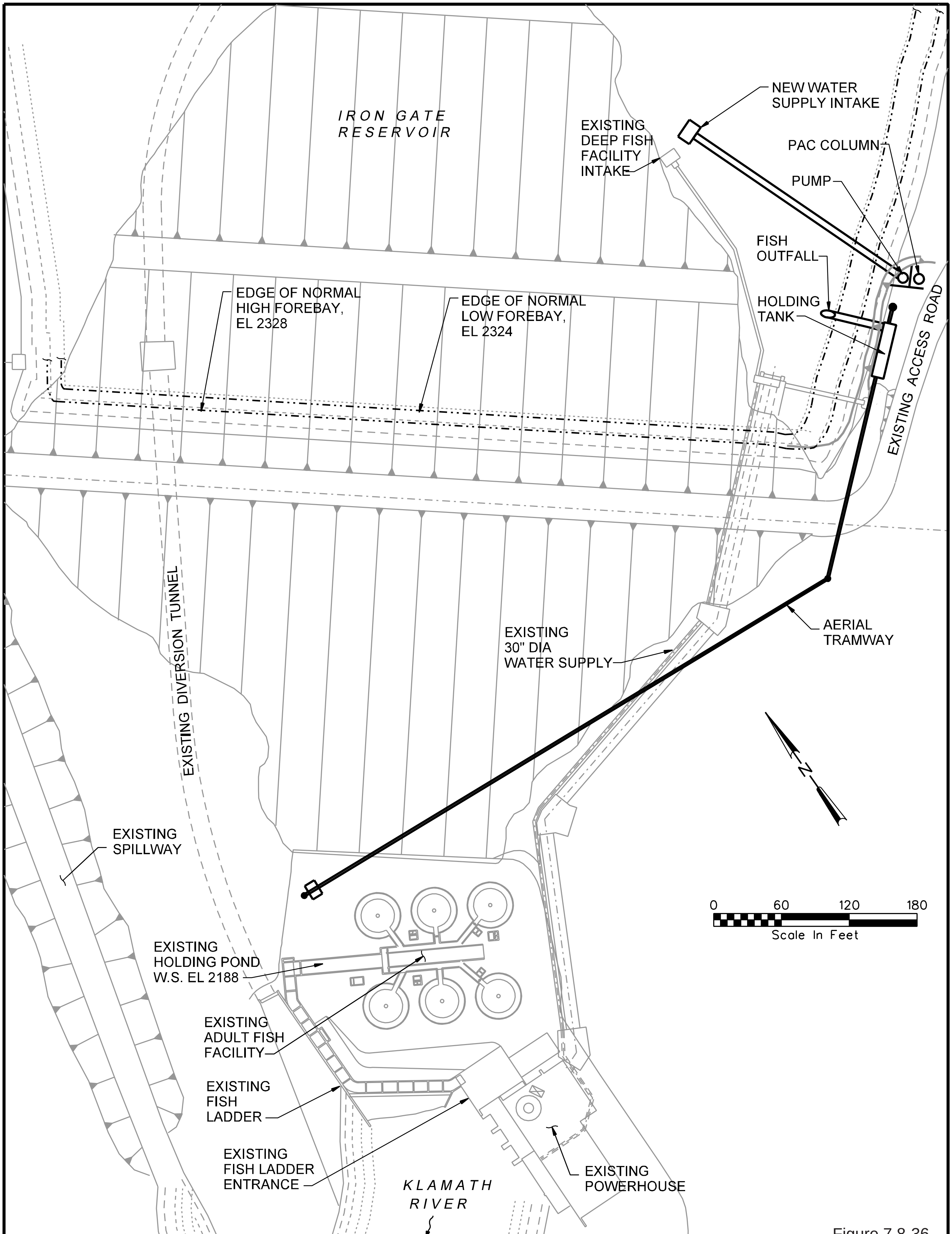

Figure 7.8-36
IRON GATE
AERIAL TRAMWAY

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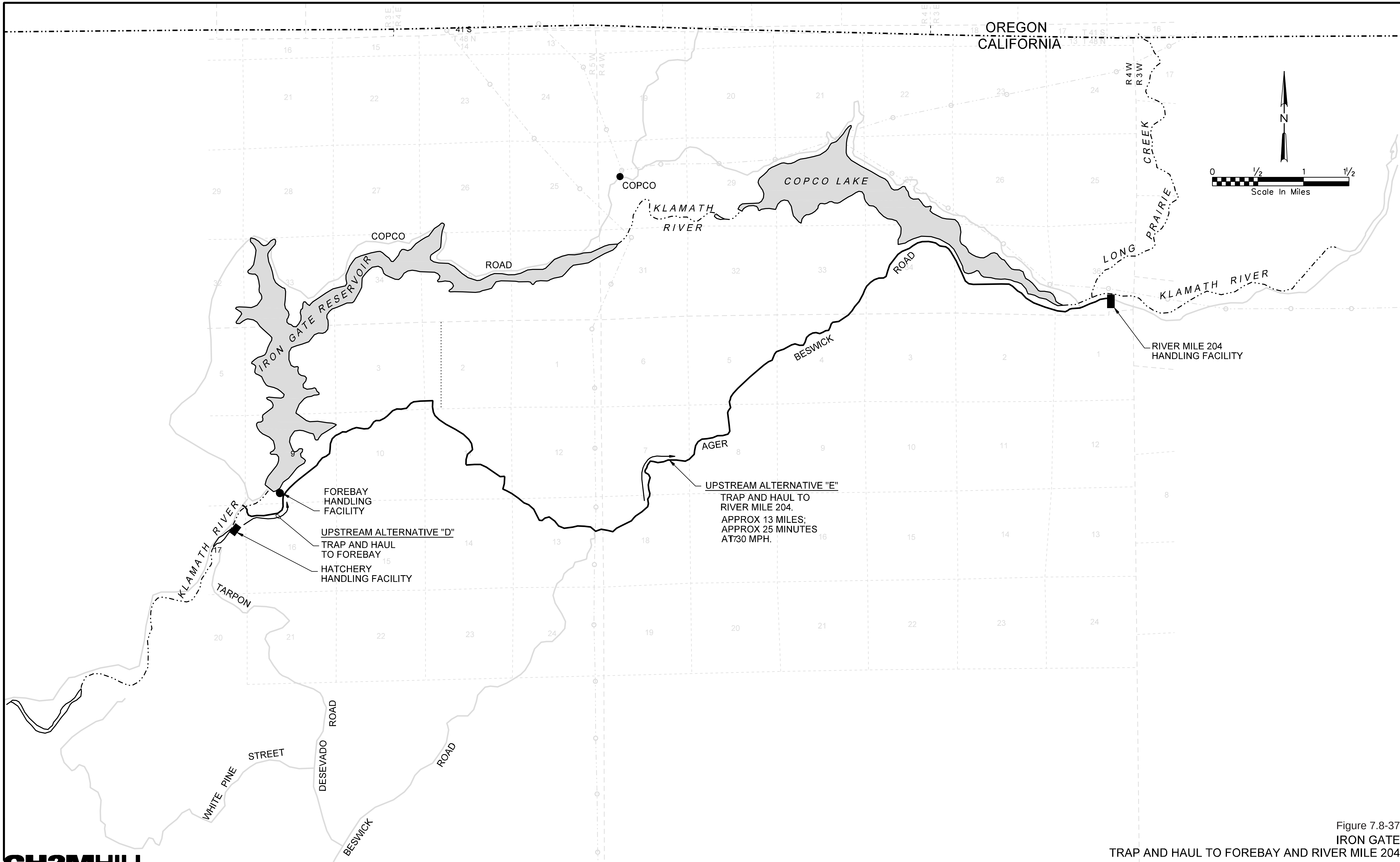

Figure 7.8-37
IRON GATE
TRAP AND HAUL TO FOREBAY AND RIVER MILE 204

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7.8.9 Fall Creek Diversion Dam

7.8.9.1 Existing Fish Passage Facilities

The fish species of primary concern at this site are resident trout. The original construction of the Fall Creek Development did not include fish screens on either the Fall Creek or Spring Creek diversions. Fish ladders were not included over either dam and there was no tailrace barrier provided at the powerhouse.

7.8.9.2 Conceptual Downstream Fish Passage Facilities

Fish Screens

The intakes on Spring Creek and Fall Creek are sized for 16.5 cfs and 50 cfs, respectively. Conventional canal screens meeting the design approach velocity (V_n) of 0.4 fps typically are specified for similar sites. It is assumed that the bypass flow for each screen would be approximately 2 cfs and would be returned to the base of the diversion dams.

On-creek screens should be investigated. However, based on the initial field trip conducted in September 2001**,** the pools upstream of the diversion dams seemed too shallow for on-creek screens, thus consideration of screens being placed in the diversion canals. Figure 7.8-38 presents a conceptual fish screen layout.

The estimated Project cost for screening the Fall Creek diversion is approximately $464,000 as described in Table 7.8.17. O&M costs also were considered in the evaluation of the Project. The present worth cost of operating the Fall Creek screen is estimated to be approximately $646,000.

Existing minimum instream flows at Fall Creek are approximately 0.5 cfs. The 2-cfs fish screen bypass flow would result in an additional water cost affecting power production. The present worth of the lost energy cost is estimated to be approximately $449,000.

7.8.9.3 Conceptual Upstream Fish Passage Facilities

Fish ladders over the diversions or a tailrace barrier at the powerhouse may be required to facilitate upstream fish passage at the Fall Creek Development. The following provides a discussion of such facilities.

Fish Ladders

Fish ladders for the two low head diversions at Fall Creek and Spring Creek could be pool and weir or denil-type ladders. A Project cost for a fish ladder at Fall Creek is estimated to be approximately $45,000, as described in Table 7.8-18. O&M costs also would apply, and the present worth of these costs is estimated to be $323,000.

The fish ladder should be designed to conserve water. It is estimated that this could be accomplished with a flow of approximately 2 cfs each ladder. Similar to the fish screen bypass, the 2 cfs would result in a present worth energy loss of approximately $446,000. Figure 7.8-39 presents a conceptual layout of the fish ladder at the Fall Creek diversion.

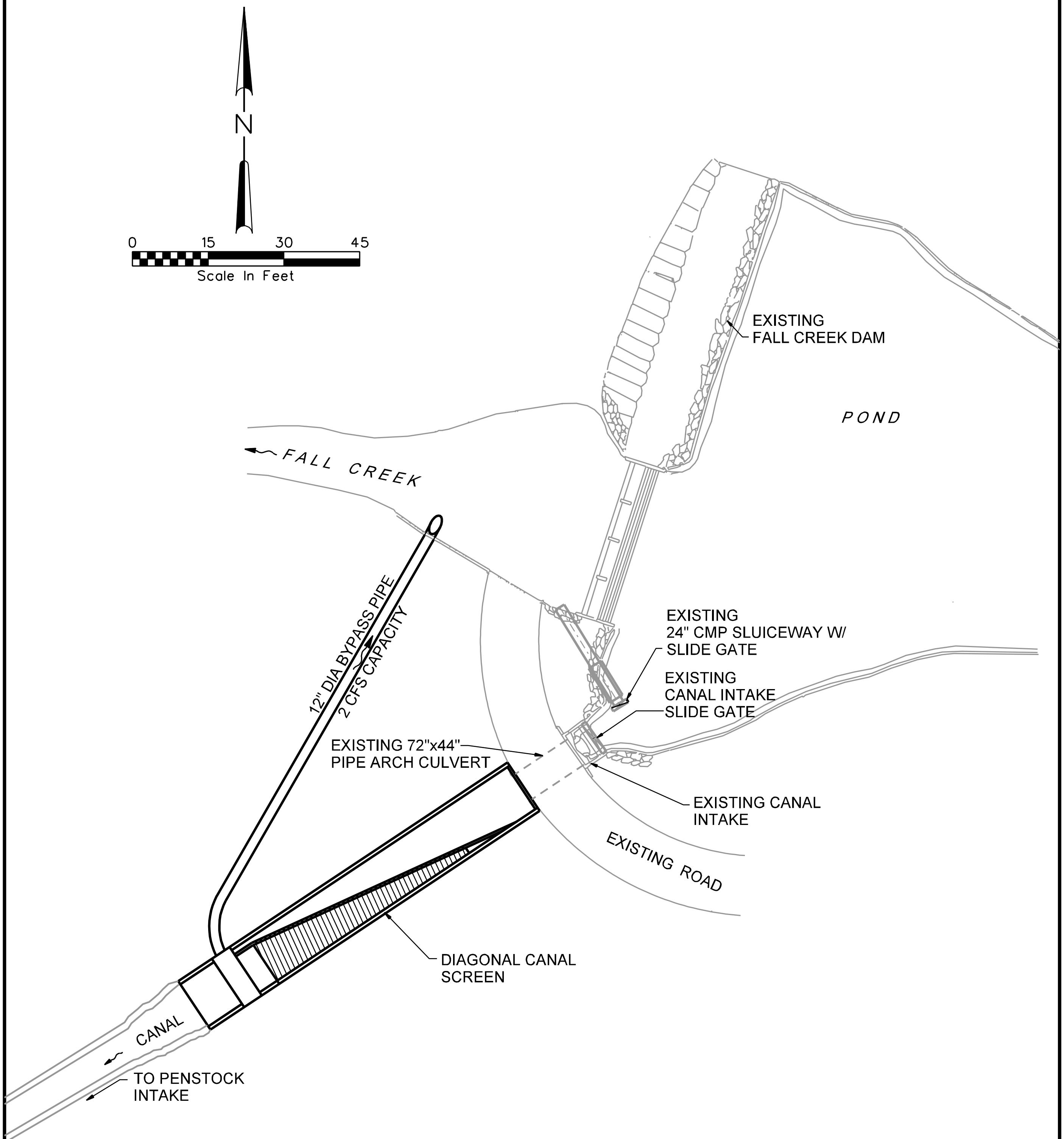

Figure 7.8-38

FALL CREEK
CONVENTIONAL DIAGONAL SCREEN

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Table 7.8-17. Conceptual Fall Creek downstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Conventional Diagonal Screen	7.8-38	Protects fish and meets agency criteria.	Added capital, O&M, and water cost to the development.	$464,000	$646,000	$449,000

Table 7.8-18. Conceptual Fall Creek upstream fish passage facilities.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Fish Ladder	7.8-39	Provides upstream passage at the diversion dam.	Added water cost.	$30,000	$646,000	$1,430,000
Tailrace Barrier	N/A	Precludes adults from being falsely attracted to the power house tailrace, being delayed or being injured	Not proven to be required.	$128,000	$323,000	$1,140

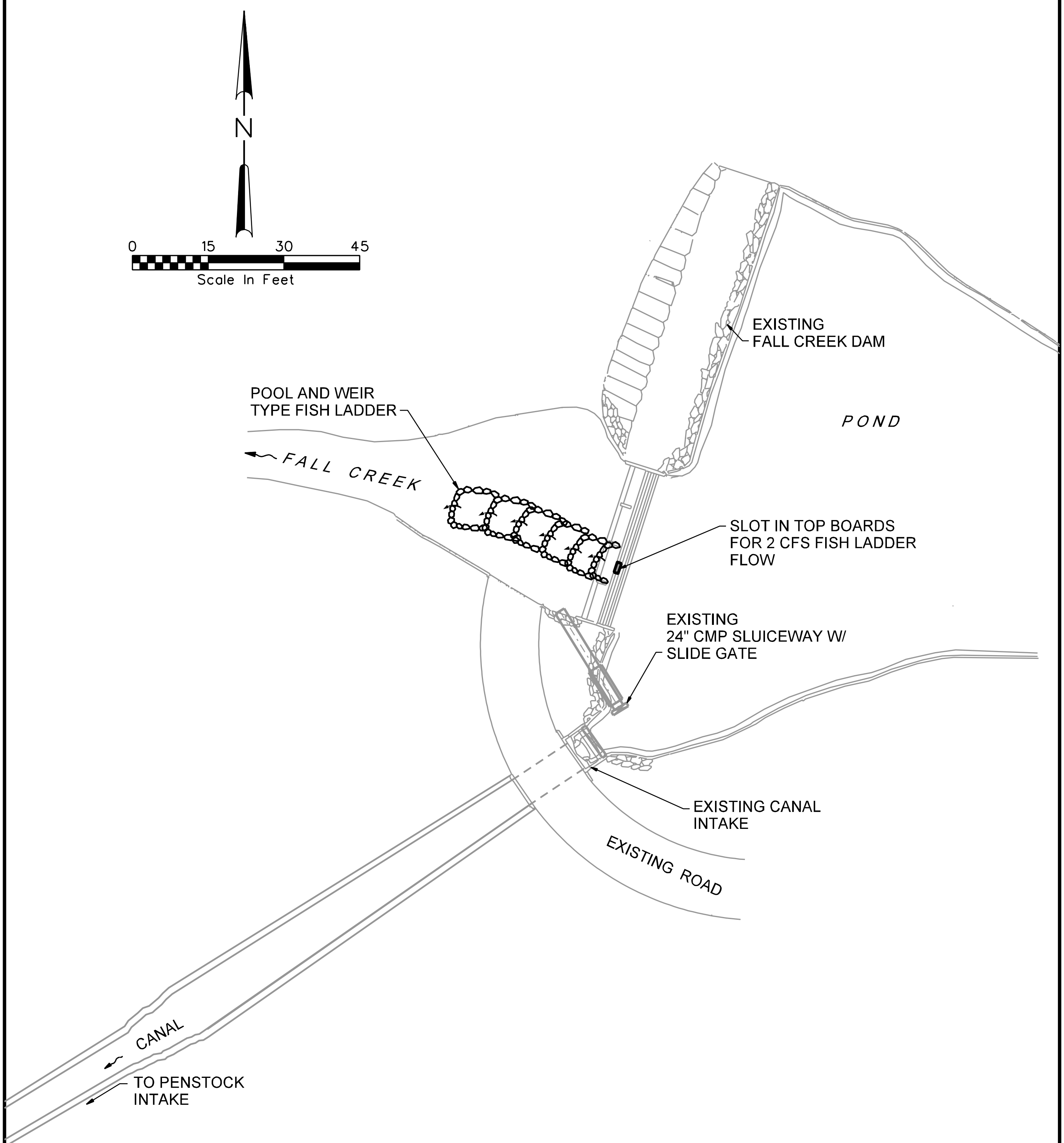

Figure 7.8-39
FALL CREEK
FISH LADDER

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Tailrace Barrier

A tailrace barrier, if needed, would cost approximately $128,000. Present worth O&M costs are estimated to be approximately $323,000. Present worth energy costs would be minimal. Table 7.8-18 presents a summary of this facility.

7.8.9.4 Other Fish Passage Facilities Alternatives

Relocate Diversion Downstream

Fish habitat may be gained by relocating the Fall Creek point of diversion downstream. The new diversion would be located approximately 0.3 mile downstream near the location of the existing falls. The diversion entrance would be lowered from the current elevation of 730 feet to approximately 690 feet, resulting in a gross head reduction of approximately 40 feet.

The cost of the new Fall Creek diversion is estimated to be approximately $60,000. An 1,800-foot-long, 48-inch-wide flume would be needed to connect to the existing penstock. Construction of the flume would be difficult on the proposed hillside route, and would cost approximately $829,000. The old penstock above the connection point could act as a surge tank. The total Project cost is estimated to be approximately $1.11 million. O&M costs would not increase significantly from current expenditures.

It is possible that the requirement for fish screens and a fish ladder on Fall Creek would be waived under this scenario because of the natural passage barrier (falls). The existing instream flow of 0.5 cfs likely would be maintained. However, based on an average annual generating capacity of 12,820 MWh and an expected gross head reduction of 40 feet, generating capacity would be reduced by approximately 5 percent. This energy loss is estimated to have a present worth cost of approximately $454,000.

Figure 7.8-40 presents the conceptual location and configuration of the relocated diversion facility. Table 7.8-19 provides a summary of this alternative, including the various costs identified above.

7.8.10 Fish Passage Analysis

Members of the Engineering Subgroup have contributed to a summary matrix, which is intended to guide selection of suitable technologies that may be required for improved fish passage (see Table 7.8-20). In some cases, the individual representatives of the state and federal agencies had specific recommendations. In other cases, they did not. For this section, and at this time, standard technologies have been selected with guidance and input from the various resource agencies. All conceivable technologies reported in the literature purposely have not been reviewed because many of the experimental technologies would not meet with resource agency approval.

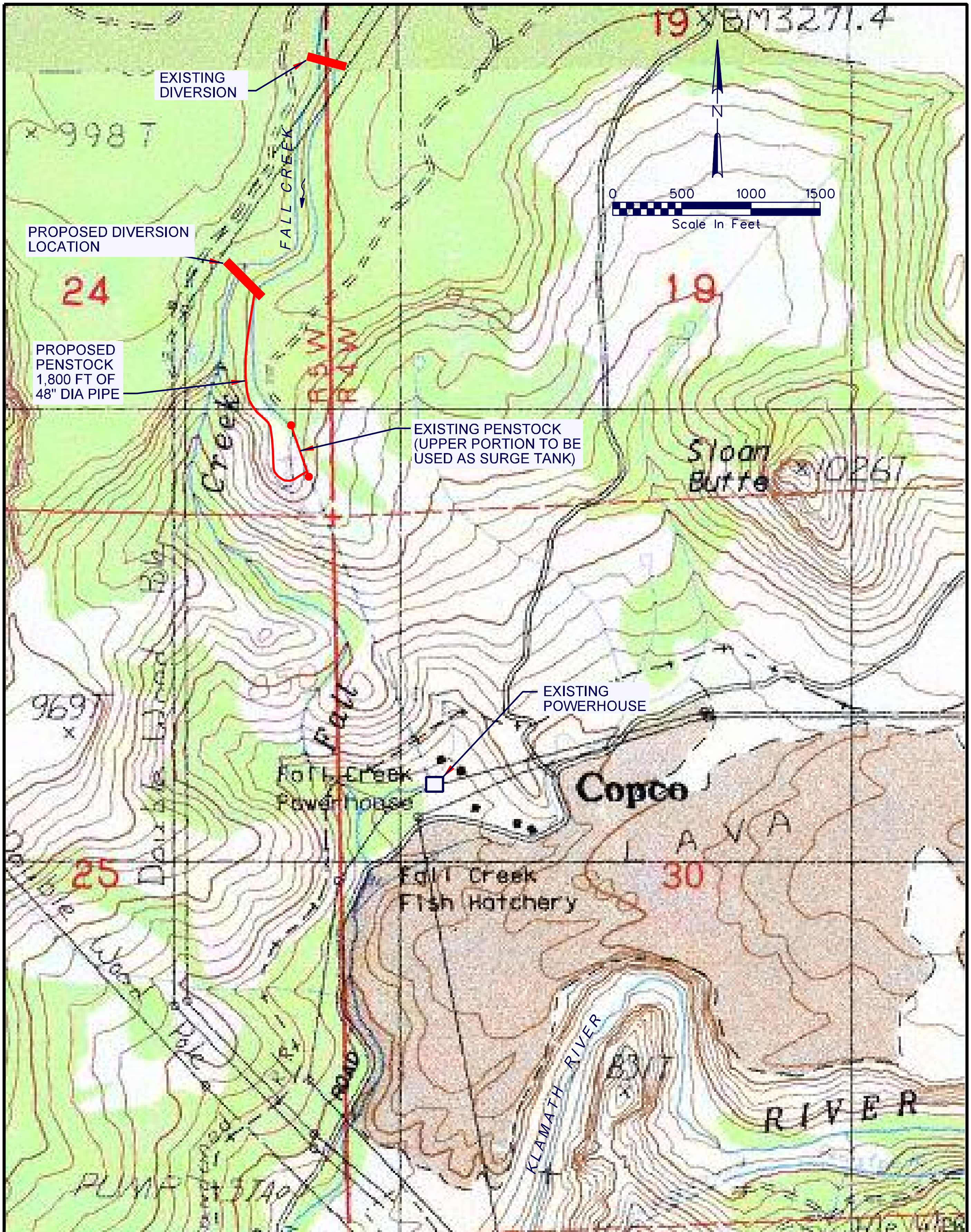

Figure 7.8-40
FALL CREEK
RELOCATE DIVERSION DOWNSTREAM

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Table 7.8-19. Other fish passage facilities alternatives.

Facility Being Considered	Figure No.	Pros	Cons	Estimated Project Capital Cost	Present Worth of Estimated O&M Costs[1]	Present Worth of Estimated Energy Costs[1,2]
Relocate Diversion Dam Structure Downstream	7.8-40	Reduces bypass reach by 0.3 mile.	Additional capital costs. Energy costs.	$1,110,000	N/A	$454,000

[1] Present worth costs are calculated using a real discount rate of 6.6 percent for 30 years.

[2] Energy costs are calculated using a $0.05 per kilowatt-hour (kWh) regional cost of energy.

NA = Not Applicable

7.9 IRON GATE HATCHERY EVALUATION

7.9.1 Methods

Iron Gate fish hatchery production and related fish management practices have played important roles in the management of fish populations in the basin. The goal of this study was to summarize ongoing fish management and hatchery operations and identify potential limiting factors to production so that current hatchery practices could be modified as necessary in light of the final fish passage option. The resulting information is a descriptive summary of past and current fish management and hatchery goals, policies, and activities, including marking practices, and an assessment of the effectiveness of the hatchery in meeting its goals.

The Iron Gate fish hatchery has been evaluated previously for PacifiCorp (FishPro, 1992). The evaluation described hatchery practices, such as incubation, adult holding, spawning, extended rearing, inventories, marking, and release facilities. Production information included goals as well as actual current production by species, race, and release size. Observations and concerns, as well as recommended changes in hatchery practices and facilities, were presented on the basis of this evaluation. PacifiCorp updated this evaluation and reviewed with the CDFG the status of recommendations made in the FishPro (1992) report. The form used by CDFG hatchery personnel to update the status/disposition of the recommendations in the FishPro report is included in Appendix 7B. The CDFG and NOAA Fisheries also jointly reviewed hatchery programs in California to identify where there were potential conflicts with native salmonids and to identify opportunities for using hatcheries to help recover depressed stocks (CDFG and NOAA Fisheries, 2001). The Iron Gate fish hatchery was included in this review. Discussions within the Hatchery Subgroup have identified several specific investigations that would provide information related to future hatchery operations. Investigations are completed as outlined below.

7.9.1.1 Feasibility of Producing Spring Chinook Salmon at Iron Gate Hatchery

The feasibility of producing a spring Chinook run at Iron Gate fish hatchery was evaluated using a number of assumptions. First it was assumed that the broodstock will come from within the Klamath-Trinity River basin and would be an ocean-type stock. It also was assumed that this program would be in addition to, rather than replacing, a portion of the existing program. Temperature regimes from Iron Gate fish hatchery and Fall Creek fish hatchery were evaluated as to suitability for holding maturing broodstock. Land space and water supply volumes were also evaluated at both Fall Creek and Iron Gate fish hatcheries. An analysis was conducted to determine if there was sufficient water quantity, water quality, and land space for facilities to hold maturing broodstock and to rear juveniles. Biological considerations also were identified.

7.9.1.2 Heating Incubation Water at Iron Gate Hatchery

The concept of heating incubation water is based on the desire to limit the competition of hatchery and wild fish for thermal refugia in the Lower Klamath River during June when water temperatures rise to stressful levels. The assumption is made that the later fall Chinook lots, which typically are released during the first week of June, could be released earlier if their incubation period were compressed using warmer water. Also of concern is the relatively small size of steelhead smolts at release and the problem of residualism in the Iron Gate fish hatchery stock. Three alternatives were evaluated. A modest alternative heated water only for incubating

Table 7.8-20. Options for potential fish passage facilities.

Development/ Passage Direction	Potential Technology	General Description	NOAA Fisheries[1]	U.S. Fish and Wildlife Service (USFWS)	California Department of Fish and Game (CDFG)	Oregon Department of Fish and Wildlife (ODFW)
East Side Upstream	A. East Side tailrace barrier	The tailrace did not appear to be a problem for false attraction at the East Side powerhouse.	Tailrace barrier may be required if anadromous fish ever access this reach.	Agree with NOAA Fisheries	CDFG supports ODFW's comments regarding a tailrace barrier at the Link River Eastside diversion.	Higher flows in the bypass might reduce false attraction to the tailrace. However, because of the high volume of discharge from this powerhouse, a barrier may be needed.
East Side Downstream	A. East Side fish screens	Fish screens will be required for downstream migrating fish. Conventional and high-speed screens.	Feasible.	Agree with NOAA Fisheries.	CDFG supports ODFW's comments regarding fish screens at the East Side power diversion.	Screens must protect lamprey, suckers, and resident trout. ODFW criteria for lamprey and suckers will be provided at a future date.
West Side Upstream	A. Tailrace barrier	This tailrace did not appear to be a problem for false attraction at the West Side powerhouse.	Not required.	Agree with NOAA Fisheries.	CDFG supports ODFW's comments regarding a tailrace barrier at the Link River - West Side powerhouse.	Higher flows in the bypass might reduce false attraction to the tailrace. Pending the outcome of the instream flow studies and resulting minimum flows, the need for a tailrace barrier is uncertain, but the physical features of this site do not preclude construction of a tailrace barrier
West Side Downstream	A. Fish screen	Fish screens will be required for downstream migrating fish. Conventional and high-speed screens.	Costly, but feasible	Agree with NOAA Fisheries.	CDFG supports ODFW's comments regarding fish screens at the Link River West Side diversion.	Screens must protect lamprey, suckers, and resident trout. ODFW criteria for lamprey and suckers will be provided at a future date.
Link River Dam Upstream	A. Fishway	New fishway currently being designed for resident fish by USBR. This is not a part of the Klamath Hydroelectric Project because the USBR will own the new fishway. Generally agreed that the new fishway will be suitable for anadromous adults.	New fishway being constructed for suckers will likely be OK for salmon.	Not applicable.	CDFG supports ODFW's comments regarding the fishway at the Link River dam.	Need to sort out responsibility for evaluation, maintenance, monitoring, and implementing standard operating procedures (SOPs). Fishway will need to pass resident trout, lamprey, and suckers. Contractual agreement requires PacifiCorp to operate the fishway, therefore, it has the responsibility to maintain and develop operational criteria.
Link River Dam Downstream	A. Fishway and spillway	Juvenile passage using fishways, A-Canal bypass system, or spillway appears to be acceptable at this USBR dam.	Likely acceptable	Not applicable.	Not applicable.	Not applicable.
Keno Upstream	A. Existing fishway	May be sufficient for anadromous adults. Will need either minor or major rehabilitation for resident fish. Need to assess when spillway is discharging at higher flow to determine effectiveness of attraction flow.	Technically feasible.	Agree with NOAA Fisheries.	CDFG supports ODFW's comments regarding the existing fish ladder at the Keno facility.	Fishway must provide passage for suckers and lamprey. Uncertainty regarding passage efficiency of current fishway. Appears to have inadequate attraction flow. Entrance appears to be too wide to provide an adequate attraction jet. May need to adjust spill configuration to improve attraction to entrance.
Keno Downstream	A. Juvenile passage	Spillway, fishway, AWS, and sluiceway appear to provide adequate hydraulic passage.	Keno downstream release strategies may need tune-ups and operational refinements.	No comment.	CDFG supports ODFW's comments regarding juvenile fish passage at the Keno facility.	Narrow spillway gate opening at low flow may create fish passage problem.
J.C. Boyle Upstream	A. Existing fishway	May not be sufficient for adult fish because of design configuration and water temperature. Need to see the site when spillway is discharging.	Adequacy for anadromous fish is unknown. Unlikely to be effective when spilling due to insufficient attraction flow.	Agree with NOAA Fisheries.	CDFG supports ODFW's comments regarding the fishway at the J.C. Boyle facility.	Currently, the fishway is not adequate for resident rainbow trout and does not meet current passage criteria. Trout passage declined 99 percent from 1959 to 1989-91. Fishway needs to be designed to pass suckers and lamprey. One of the physical features that must be addressed in fishway design at this site is water temperature. The fishway water temperature can exceed 70^{o}F, while the temperature in the bypass reach is 50^{o}F.
	B. Tailrace barrier	Tailrace barrier may be needed at J.C. Boyle powerhouse.	Need has not yet been determined, insufficient information.	Agree with NOAA Fisheries.	CDFG supports ODFW's comments regarding a barrier at the J.C. Boyle powerhouse tailrace.	A tailrace barrier might be necessary. Higher flows in the bypass might reduce false attraction to the tailrace. Pending the outcome of the instream flow studies and resulting minimum flows, the need for a tailrace barrier is uncertain, but the physical features of this site do not preclude construction of a tailrace barrier

Table 7.8-20. Options for potential fish passage facilities.

Development/ Passage Direction	Potential Technology	General Description	NOAA Fisheries[1]	U.S. Fish and Wildlife Service (USFWS)	California Department of Fish and Game (CDFG)	Oregon Department of Fish and Wildlife (ODFW)
J.C. Boyle Downstream	A. Existing intake screens	Approach velocity more than 2 feet per second, therefore, the existing screens are not sufficient for juvenile fish. Bypass also needs to be compared to current criteria. May need conventional or high-speed screens.	Costly, but feasible.	Agree with NOAA Fisheries.	CDFG supports ODFW's comments regarding the intake screens at the J.C. Boyle facility.	Current screens do not meet criteria for resident fish. Criteria for mesh size and approach velocity is exceeded, and severe maintenance problems are apparent. Current screens have frequent problems with icing. Because there are no back-up screens, there is no screening when panels are pulled for repair.
	B. Surface collector	Consider Baker River type surface collector in lieu of fish screens for total intake flow.	Downstream technologies would be considered individual experiments until their utility is proven on Klamath PacifiCorp projects.	Agree with NOAA Fisheries.	As previously noted, CDFG does not support the use of a Baker Gulper-type surface collector. CDFG's June 19, 2000, Statewide Fish Screening Policy specifically requires screens on diversion in anadromous waters unless sampling demonstrates otherwise.	ODFW does not consider the Baker River surface collector to be an acceptable fish passage facility. ODFW has not supported its use at other hydro projects. The problems with this type of facility include: difficulty of sealing sides and bottom and lack of fish protection during maintenance. This facility does not meet criteria necessary to protect downstream migrants.
Copco No. 1 Upstream	A. Tailrace barrier at powerhouse	Only required if anadromous adults are allowed into Copco No. 2 pool and the need is demonstrated.	Need has not yet been determined, insufficient information.	Agree with NOAA Fisheries.	It is CDFG's opinion that a tailrace barrier may be needed, depending on the design of the fishway.	
	B. Fishway	Needed if anadromous adults in this reach. May be joint fishway with Copco No. 2, skipping the Copco No. 2 pool.	Open to consideration of a ladder, but consider it an unlikely solution.	Agree with NOAA Fisheries.	CDFG would support the use of a properly designed fish ladder at the Copco facilities. As previously noted, CDFG's preferred alternative is a fish ladder that extends from below Copco No. 2 dam to Copco Lake, provided that water quality issues and barrier height concerns are properly addressed.	
	C. Trap and haul	Trap fish at the top of Copco No. 2 ladder and then truck them to the Copco No. 1 forebay or river mile (RM) 204.			CDFG does not consider trap and haul to River Mile 204 to be a viable long-term solution	
	D. Fish lift/lock	Alternative to B. – Fishway, above.	Feasible.	Agree with NOAA Fisheries.	CDFG would support a fish lift or Borland-type fish lock at the Copco No. 1 dam.	
Copco No. 1 Downstream	A. Fish screens for intake	Screen intake required because juvenile fish are present. Conventional and high-speed screens considered.	Feasible.	Agree with NOAA Fisheries.	CDFG recommends that the Copco No. 1 intake be equipped with properly designed fish screens. CDFG does not support the use of high speed intake screens. High speed screens are considered experimental technologies and have not been adopted by CDFG. In addition, the approach velocity of these screen designs exceeds CDFG's June 19, 2000 established Fish Screening Criteria.	
Copco No. 2 Upstream	A. Tailrace barrier at powerhouse	Tailrace barrier may be needed.	Need has not yet been determined, insufficient information.	Agree with NOAA Fisheries.	It is CDFG's opinion that a barrier may be needed on the Copco No. 2 tailrace, depending on baseload versus peaking operations, and the quantity of bypass flow.	
	B. Fishway at diversion dam	Fishway over Copco No. 2 is needed to get adults from the Copco No. 2 stilling basin to the Copco No. 2 forebay.	Feasible	Agree with NOAA Fisheries.	CDFG supports the use of a properly designed fish ladder at the Copco No. 2 diversion dam.	
	C. Fishway extending to Copco No. 1 forebay	Fishway over Copco No. 2 continuing up to the Copco No. 1 forebay.	Not ruled out, but considered to be an unlikely solution.	Agree with NOAA Fisheries.	CDFG supports the use of a properly designed fish ladder at the Copco No. 2 diversion dam, which extends to Copco Lake, provided that: (1) water quality and temperature in the fishway, and upstream and downstream of the fishway, are acceptable for successful fish passage; and (2) it can be shown that the fishway could provide successful passage over a barrier of this height. If these conditions could be met, this would be CDFG's preferred alternative for the Copco No. 1 and Copco No. 2 facilities.	

Table 7.8-20. Options for potential fish passage facilities.

Development/ Passage Direction	Potential Technology	General Description	NOAA Fisheries[1]	U.S. Fish and Wildlife Service (USFWS)	California Department of Fish and Game (CDFG)	Oregon Department of Fish and Wildlife (ODFW)
Copco No. 2 Downstream	A. Fish screen on power intake	Required if juveniles are in the Copco No. 2 pool.	Costly, but feasible.	Agree with NOAA Fisheries.	CDFG recommends that the Copco No. 2 diversion dam be equipped with a properly designed fish screen.	
Iron Gate Upstream	A. Existing fishways plus trap and haul to Iron Gate reservoir.	Upgrade existing trapping facilities at both hatchery and powerhouse to accommodate trap and haul of adults to Iron Gate reservoir.	Feasible.	Agree with NOAA Fisheries	CDFG would support a trap and haul program to Iron Gate reservoir.	Oregon is interested in fish passage measures at the lower projects because of its interest to restore anadromous species to historic habitat in Oregon.
	B. Existing fishways plus trap and haul to RM 204	Upgrade existing trapping facilities at both hatchery and powerhouse to accommodate trap and haul of adults to RM 204 (just upstream of Copco No. 1 reservoir).	Feasible.	Agree with NOAA Fisheries.	CDFG would not support a trap and haul program to RM 204.	
	C. Existing fishways plus tram lift	Upgrade existing trapping facilities at both hatchery and powerhouse to accommodate tram lift of adults to Iron Gate reservoir.	Feasible.	Agree with NOAA Fisheries.	CDFG would support the use of a properly designed tram lift at Iron Gate dam.	
	D. Existing fishways plus new fish lock (e.g., Borland-type)	Upgrade existing trapping facilities at both hatchery and powerhouse and install a new Borland-type fish lock.	Feasible.	Agree with NOAA Fisheries.	CDFG would support the use of a properly designed Borland-type fish lock.	
	E. New full–height fishway	Upgrade existing trapping facilities at both hatchery and powerhouse and add new fishway to allow adults to gain access to Iron Gate reservoir.	Not feasible.	Agree with NOAA Fisheries.	CDFG would support the use of a properly designed fish ladder at Iron Gate dam. However, there is concern about the potential for successful passage over a barrier of this height. Notwithstanding this concern, if it can be shown that the fishway could provide successful passage over the barrier, this would be CDFG's preferred alternative	
	F. Tailrace barrier at Iron Gate powerhouse	No evidence at this time that tailrace barrier is needed at this site.	Not required.	Agree with NOAA Fisheries.	CDFG concurs that a tailrace barrier is not necessary at this time. However, a tailrace barrier may be needed in the future depending on the option selected to improve upstream fish passage.	
Iron Gate Downstream	A. Fish screens for intake	Provide positive barrier fish screen for all power house intake flow. Conventional and high-speed screens to be considered.	Costly, but feasible.	Agree with NOAA Fisheries.	CDFG recommends that the intake of the Iron Gate powerhouse be equipped with a properly designed fish screen. CDFG's June 19, 2000, Statewide Fish Screening Policy requires screens on diversions in anadromous waters unless sampling demonstrates otherwise.	Oregon is interested in fish passage measures at the lower projects because of its interest in restoring anadromous species to historic habitat.
	B. Surface collector	Consider Baker-River-type surface collector in lieu of fish screens for total intake flow.	No nets, considered experimental, not preferred.	Agree with NOAA Fisheries.	CDFG does not support the use of a Baker Gulper-type surface collection system. CDFG's June 19, 2000, Statewide Fish Screening Policy requires screens on diversions in anadromous waters unless sampling demonstrates otherwise.	ODFW does not consider the Baker River surface collector to be an acceptable fish passage facility and have not supported its use at other hydro projects. Problems with this type of facility include difficulty in sealing the sides and bottom, and lack of fish protection during maintenance. Facility does not meet criteria to protect downstream migrants.
	C. High-speed fish screen	Eicher- or MIS-type high-speed screens	Not ruled out but seldom approved by NMFS.	Agree with NOAA Fisheries.	CDFG does not support the use of high speed intake screens. High speed screens are considered experimental technologies and have not been adopted by CDFG. In addition, the approach velocity of these screen designs exceeds CDFG's June 19, 2000 established Fish Screening Criteria.	
	D. Behavioral devices (strobes, sound, electricity etc.)		Not Acceptable.	Agree with NOAA Fisheries.	CDFG does not support the use of behavioral devices in lieu of proven positive barrier technologies. In addition, CDFG's June 19, 2000, Statewide Fish Screening Policy specifically requires screens on diversions in anadromous waters unless sampling demonstrates otherwise.	

Table 7.8-20. Options for potential fish passage facilities.

Development/ Passage Direction	Potential Technology	General Description	NOAA Fisheries[1]	U.S. Fish and Wildlife Service (USFWS)	California Department of Fish and Game (CDFG)	Oregon Department of Fish and Wildlife (ODFW)
	E. Through turbine passage		Not Acceptable.	Agree with NOAA Fisheries.	CDFG does not support the application of "through turbine passage" methods for juvenile anadromous fish, except for low head situations where there is virtually no potential for harm due to runner strike or pressure gradients. CDFG's June 19, 2000, Statewide Fish Screening Policy specifically requires screens on diversions in anadromous waters unless sampling demonstrates otherwise.	
	F. Louvers		Not Acceptable.	Agree with NOAA Fisheries.	CDFG does not support the use of louvers. CDFG's June 19, 2000, Statewide Fish Screening Policy specifically requires screens on diversions in anadromous waters unless sampling demonstrates otherwise.	
	G. Any net-only system		Not Acceptable.	Agree with NOAA Fisheries.	CDFG does not support the use of "net only" systems, unless they meet CDFG's established screening criteria. CDFG's June 19, 2000, Statewide Fish Screening Policy specifically requires screens on diversions in anadromous waters unless sampling demonstrates otherwise.	
Fall Creek Upstream	A. Tailrace barrier at power house	May be needed for pelton unit powerhouse.	No comment on Fall Creek.	No comment on Fall Creek.	It is CDFG's opinion that a barrier may be needed at the tailrace of the Fall Creek powerhouse.	
	B. Fishway at Fall Creek diversion dam	Fishway will be needed for resident fish.	No comment on Fall Creek.	No comment on Fall Creek.	CDFG recommends that the Fall Creek diversion dam be equipped with a fishway designed for resident species.	ODFW supports CDFG's recommendations that a fishway be added.
	C. Fishway at Spring Creek diversion	Fishway will be needed for resident fish.	No comment on Spring Creek.	No comment on Spring Creek.	CDFG would support a recommendation by ODFW (and others) for a fishway designed for resident species on the Spring Creek diversion dam.	ODFW recommends that a fishway designed for resident species be added to the Spring Creek diversion dam.
Fall Creek Downstream	A. Screen on Fall Creek diversion dam	Fish screen will be needed for resident fish.	No comment on Fall Creek.	No comment on Fall Creek.	CDFG recommends that the Fall Creek diversion be equipped with a fish screen designed for resident species.	ODFW supports CDFG's recommendations that fish screens for resident fish be added to the Fall Creek diversion dam.
	B. Screen on Spring Creek diversion	Fish screen will be needed for resident fish.	No comment on Spring Creek.	No comment on Spring Creek.	CDFG would support a recommendation by ODFW (and others) for a fish screen designed for resident species on the Spring Creek diversion.	ODFW recommends that a fish screen designed for resident species be added to the Spring Creek diversion.

[1] Notwithstanding the notes above, NOAA Fisheries expects solutions to passage issues at the PacifiCorp Klamath projects to be developed through a team approach. Thus, even if noted as "unlikely" or " not feasible," NOAA Fisheries will be open, in a technical design forum, to later consideration of many of the above-noted technologies.

steelhead brood lots. An intermediate alternative heated water 5°F to 9°F for the later Chinook brood lots (last 25 percent). Finally, an evaluation was made for heating all of the incubation water in the hatchery to 5°F to 9°F above ambient. The ramification on production timing and facilities was developed and biological considerations were identified. However, no considerations were made regarding what effect this heated discharge would have on the Klamath River.

7.9.1.3 Increase Chinook Tagging and Marking

There is a desire among fisheries managers to achieve Constant Fractional Marking (CFM) of hatchery stocks in the Klamath-Trinity basin and elsewhere. Currently, the Trinity River fish hatchery marks 25 percent of Chinook production while Iron Gate fish hatchery marks about 5 percent. Two alternatives were evaluated to achieve a 25 percent marking rate at Iron Gate fish hatchery. The first alternative expanded facilities to mark and tag fish by hand and using hand-operated machines. The second alternative evaluated using an automated tagging facility.

7.9.1.4 Expand Fall Chinook Yearling Production

The Joint Hatchery Review Committee (NMFS and CDFG, 2001) recommended that an expansion of the yearling Chinook program should be evaluated for desirability. This was assessed with the assumption that any shift of smolt production to yearling production would be accompanied by a corresponding reduction of smolt production in terms of weight. Three alternatives were evaluated. The first alternative would shift 2.6 million out of 4.6 million smolts to yearling production. The second alternative would shift all smolts to yearling production. The third alternative is similar to the first alternative, but would include a new spring Chinook program. All three alternatives require a new rearing facility at Fall Creek. Water supply and quality have been evaluated to meet the needs of the various alternatives.

7.9.2 Results and Discussion

7.9.2.1 Hatchery Production Overview

Iron Gate dam was built in 1961 by Pacific Power and Light Company (now PacifiCorp). To mitigate for loss of anadromous fish habitat upstream of the dam, PacifiCorp was required to build and fund the Iron Gate Salmon and Steelhead hatchery (Figure 7.9-1). The adult salmon ladder, trap, and spawning facility was built at the base of the dam and was put into operation in February 1962 (Figure 7.9-2). The hatchery complex, including egg incubation, rearing, maintenance, and administration facilities, as well as staff residences, was constructed about 400 yards downstream in March 1966 (Figure 7.9-3). The largest feature of the hatchery complex is the 32 rearing ponds, each measuring 10 by 100 feet. The facilities have operated every year since construction with little modification.

Iron Gate fish hatchery is operated by the CDFG. The program is funded both by the CDFG and PacifiCorp. By agreement, PacifiCorp funds 80 percent of the total operating costs of the hatchery to satisfy its annual mitigation goals for fall Chinook fingerlings, coho yearlings, and steelhead yearlings. Beginning in 1979, portions of the fall Chinook fingerling production have been reared to the yearling stage for release in November. This extra cost has been funded by the CDFG.

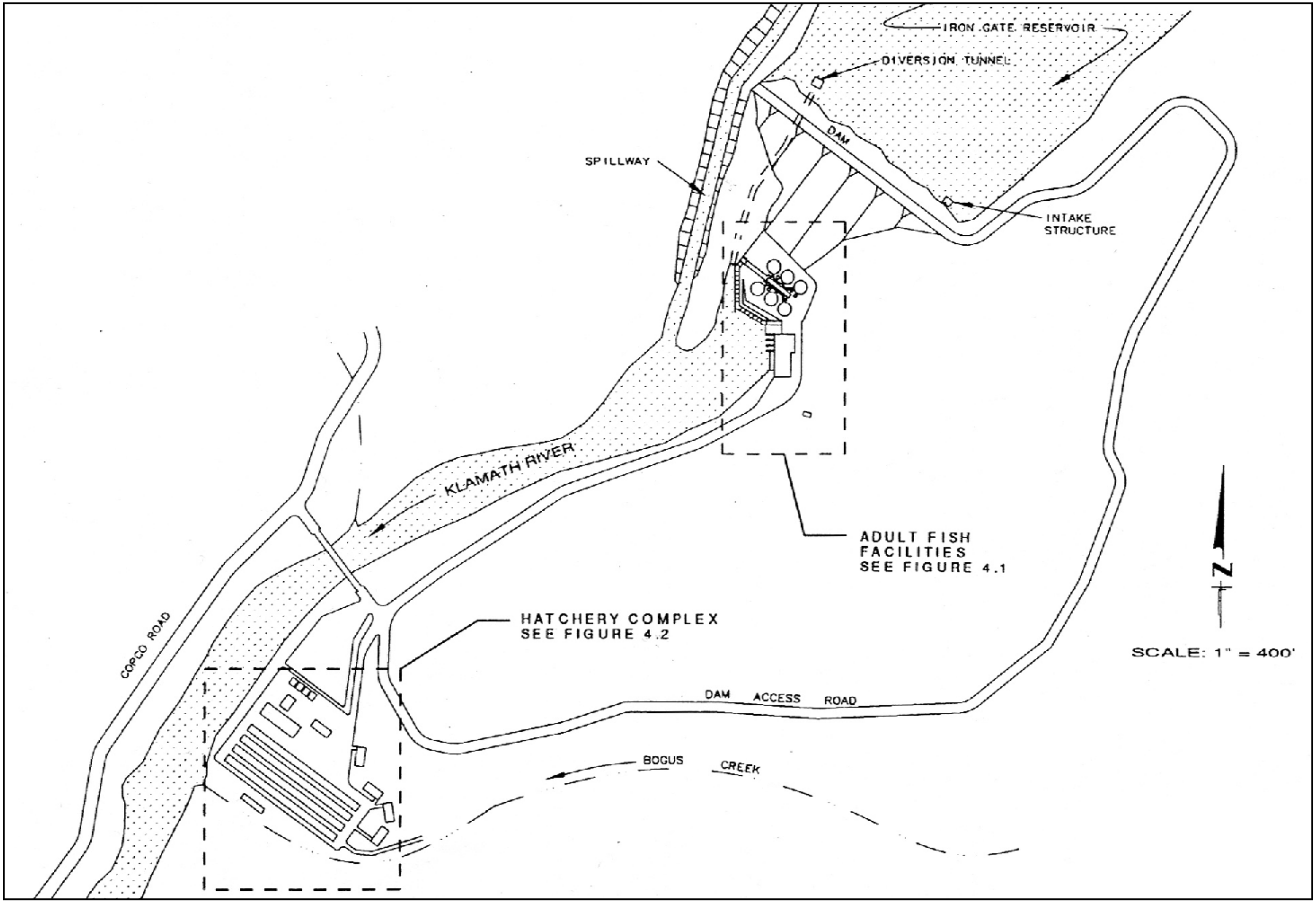

Figure 7.9-1 **Site Plan**
Klamath River Hydroproject Relicensing, PacificCorp

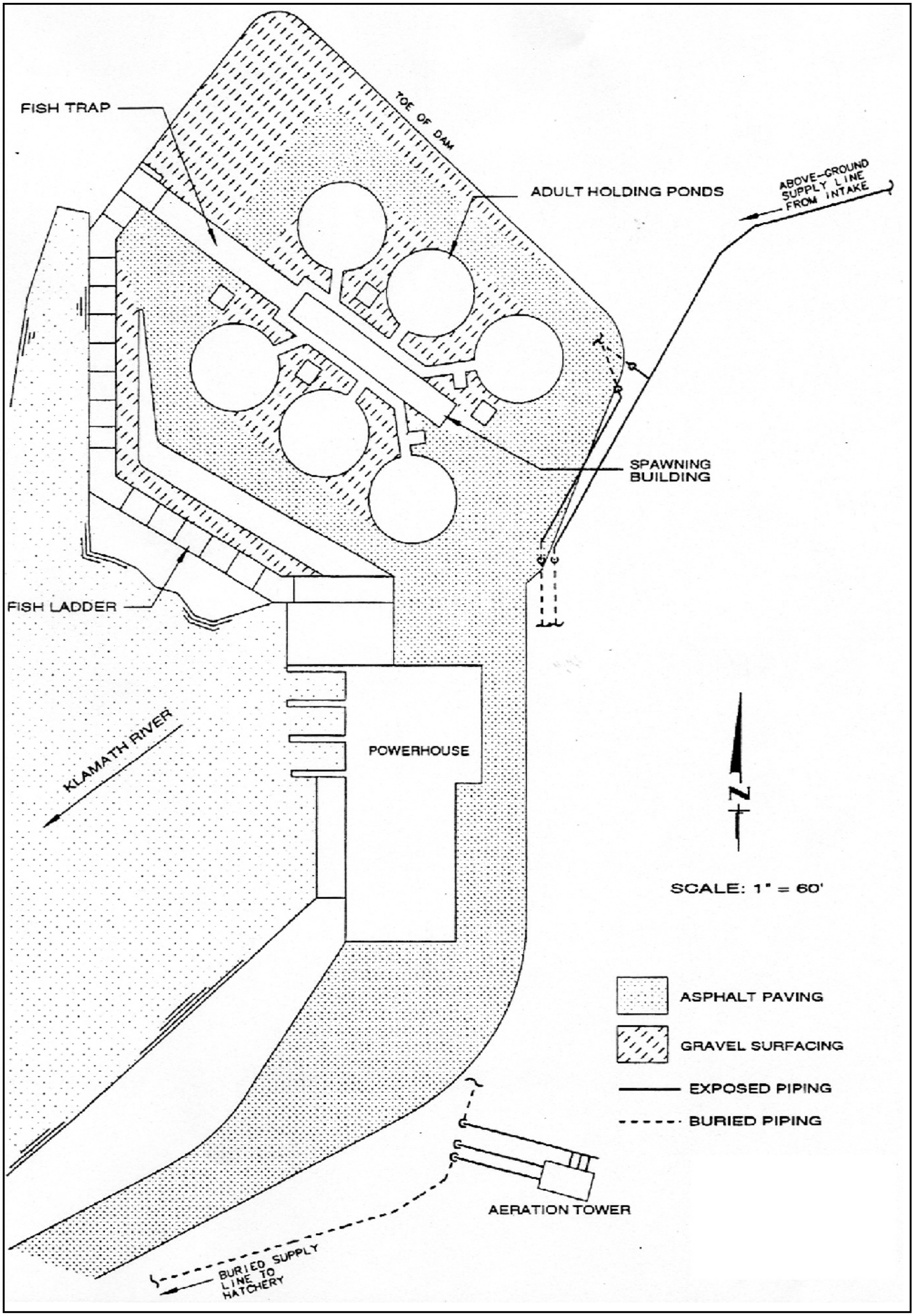

Figure 7.9-2 **Adult Fish Facilities**
Klamath River Hydroproject Relicensing, PacificCorp

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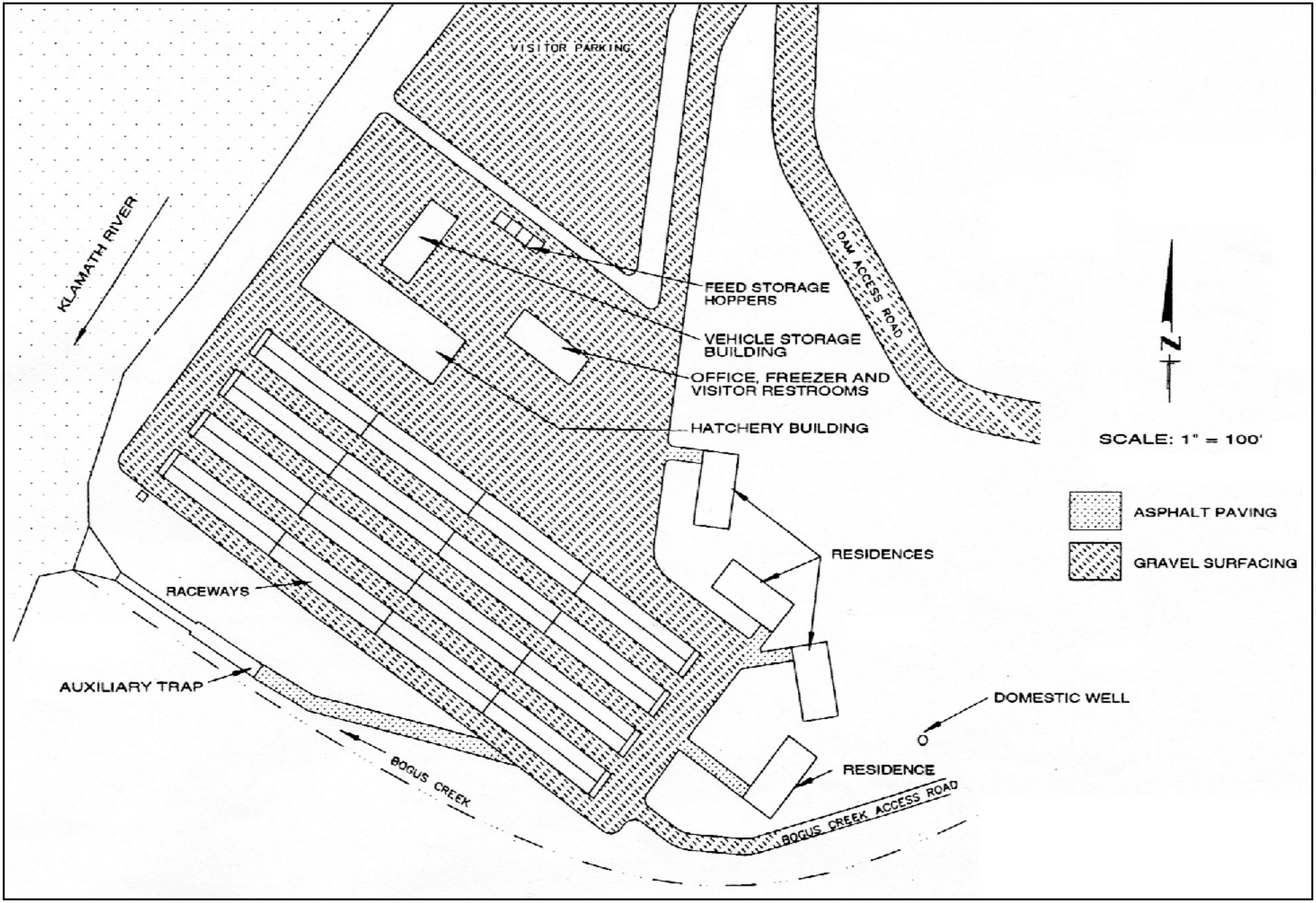

Figure 7.9-3 **Hatchery Complex**
Klamath River Hydroproject Relicensing, PacificCorp

7.9.2.2 Production Goals

The current production goals for the Iron Gate fish hatchery are shown in Table 7.9-1 for the PacifiCorp mitigation and CDFG enhancement programs. The original mitigation goals were set in the Order Issuing License for Iron Gate dam (Federal Power Commission, 1961). However, in 1979, the CDFG and PacifiCorp agreed to modify the program to shift some of the Chinook production to yearling releases. These fish would be reared either at Iron Gate fish hatchery, Fall Creek fish hatchery, or at both. The original order to release 6 million fall Chinook fingerlings (smolts) was changed to a production goal of 4.6 million then 4.92 million. Coupled with that change was a transfer of 180,000 smolts to Fall Creek fish hatchery for yearling production, and the retention of 900,000 smolts at Iron Gate fish hatchery for yearling releases. Another major change is the altered strategy in fall Chinook size at release. Originally, 6 million Chinook were released at 300/pound (lb), plus an additional 5.5 million swim-up fry. The CDFG has determined that releases at 90/lb for smolts and 8/lb for yearlings is more effective.

Table 7.9-1. Production goals for Iron Gate fish hatchery.

	Funding Party	Number	Target Size (fish/lb)
Fall Chinook Salmon			
Egg take	PacifiCorp	12,800,000	N/A
Fingerling releases	PacifiCorp	4,600,000	90
Fingerling transfers	PacifiCorp	500,000	90
Yearling releases	CDFG	900,000	8
Coho Salmon			
Egg take	PacifiCorp	500,000	N/A
Fingerling releases	PacifiCorp	0	N/A
Fingerling transfers	PacifiCorp	0	N/A
Yearling releases	PacifiCorp	75,000	15
Steelhead Trout			
Egg take	PacifiCorp	1,000,000	N/A
Fingerling releases	PacifiCorp	0	N/A
Fingerling transfers	PacifiCorp	0	N/A
Yearling releases	PacifiCorp	200,000	8

N/A = Not applicable

The current goals for steelhead trout also differ from the original goals in that the target size has been changed from 10/lb to 6 inches. Production numbers have stayed the same at 200,000. Production goals for coho salmon are 75,000 smolts at a size of 10 to 20/lb.

Egg take goals are greater than necessary to achieve the established production goals. This is done to address uncertainties from year to year in the hatchery and to allow culling of production lots as desired. The original egg take goal for Chinook was 12.8 million. This was increased to 18 million by the CDFG following some high return years to allow for excess eggs to be used for production elsewhere. In 1975, about 2.2 million eggs were transferred to the Trinity River fish hatchery, 4.1 million to Mad River fish hatchery, and 80,000 to Humboldt State University. In 1982, about 2.2 million eggs were transferred to Trinity River fish hatchery and 1.2 million to

Mad River fish hatchery. From 1979 to 1991, between 100,000 and 300,000 fall Chinook per year were transferred to satellite rearing facilities on seven Klamath River tributaries near Happy Camp and Orleans (Rushton, pers. comm., 2003).

Since then, the practice of inter-basin transfer has fallen out of favor for genetic and pathogen control reasons. The current egg take goal for Chinook is 10 million. Coho egg take goals are 500,000 for the yearling release of 75,000 fish. The disparity between egg and smolt numbers is the result of a past problem with soft-shell disease. The soft-shell disease problem has been largely solved with iodine bath treatment, but the high egg take goal is still in place. There appears to be a good understanding between PacifiCorp and the CDFG that egg take goals have been set as a guide to reach production goals rather than as an absolute number.

7.9.2.3 Production Constraints

In 1996, the CDFG prepared a document entitled "Iron Gate Hatchery Production Goals and Constraints" (CDFG, 1996). The production goals, discussed above, are summarized in Table 7.9-1. Production constraints refer to directives regarding hatchery practices for the purpose of minimizing hatchery-related environmental impacts.

For all species cultured, only fish volitionally entering the hatchery are used as brood stock. Stocks from other drainages or other Klamath River tributaries are not spawned or cultured at the hatchery. Generally, this has been the practice since the hatchery began operation. However, there were 4 years when coho returns to the hatchery were low to the point where eggs were imported. In 1966, 1967, 1968 and 1970, the majority of coho production (60-70 percent) at Iron Gate was from eggs imported from the Cascade fish hatchery on the Columbia River (Rushton, pers. comm., 2003).

The annual egg allotment for all species are distributed throughout the duration of the spawning run in proportion to the instantaneous magnitude of the run. Maintaining genetic diversity by distributing egg allotment throughout the spawning run takes precedence over meeting numeric production goals.

No eggs or juveniles of any species in excess of the production goals are kept at the hatchery. At the end of the spawning run, any eggs or juveniles remaining and in excess of production goals are destroyed unless needed for CDFG-approved inland programs. Excess eggs or juveniles are not stocked in anadromous waters.

Returning adult fish are allowed free access to the hatchery, consistent with hatchery physical constraints, available water quality, and manpower. In the advent that any of these or other unforeseen adverse conditions occur and the potential for fish loss is great, free access may be curtailed temporarily.

All adult salmon entering the Iron Gate fish hatchery are destroyed in the following manner:

- The heads of all adipose-clipped salmon are removed from carcasses and sorted for coded wire tag processing.

- Carcasses are donated to non-profit organizations upon application to the hatchery manager. The hatchery manger has the authority to determine the allocation of the carcasses to be donated.

- Carcasses not donated to non-profit organizations are disposed of at a refuse disposal site or returned to the river as directed by the CDFG Northern California-North Coast Region Manager (Regional Manager).

All adult steelhead processed in the hatchery are returned to the river. Any dead steelhead are disposed of as provided above for salmon.

All juvenile salmon and steelhead are released into the Klamath River at the hatchery release facility. Iron Gate fish hatchery stocks or production are not stocked in other drainages or in other tributaries to the Klamath River.

Any exception to or modification of the mitigation program requires the joint written approval of the CDFG Regional Manager and the CDFG Inland Fisheries Division Chief.

7.9.2.4 Juvenile Salmon and Steelhead Production

The historical production of juvenile fish at Iron Gate fish hatchery from 1965 to 2001 is illustrated in Figures 7.9-4, 7.9-5, and 7.9-6 for Chinook, coho, and steelhead, respectively. The Chinook graph shows yearling release numbers stacked on top of the smolt numbers. No indications are made to distinguish between releases on site to those made to off-site stations (a discontinued practice). For the coho and steelhead graphs, the fingerling and yearling smolt releases are shown side-by-side for each year. Note that coho and steelhead fingerling releases were discontinued for the most part in the early 1980s.

Chinook production fluctuated substantially in the years preceding 1989. Numbers of Chinook smolts ranged from 454,546 in 1965 to 12,727,288 in 1985. The period from 1977 through 1984 had relatively low production, well below production goals. After 1989, production of smolts has been consistently at or close to goals. With the exception of the mid-1970s and 1990, yearling release numbers have been close to the goal of 1,080,000. No yearlings were produced in 1974, 1977, 1978, or 1990.

Coho production has varied from zero to 200,000 yearling smolts. The production goal of 75,000 yearlings has been met in 26 of the last 37 years, or 70 percent of the time. Production was frequently below target during the 1970s. Production in the 1980s was usually above target with much greater numbers in the late 1980s. Since 1994, production has been maintained close to production goals. Fingerling releases were made periodically before 1984 and were relatively large in 1969 and 1982, corresponding to relatively large adult returns.

Steelhead production has varied widely through the years ranging from a high of 642,857 yearlings in 1970 to a low of 10,702 in 1997. Production has declined steadily since the peak year in 1970. Production goals were met in most years before 1991. The goal of 200,000 smolts has not been met since 1991. Fingerling releases have been made in the past, but not since 1988. During the 1980s, fingerling releases of 200,000 to 300,000 were common with a peak of 1.1 million in 1970.

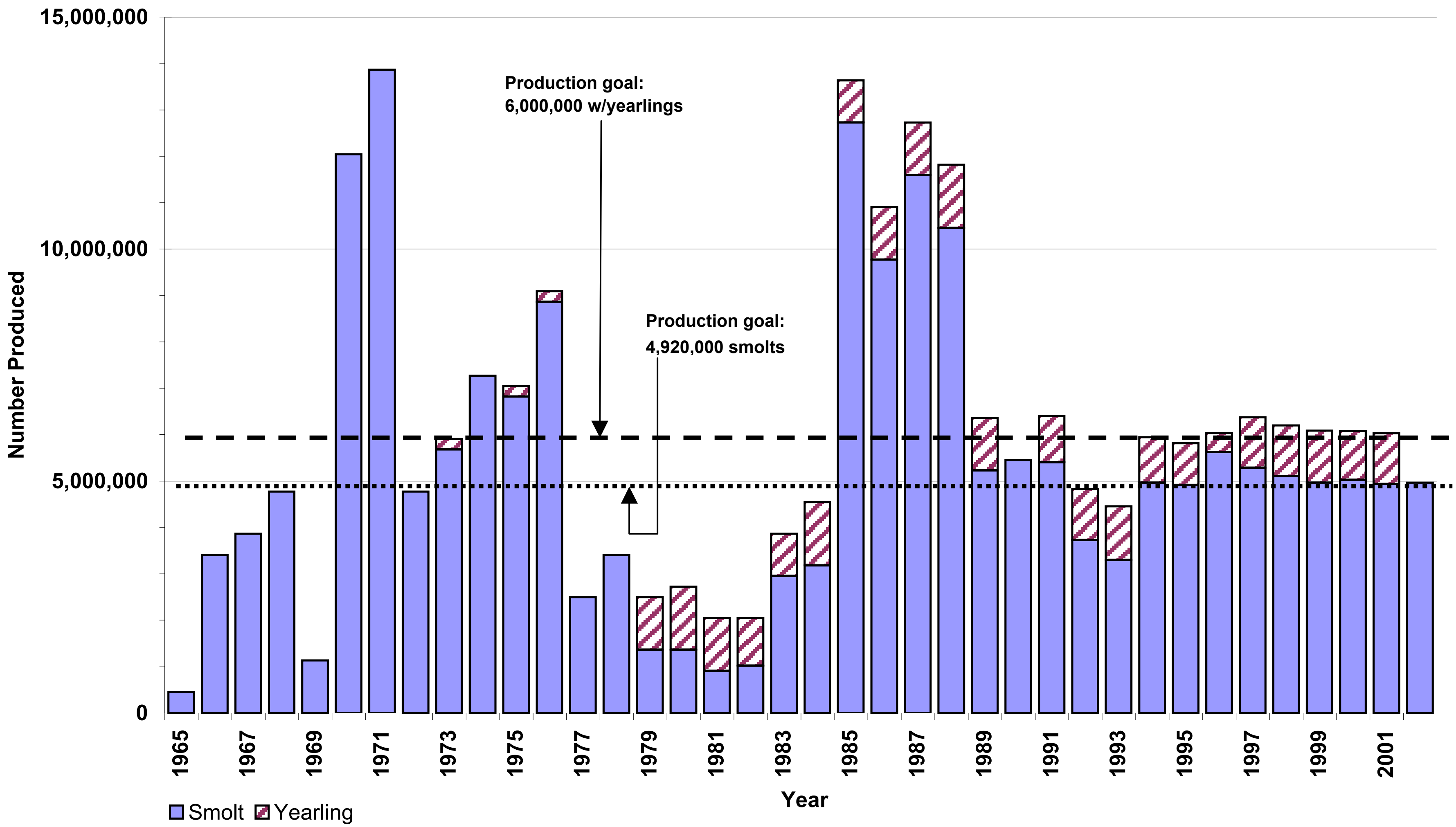

Figure 7.9-4 **Chinook Production at Iron Gate Hatchery (1965-2001)**

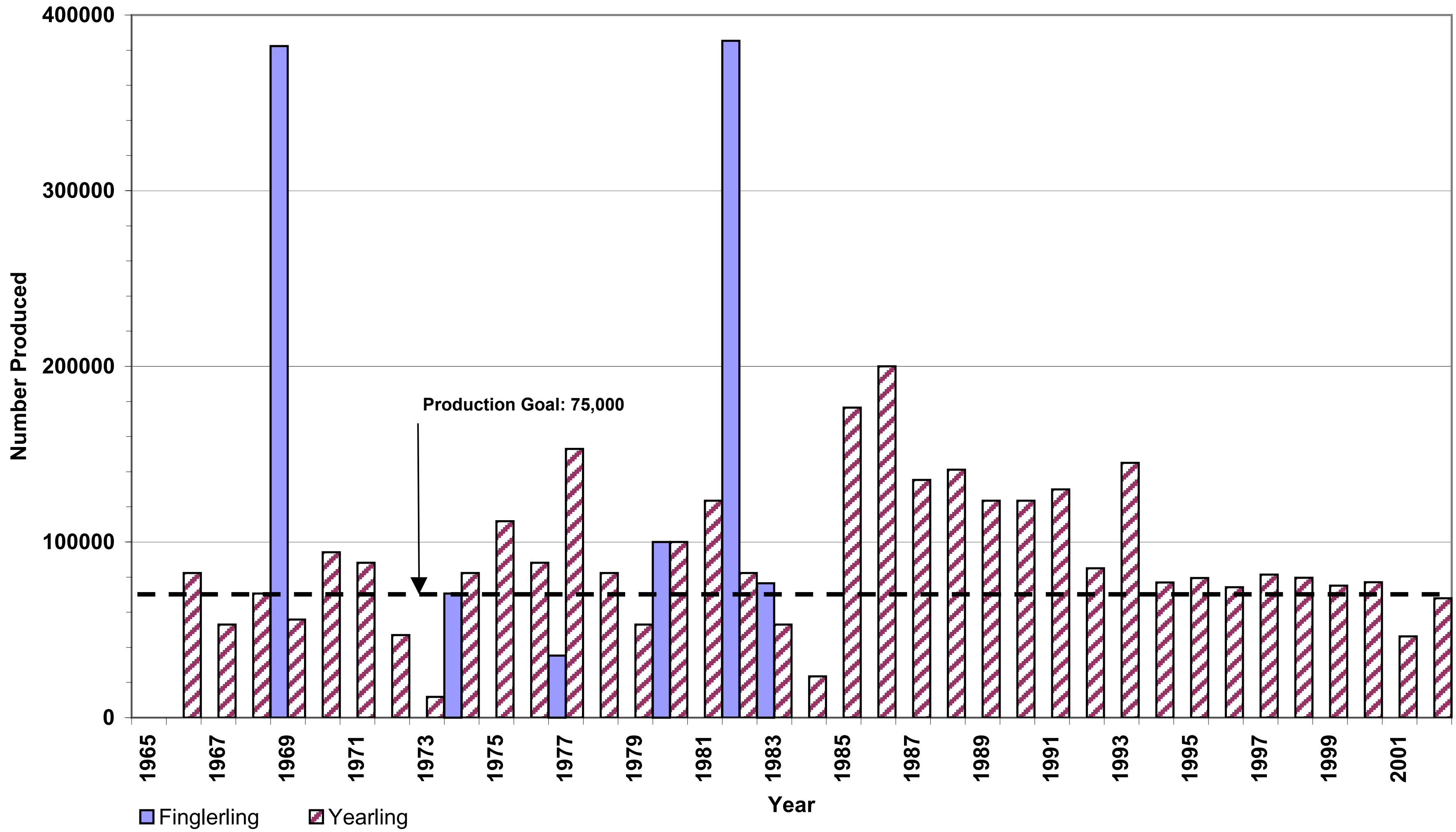

Figure 7.9-5 **Coho Production at Iron Gate Hatchery (1965-2001)**

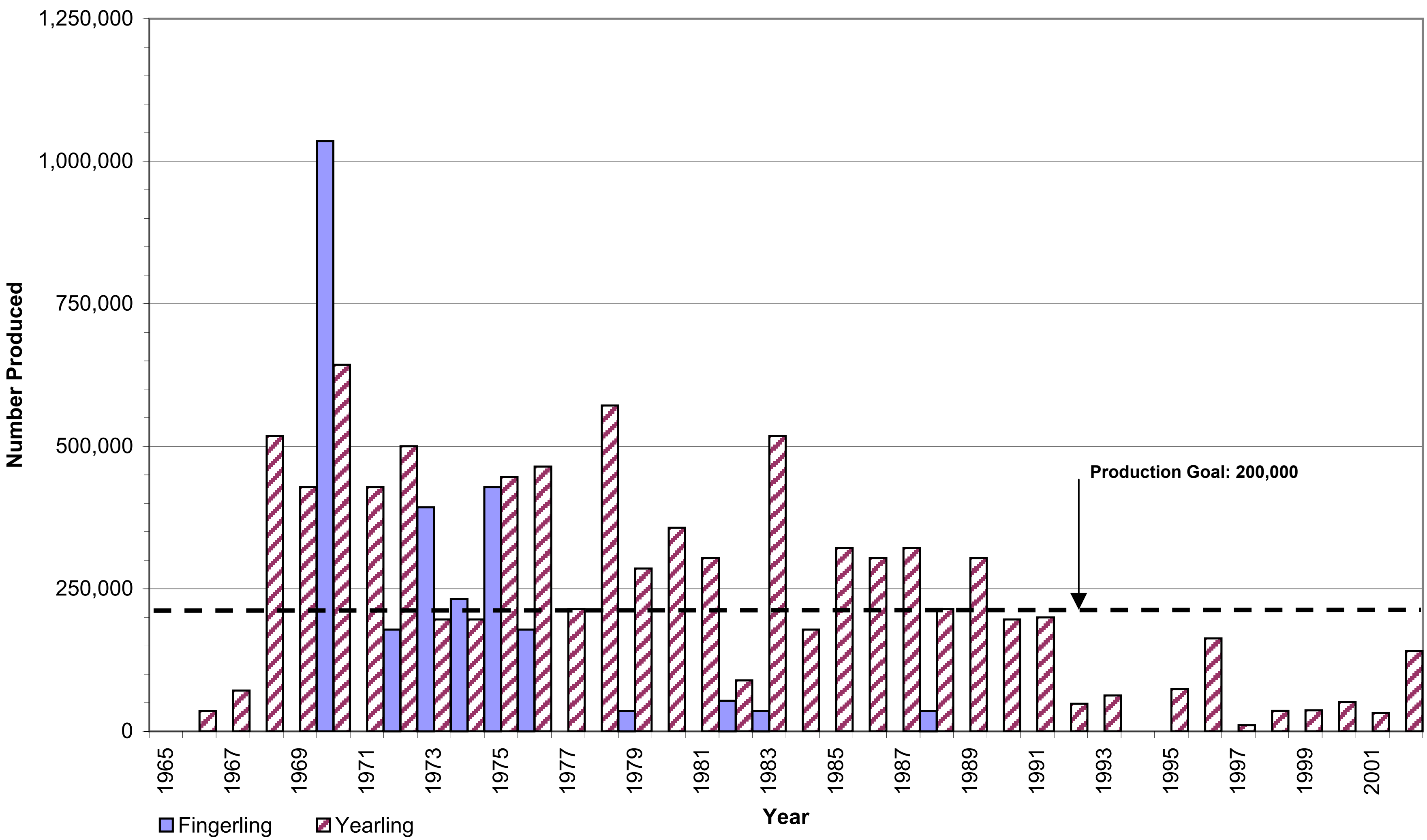

Figure 7.9-6 **Steelhead Production at Iron Gate Hatchery (1965-2001)**

7.9.2.5 Fingerling Versus Yearling Survival

Throughout the years, numerous fish reared at Iron Gate fish hatchery have been marked with coded wire tags at the request of the CDFG. Recovery data from these tags have been used to explore the issue of whether Chinook salmon survive better when released as fingerling and yearling release groups, reared from brood years 1979 to 1984. From the results, it appears that adult survival from yearling releases is more than 3.5 times greater than fingerling releases. While increased survival is a strong factor in evaluating the overall benefit of the different rearing programs, there are also other factors that must be considered, such as timing and maturity at return.

7.9.2.6 Adult Returns

Returns of adult salmon and steelhead to the Iron Gate fish hatchery from 1964 to 2002 are shown in Figure 7.9-7. The values shown do not include jacks (defined as fish less than 22 inches long). From 1963 to 1999, Chinook returns to the hatchery ranged from 954 in 1969 to 22,681 in 1995. Return numbers have increased slowly and erratically over the years. In 2000 and 2001, record numbers of Chinook returned to Iron Gate fish hatchery, with 71,151 returning in 2000. Most biologists credit favorable ocean conditions for this surge in Chinook run sizes (Suzomoto, 2003).

Coho returns have ranged from zero to 4,097, averaging 830 fish from 1963-2002 (see Figure 7.9-7). Coho returns to Iron Gate fish hatchery have increased on average over the years, but erratically. What has changed the most are the magnitude of the peak years, such as 1996/1997 when over 4,000 adult coho returned to the hatchery. These peak years are interspersed with returns as low as a few hundreds fish. There is some indication of a 3-year cycle, which would be typical for coho in the absence of environmental variation.

Steelhead returns also have been erratic, ranging from 12 to 4,411 fish (see Figure 7.9-7). Before 1969, the run size was in the range of 400 to1,500 fish. During the next 20 years, the run size increased to a range of 100 to 4,000 fish. From 1990 to 1999, the run dropped to less than 100 fish. Since that time, the run has recovered somewhat. In 2003, the egg take met collection goals (200,000) for the first time in a decade with an adult return of 495 adult fish.

7.9.2.7 Facility Review and Recommendations

In 1991, recommendations were made to improve or repair various facilities and operational procedures at Iron Gate fish hatchery (Fish Pro, 1991). Some of these recommendations have been implemented since 1991, some have been deemed unnecessary, and others are still recommended. A questionnaire was developed to facilitate discussion of the continued need or success of the implementation of the Fish Pro (1991) recommendations. The questionnaire was provided to the Iron Gate fish hatchery manager and the CDFG senior hatchery supervisor to fill out. A workshop was held later to discuss the outcome.

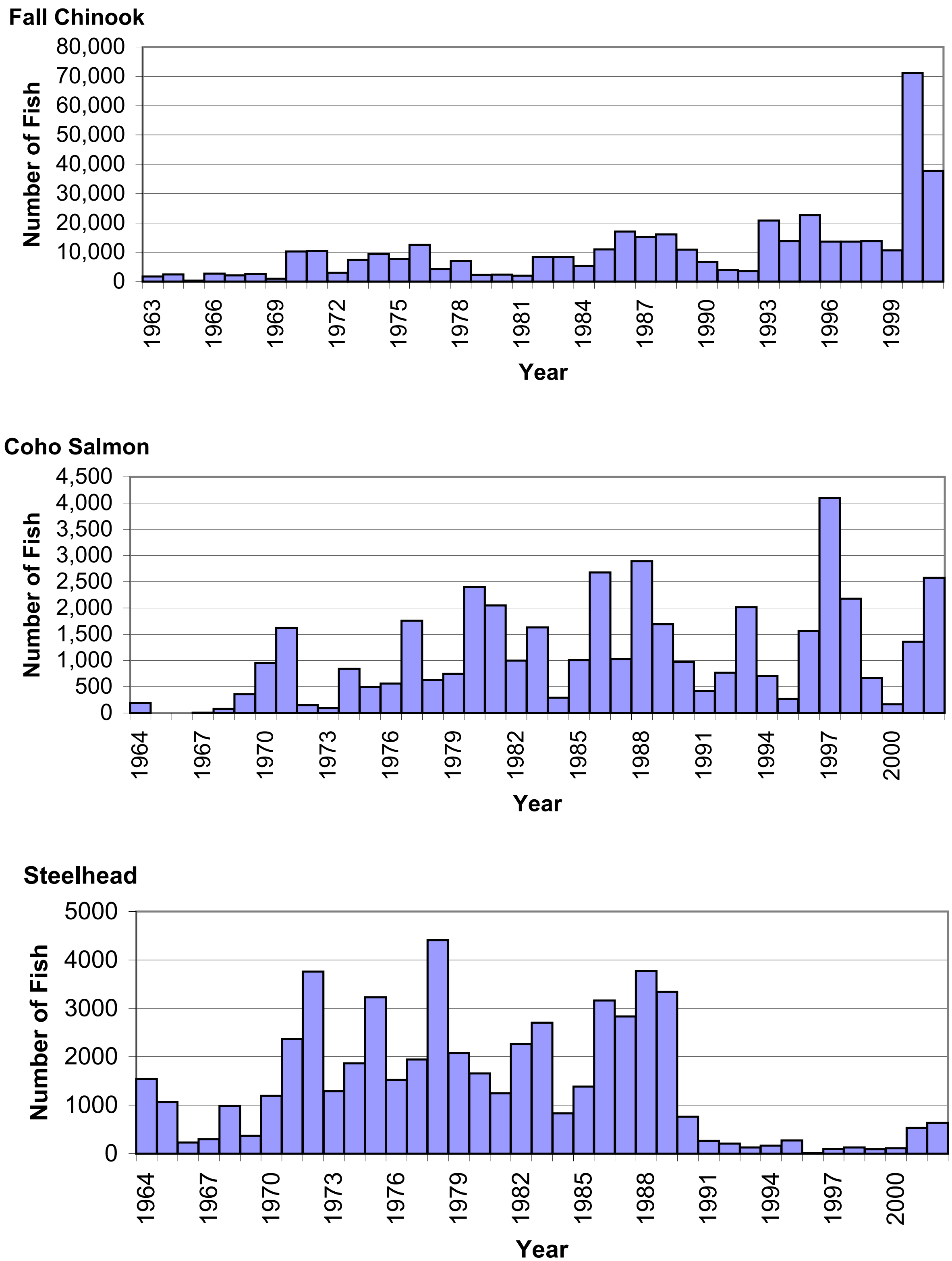

Figure 7.9-7 **Adult, Salmon, and Steelhead Returns**

A summary of the findings of the hatchery facilities and operational review workshop is provided in Appendix 7C, which is divided into two major sections covering operational changes and facility repairs and improvements. Under operational changes, the topics of spawning, incubation, fish marking, and release are considered. Under facilities, the topics include the intake structure, aeration tower, exterior plumbing, fish ladders, adult holding facilities, raceways, the spawning building, the administration building and freezer, vehicle storage building, residences, domestic water supply, domestic wastewater system, and roadways are considered. Many of the measures recommended by Fish Pro (1991) either have been implemented or made unnecessary by other operational changes. Other recommendations were determined to be unnecessary or undesirable by the Iron Gate fish hatchery staff.

Table 7.9-2. Current Iron Gate fish hatchery marking and tagging.

Species	Number*	Stage at Release	Tag/Mark
Fall Chinook	200,000	Smolt	Ad clip, CWT
Fall Chinook	100,000	Yearling	Ad clip, CWT
Subtotal	**300,000**		
Coho	75,000	Year +	Maxillary clip
Steelhead	200,000	Year +	Maxillary clip + Ad clip
Subtotal	**275,000**		
Total	**575,000**		

CWT = Coded wire tag.

* Numbers of fish currently marked and tagged at Iron Gate fish hatchery.

7.9.3 Operational Measures

Of the operational measures recommended in the Fish Pro (1991) report, only a few minor changes still are recommended that are essential. These include an additional live car for steelhead spawning and a new 12-inch-diameter pipeline to the incubation building. The need to add incubation stacks has been alleviated by a reduced egg take and modification to the existing incubator stacks. A brining system no longer is needed for the incubation system because brine treatment of eggs has been substituted with iodine treatment. The addition of six intermediate-sized raceways is viewed as potentially beneficial, but not essential. The previous recommendation to modify the adult holding pond for juvenile rearing has been rejected by the Iron Gate fish hatchery staff as the result of an unsuccessful trial.

Fish Pro (1991) recommended that a mobile fish tagging system be fabricated for ease of use and to eliminate the need to fabricate tagging sheds each year. Since then, the NMFS and CDFG have asked for the evaluation of increasing the number of fish tagged each year. Fish Pro (1991) also recommended heated incubation water. Both of these measures are reevaluated in detail later in the next section.

7.9.4 Facilities

Some facility modifications, upgrades, and repairs recommended by Fish Pro have been completed. However, some of the lower priority recommendations have not been implemented yet. The greatest current facility problem is the raceway surfaces. The concrete walls and bottoms were deteriorating, so a thick paint-on compound was applied to cover and seal the concrete. Unfortunately, the coating has not held up and is sloughing off in sheets. Removal and reapplication of an alternative coating would require extensive effort. The hatchery manager believes that it would be more practical to replace the raceways entirely. The gravel driveways between the raceways were identified as undesirable and warranted upgrading to asphalt. While this has not been completed, portions of the gravel driveways are being replaced with asphalt each year.

The hatchery building and water delivery system is getting old, but is still fully functional. The electrical system needs to be replaced in the near future. The water manifold is becoming corroded and should be replaced. Drainage in the hatchery building is a problem and a center drain trough running the length of the building would be highly desirable.

The auxiliary trap should to be modified so that salmon do not injure themselves. The situation does not harm hatchery production, but it does have public relations implications. At present, the water supply inlet to the trap is at the end of the trap. Salmon swim to the inlet and jump over it and into the aluminum bars of the gate. Because the public has access to this facility, the frequent battering of fish on the gate is undesirable. The solution is to relocate the water inlet to the bottom of the trap so that water upwells into the trap.

Some minor repairs and upgrades were identified in the Fish Pro (1991) report that have not been completed and have been identified as still worthy of implementation. Many of these repairs and upgrades concern Americans with Disabilities Act (ADA) compliance. For instance, the observation gallery in the spawning building needs ADA-approved grating. A ramp needs to be constructed at a shallower angle to the auxiliary trap. An ADA-compliant bathroom needs to be installed. Some upgrades are still desired for the four residences on-site: two more heat pumps to install and an additional bathroom at each residence.

7.9.4.1 New Considerations

Two recommendations made in the Fish Pro (1991) hatchery evaluation report required re-evaluation in light of situational changes that have occurred in the past 12 years. These included a recommendation for updated tagging equipment and a recommendation to heat some of the egg incubation water. The issue of tagging equipment needs has been heightened recently by the desire of the CDFG and NOAA Fisheries to greatly increase the fraction of fall Chinook salmon to be tagged at the hatchery. Regarding the issue of heating incubation water, the CDFG and NOAA Fisheries recommended an evaluation of using heated incubation water to accelerate egg development with the objective of releasing late Chinook lots earlier (CDFG and NMFS Fisheries, 2001). The goal would be to lessen competition between hatchery and wild Chinook for thermal refugia in the lower river during early summer when temperatures rise to stressful levels. The re-evaluation of these two issues is presented in the sections below.

During Hatchery Subgroup meetings conducted in 2002 and 2003, stakeholders requested evaluations of two additional topics: (1) the shifting of some fall Chinook production from smolt releases (May-June) to yearling releases (October-November) and (2) the feasibility of producing spring Chinook at the Iron Gate or Fall Creek fish hatcheries. These two new evaluations are presented in the sections below.

7.9.4.2 Increased Chinook Tagging and Marking

Currently, about 5 percent of the Iron Gate fish hatchery Chinook are tagged with coded wire tags (CWT) and marked with an adipose fin clip. All steelhead and coho are marked in some fashion with fin and/or maxillary clips. It is anticipated that the CDFG may want to increase the percentage of Chinook at Iron Gate fish hatchery to match the percent tagged/marked at the Trinity River fish hatchery to achieve a CFM rate in the Klamath-Trinity River basin. The final marking rate has not been determined, but it could be the same 25 percent accomplished at Trinity River fish hatchery as recommended by Hankin and Newman (1999).

Currently, fish tagging is conducted by CDFG personnel in two small, temporary work stations fabricated each year. If the number of fish to be tagged increases, new facilities would need to be built or borrowed.

Numbers and Effort

The approach to determine potential changes to facilities and operations at Iron Gate fish hatchery from increased marking and tagging was to first compare the current marking and tagging program at both Iron Gate fish hatchery and Trinity River fish hatchery (see Tables 7.9-2, 7.9-3, and 7.9-4). While the Trinity River fish hatchery marking and tagging program represents the standard to which Iron Gate hatchery may need to match, there is an important difference. Much more of the tagging effort would need to be expended on pre-smolt fish at Iron Gate fish hatchery compared to Trinity River fish hatchery. Pre-smolt fish are harder to handle, but more importantly, the window of opportunity for tagging is only 6 weeks. The fish have to be large enough to handle, but need a recovery period before being released.

Table 7.9-3. Iron Gate hatchery marking and tagging at 25 percent.

Species	Number*	Stage at Release	Tag/Mark
Fall Chinook	1,150,000	Smolt	Adipose clip, CWT
Fall Chinook	250,000	Yearling	Adipose clip, CWT
Subtotal	**1,375,000**		
Coho	75,000	Year +	Maxillary clip
Steelhead	200,000	Year +	Maxillary clip + adipose clip
Subtotal	**275,000**		
Total	**1,650,000**		

CWT = Coded wire tag.

* Numbers of fish that could be marked and tagged at Iron Gate fish hatchery if CFM rate of 25 percent were used.

The next step was to determine what staff and facilities would be required at Iron Gate fish hatchery to mark and tag 25 percent of the fall Chinook production as is done at Trinity River fish hatchery, as presented in Table 7.9-2:

- It takes ten people 6 weeks with four tagging machines in two sheds for the tagging and marking of 300,000 fall Chinook (smolts and yearlings).

- 300 man-days
- 17,500 fish per working day on average
- 1,750 fish per man-day
- Coho are marked at a rate of 2,710 fish per man-day.
- Steelhead are marked at a rate of 2,616 per man-day.

The effort associated with the numbers in Table 7.9-3 would be as follows:

- The bottleneck is tagging and marking 1,150,000 fall Chinook in 6 weeks.
- Using present techniques, it would take 25 people, with ten machines, in five sheds to mark and tag 1,150,000 pre-smolt Chinook in 6 weeks.
- 657 man-days to mark and tag the pre-smolt fall Chinook
- It would take an additional 4.2 weeks for ten people with four machines to mark and tag the remaining 525,000 fish.
- 140 man-days to mark and tag 250,000 yearling fall Chinook
- 103 man-days to mark 200,000 coho and 75,000 steelhead
- Yearling and year + fish would be done before and/or after the 6-week smolt window.
- Total effort would be 900 man-days during a period of 2.5 months.

Table 7.9-4 shows the comparable marking and tagging numbers at Trinity River fish hatchery, which has a marking rate of 25 percent.

Table 7.9-4. Marking and tagging at Trinity River fish hatchery**.**

Species	Number*	Stage at Release	Tagging Labor	Tag/Mark
Fall Chinook	500,000	Smolt	Tribe	Adipose clip, CWT
Spring Chinook	250,000	Smolt	Tribe	Adipose clip, CWT
Subtotal	**750,000**		Tribe	
Fall Chinook	225,000	Yearling	Tribe	Adipose clip, CWT
Spring Chinook	100,000	Yearling	Tribe	Adipose clip, CWT
Coho	500,000	Year +	CDFG	Maxillary clip
Steelhead	800,000	Year +	Tribe	Adipose clip
Subtotal	**1,625,000**			
Total	**2,375,000**			

* Numbers of fish currently marked and tagged at Trinity River fish hatchery.

CWT = Coded wire tag.

CDFG = California Department of Fish and Game.

Tagging and marking steelhead and Chinook by hand takes 8 to 9 months, with four people working for 4 months and eight people working for 4 months. Tagging and marking coho takes three to four additional people working for 4 months. This breaks down as follows:

- Tribe marks and tags 1,875,000 fish
  - 960 man-days during 8 months
  - 11,718 fish per working day
  - 1,953 fish per man-day
- CDFG marks 500,000 coho
  - 320 man-days during 4 months
  - 6,250 per working day
  - 1,562 per man-day
- Total effort is 1,280 man-days during a 9-month period

Tagging Facilities at Iron Gate Fish Hatchery

To expand marking and tagging of fall Chinook at Iron Gate fish hatchery to a 25 percent level, additional equipment would be required. As stated above, four additional tagging machines would be needed if the pre-smolt Chinook were to be tagged and marked in 6 weeks at a cost of $30,000 each. In addition, three more tagging sheds would need to be fabricated each year. The significance of 6 weeks is that Chinook fingerlings are not easy to handle before mid-April and they all have to be released at the end of May.

An automated tagging and marking system was evaluated to use at Iron Gate fish hatchery to achieve a 25 percent tagging rate. Northwest Marine Technology (NMT) has an automated tagging and marking system that could be used for mass tagging/marking at the Iron Gate fish hatchery. The following is a summary of NMT equipment performance to be compared with marking and tagging by hand as it is now done at Iron Gate fish hatchery:

- One mobile tagging trailer
- Five channels or tagging machines per trailer
- 48,000 fish processed per 8-hour shift
- 240,000 fish per week
- All Chinook smolts could be done in 4.8 weeks
- All CWT and adipose clipping (1,575,000 fish) done in 6.6 weeks
- Labor for this is 66 man-days
- The NMT system does not do maxillary clips, so this would require additional effort.
- The maxillary clipping, done by hand, adds 176 man-days.
- Total labor = 242 man-days
- Cost of tagging system is $795,000
- Annual cost of maintenance is $21,000

The cost of an automatic tagging system is high and not practical until the number of fish to be tagged approaches the number currently at Trinity River fish hatchery or at Iron Gate fish hatchery when tagging at a 25 percent rate. The NMT asserts that money is saved whenever numbers approaching 1 million fish need to be tagged. The exact break-even point would require a detailed analysis, including prevailing labor wages, benefits, per diem, etc.

Operations

Operational considerations are mostly labor related. The cost of electricity is relatively minor. Tagging and marking by hand is labor intensive. Table 7.9-5 compares labor costs in rough numbers using general assumptions.

Table 7.9-5. Potential operational costs.

Hatchery	Number of Fish	Man-Days	Labor at $80/Day	Annual Maintenance	One-Time Equipment Purchase
Trinity	2,375,000	1280	$102,400	NA	NA
Iron Gate	1,650,000	900	$72,000	$30,000[2]	$190,000
Iron Gate automated	1,650,000	242	$27,500[1]	$21,000	$795,000

1 A portion of this estimate includes a highly trained technician at $200/day.

2 Does not include labor expenses to fabricate five tagging sheds each season.

Some operational costs have been left out of the discussion because of their commonality between hand tagging and automated tagging or because of the minor cost. For instance, electricity is not a significant cost and may be the same for both operations. The cost to erect three additional sheds may be relatively minor. A large common cost is the coded wire tags. For 1.5 million fish, the cost of coded wire tags is $100,000. However, this cost is the same if the coded wire tags are installed into fish by hand or by an automated system.

Using the cost values in Table 7.9-5, the break-even point for an automated system is about 8 years, unless additional recovery were made by renting the trailer to other hatcheries. Unfortunately, the fish tagging crunch (sub-yearling Chinook), happens at every hatchery at about the same time. However, there is considerable latitude when to tag yearling Chinook. The trailer could be used at Iron Gate fish hatchery for smolt Chinook from April through May, at Iron Gate fish hatchery for yearling Chinook done June, at Trinity River fish hatchery in July, and at Mad River fish hatchery in August. There still would be 7 to 8 months for use anywhere adipose fin clips and/or coded wire tags are needed on yearling or year+ fish.

According to Mark Hampton (CDFG), who leads the marking and tagging program at Iron Gate fish hatchery, the comparison between an automated system and hand tagging operations at the hatchery is more a matter of labor than the cost of the system. Hampton stated that he does not believe that it is possible to recruit and consistently employ a workforce of 25 within the geographic range of Iron Gate fish hatchery: it a challenge now to recruit and maintain a crew of ten (Hampton, pers. comm., 2003).

Biological Considerations

There is a mortality rate associated with tagging. Hand tagging and marking rarely are monitored, but mortality is thought to be on the order of 0.5 to 1.0 percent, depending on the experience and care of the crew members. The NMT automated system advertises 0.5 percent direct mortality. More fish tagged means additional mortality. This easily can be compensated in production as long as the egg take is met. However, there is some evidence that tagged fish show a reduced return rate (latent mortality), although this is not well studied.

Increased tagging brings positive benefits to the harvest and fisheries management biologists. Having a higher and constant fractional marking rate allows fisheries managers to calculate management metrics with greater precision thus potentially allowing better and more timely management decisions. Relative and absolute hatchery contribution and straying rates are the most important management metrics that would benefit from increased or CFM rates in the Klamath-Trinity River basin.

7.9.4.3 Heating Incubation Water

The 2001 Joint Hatchery Review Committee Report stated that heated incubation water could be beneficial for late egg lots of fall Chinook salmon at Iron Gate fish hatchery and recommended its use be considered. The rationale was to get the late lots of Chinook up to 90/lb and out of the hatchery before the first week in June when water flow in the river typically drops and temperatures rise. The assumption was that survival would increase for these fish. Also assumed was that wild/hatchery fish competition would be reduced in the lower river during the stressful conditions of early summer because the larger-sized hatchery smolts may spend less time in the lower river before moving into the estuary and ocean.

The Fish Pro (1992) report recommended applying heated water for the incubation of all Chinook, coho, and steelhead. This would increase the size of all production lots. Presumably, the early Chinook lots might reach the 90/lb size and smolt by late April or early May. If this were possible, and a volitional release system were in place, some of the production lots might leave the hatchery in early May. Again, presumably this would relieve some of the wild/hatchery fish competition thought to be a problem in the lower river.

Generally, steelhead at Iron Gate fish hatchery are smaller than desired at release. Ideally, steelhead should reach a size of 8/lb at release. At present they are only 10 to14/lb at release. Getting a jump on growth in their first summer would help considerably. The fact that production is usually below production goals reinforces the validity of doing this.

Coho smolt quality is considered good at Iron Gate fish hatchery and no changes to incubation or rearing are warranted for this species.

One of the constraining factors in the incubation system at Iron Gate fish hatchery is that there is no head box. In most hatcheries, incubation water enters an open channel situated above the incubators allowing gravity flow to each incubation unit. This makes flow adjustment to each stack independent from the others. At Iron Gate fish hatchery, water is delivered to the incubation area in a pressurized manifold. Manifold pipes split off to each Heath® stack row and, ultimately, to a valve over each incubator stack. This arrangement precludes using a system where heated water is added directly (and mixed) into discreet incubator stacks. Direct water mixing would work only for the entire system as a whole as was envisioned in the Fish Pro (1992) report.

Approach

Several alternative strategies of how to apply heated incubation water to improve hatchery goals at IGH were explored. The alternatives are based in part on the concerns discussed in the biological concerns section and objectives stated above. The alternatives are as follows:

- Heat only the steelhead incubation water
- Heat only the steelhead and last Chinook lots (last quarter)
- Heat all of the incubation water

Steelhead. Steelhead are incubated in six dedicated double heath stacks. Each stack receives about 5 gpm of water. With only a need for 30 gpm, a small heat exchanger could be used coupled with a small industrial-sized hot water heater or maybe a pair of large household units. There would be a need to reconfigure some of the plumbing to isolate the steelhead stacks from the rest of the manifold.

Steelhead Plus Late Lots of Chinook. If water were heated for the last 25 percent of the Chinook egg lots and all of the steelhead, 39 stacks would be heated. These stacks would have to be isolated from the rest of the manifold and heated with a heat exchanger system. If a 50°F minimum were used in incubation, a 9°F rise would be required during the coldest months (January and February). This could advance Chinook development to the swim-up stage by 6 weeks (Tables 7.9-6A and 7.9-6B). It also would advance these fish to the point where they were ponded 2 weeks before the lots from the peak of the run. One problem associated with advancing incubation development with heated water is that the fish would be acclimated to a higher temperature than that in the raceways. A way to address this concern is to control the temperature in the early rearing troughs. Groups of fish then could be acclimated to a 8° to10°F drop in temperature during a 1-week period.

Table 7.9-6A. Chinook incubation—existing conditions.

		First Lot			Peak			Last Lot		
Date	**Average Temp. (°F)**	**Event**	**Number of Days**	**Degree Days**	**Event**	**Number of Days**	**Degree Days**	**Event**	**Number of Days**	**Degree Days**
Oct-07	57	Spawn	-	-						
Oct-28	57		21	525	Spawn	-	-			
Oct-31	57		3	75		3	75			
Nov-01	53		1	21		1	21			
Nov-12	53		11	231		11	231	Spawn	-	-
Nov-30	53		18	378		18	378		18	378
Dec-01	45		1	13		1	13		1	13
Dec-31	45		30	390		30	390		30	390
Jan-01	41		1	9		1	9		1	9
Jan-12	41		11	99		11	99		11	99
Jan-14	41	Swim-up	2	18		2	18		2	18
Jan-31	41					17	153		17	153
Feb-01	41					1	9		1	9

Table 7.9-6A. Chinook incubation—existing conditions.

Date	Average Temp. (°F)	First Lot			Peak			Last Lot		
		Event	Number of Days	Degree Days	Event	Number of Days	Degree Days	Event	Number of Days	Degree Days
Feb-28	41				Swim-up	27	243		27	243
Mar-01	45							Swim-up	1	13
Mar-23	45								22	286
Total Degree Days:				**1,759**			**1,639**			**1,611**
Average Total Degree Days:				**1,670**						

Table 7.9-6B. Chinook incubation—heated conditions.

Date	Average Temp. (°F)	First Lot			Peak			Last Lot			Heat System		
		Event	Number of Days	Degree Days	Event	Number of Days	Degree Days	Event	Number of Days	Degree Days	Temp Increase (°F)	Req. Flow (cfs)	Number of Weeks
Oct-07	57	Spawn	-	-							0	-	
Oct-28	57		21	525	Spawn	-	-				0	-	
Oct-31	57		3	75		3	75				0	-	
Nov-01	53		1	21		1	21				0	-	
Nov-12	53		11	231		11	231	Spawn	-	-	0	-	
Nov-30	53		18	378		18	378		18	378	5	3.00	4
Dec-01	50		1	18		1	18		1	18	5	3.00	4
Dec-29	50	Swim-up	28	504		28	504		28	504	9	2.00	4
Dec-31	50					2	36		2	36	9	2.00	4
Jan-01	50					1	18		1	18	9	2.00	4
Jan-21	50				Swim-up	20	360		20	360	9	2.00	4
Jan-31	50								10	180	9	0.25	1
Feb-01	50								1	18	9	0.25	1
Feb-07	50							Swim-up	6	108	9	0.25	1
Total Degree Days:				**1,752**			**1,641**			**1,620**			
Average Total Degree Days:				**1,671**									

All Production Lots. The advantage of heating the entire incubation system is that none of the incubators would need to be isolated from others and the manifold plumbing would not need to be modified. Of course, the size and cost of the system would increase accordingly. The Fish Pro (1992) report worked out an incubation schedule for a heat-augmented system for the entire Chinook production (Tables 7.9-6A and 7.9-6B). Heat was applied such that the lowest temperature experienced by the developing eggs was 50°F. The lowest average monthly water temperature at Iron Gate fish hatchery is 41°F, although daily water temperature actually goes as low as 38°F. The first lots would reach the swim-up stage by December 29 compared with January 14. Lots taken at the peak of the run would reach the swim-up stage 5 weeks early on

January 21, instead of February 28. The late production lots would be advanced the most, reaching swim-up a full 6 weeks earlier than normal.

Facilities Required

Steelhead Only. To heat water for steelhead incubation would take a small system, but it would need to be isolated from the rest of the incubation system. About 30 gpm of water would need to be heated 5° to 10°F. A pair of large household electric water heaters should suffice. Hot water from the water heaters could be pumped through a thermostatically controlled heat exchanger in an in-line mixing chamber.

Steelhead Plus Chinook Late Lots. This system would need to isolate about 25 percent of the incubation system. The installation may take some major plumbing revisions to the water delivery system. The heating system would have to handle 195 gpm (0.43 cfs) and raise the temperature between 5° and 10°F. Using the specifications given in the Fish Pro (1992) report, this would require a 250-kW electric boiler and associated heat pumps. Modifications would be needed to provide substantially more electricity service to the hatchery building. Total facility/equipment cost might be about $37,000.

All Production Lots. Heating all production lots would alleviate the need for modifying the manifold and other elements of the plumbing. Of course, the heating system would be much more extensive and expensive. Water flow into the hatchery building is about 1.0 cfs. To heat this much water between 5° and 9°F, a 510-kW electric boiler and associated heat pump would be needed. The boiler and heat pump could be positioned where the feeder pipeline entered the building and be placed upstream of the rest of the plumbing. Facility/equipment cost would be roughly $56,000.

Operations Cost

Steelhead Only. The operational costs of heating water for six incubator stacks from mid-February until the end of May would be minor: 30 gpm with a 5°F average temperature rise would be about $4,000 in electricity cost at $0.07/kWh. Presumably, the system would be thermostatically controlled, but monitoring and some adjustment would be required, potentially daily.

Steelhead and Late Production Lots. With a flow of 195 gpm, the costs to heat incubation water would increase accordingly. An average temperature rise of 7°F during a 9-week period would be about $18,600 in electricity costs at $0.07/kWh. Temperature monitoring and adjustment would be required daily.

All Production Lots. To heat 1.0 cfs of incubation water from 5° to 9°F during a 9-week period would be a substantial O&M cost. At $0.07/kWh, the cost would be about $43,000. Temperature monitoring and adjustment would be required daily.

Biological Considerations

Whenever an automated mechanical system is used in conjunction with fish, there is a risk of a major kill event. If the water heating system fails, the temperature might drop to ambient temperature in a matter of minutes. Such a thermal shock could kill significant numbers of embryos. Redundant controls can be installed, but a power failure cannot be made redundant easily without a backup generator. The heating system (at least in the Chinook alternatives) draws a considerable amount of electricity.

Steelhead. It would seem that accelerating steelhead incubation would have only positive outcomes. Currently, the fish are produced at a sub-optimal size at release. The small size at release may be part of the reason why so many Iron Gate fish hatchery steelhead are residualizing in the river. The smaller steelhead may remain in the river to gain size before entering the ocean. During that time, the temperature of the river rises considerably. Temperatures exceeding 54°F are known to induce residualism. Also, smolting is controlled to a large degree by photoperiod, which equates to a timing window. Fish that delay and miss the timing window will residualize.

Late Chinook Lots. As stated previously, there may be negative ramifications to accelerating the incubation and growth of the later Chinook egg lots. In nature, the temporal range of spawning ultimately is controlled by survival. This is a function of genetic attributes interacting with environmental conditions. Then late spawning fish form a fringe of the population that favors certain corresponding environmental conditions. Maintaining this trait is important in maintaining high genetic heterogeneity. However, by artificially accelerating growth, survival also will be enhanced. Selectively increasing the survival of this subgroup would artificially shift fitness in the direction of the later spawning fish.

Early Chinook Lots. According to calculations made by Fish Pro (Fish Pro, 1992), the earliest lots of Chinook could be ponded as early as December 29. Assuming that their rearing date to 90/lb might be moved up as early as late April, one would question whether they would smolt properly given that photoperiod and stream temperature also play significant roles in smolting and migration rate. If these advanced-sized fish moved out in late April/early May, the interaction with wild fish in the lower river might be reduced. However, if these larger smolts do not migrate downstream quickly, they likely would out-compete the smaller wild Chinook juveniles for food and space.

7.9.4.4 Spring Chinook Salmon Production

At the September 6, 2002, Hatchery Subgroup meeting it was suggested that PacifiCorp investigate the feasibility of spawning and rearing spring Chinook salmon at Iron Gate fish hatchery.

Spring Chinook once were present in the Upper Klamath River and were thought to use tributaries of Upper Klamath Lake. These runs were believed to be extirpated before 1900 (Fortune et al. 1966). Although the life history character of these fish was not studied before extirpation, most likely they were stream-type considering the elevation and location of Upper Klamath Lake and its tributaries.

A small run of spring Chinook apparently was still in existence at the time Iron Gate dam was built in 1961. From 1962 through 1974, the number of spring Chinook returning to the trap ranged from four to 80 adults. It is possible that the few fish observed at the dam were strays from other spring Chinook stocks found in downstream tributaries. However, it is also possible that some habitat suitable for spring Chinook was available in the area now inundated by Iron Gate dam. Given their requirement for cool summer water temperatures, a small run of spring

Chinook may have been able to persist in the spring-fed tributaries, such as Fall Creek or Jenny Creek, however, even these tributaries may have been near the upper thermal boundary for these fish. The life history of these fish is unknown, but was probably ocean-type based on the location of the habitat in the watershed. Attempts to rear the progeny of these fish were not successful because no adult returns were observed from smolt releases made at the hatchery.

Approach

To evaluate the feasibility of reestablishing a run of spring Chinook salmon at Iron Gate fish hatchery, life history requirements were examined first, then water availability and quality, and finally facility requirements. A reality check then was made with regard to production potential. Biological considerations, both pro and con, of producing spring Chinook were identified. The two water supplies considered were Iron Gate fish hatchery and Fall Creek fish hatchery.

Spring Chinook salmon enter the Klamath/Trinity River system from the ocean starting in May and ending in June. They must hold in cool water for 4 to 5 months before spawning, which occurs primarily in September. Ocean-type spring Chinook, unlike interior spring Chinook stocks, migrate to sea mostly as sub-yearling smolts in spring rather than year + fish.

Temperature data from 1994, 1999, and 2000 were reviewed to evaluate suitability for adult holding. Daily maximum temperature in the 50 to 52°F range is considered the upper limit for holding pre-spawn spring Chinook adults (Gatton, pers. comm., 2003). During the holding period (mid-May to mid-September), daily maximum temperatures at Iron Gate fish hatchery are generally 50 to 54°F, although there is typically a week or two in the 53 to 57°F range (Figures 7.9-8 and 7.9-9). Therefore, water temperatures at Iron Gate fish hatchery would be only marginally suited for holding adult spring Chinook salmon. At Fall Creek fish hatchery, daily maximum temperatures can be in the 54 to 59°F range from mid-June through mid-September (Figure 7.9-10), which is too warm for adult spring Chinook holding. Water temperatures at both locations would be conducive to rearing spring Chinook juveniles because their requirements are the same as fall Chinook.

At Iron Gate fish hatchery, the water delivery to the hatchery under maximum demand conditions is at or near the limit of what the present facility can reliably provide. The water intake system at Iron Gate dam draws from a depth of 70 feet. At this depth, water is drawn from below the thermocline. However, late in the season, under severe conditions of low river flow and high temperatures, the water intake may draw warmer water from above the thermocline, potentially stressing rearing juvenile production lots as well as adult holding and spawning of fall Chinook. Any increase in water withdrawal rate would exacerbate the situation and increase the risk of disease outbreaks in the hatchery as a result of high temperature stress in some years.

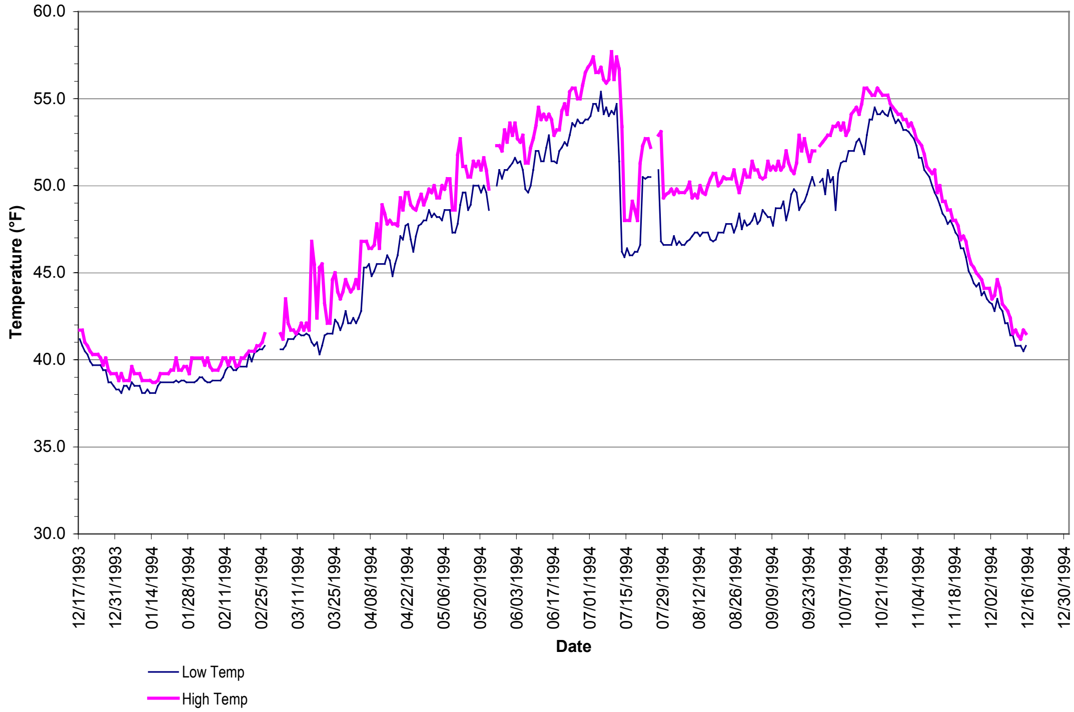

Figure 7.9-8. Temperature (ºF) 1993–1994, Iron Gate hatchery.

(Rushton, K. Water temperature data for Iron Gate Hatchery. Raw data from hatchery files. 2002)

Figure 7.9-9. Temperature (ºF) 1998–2000, Iron Gate hatchery.

(Rushton, 2002)

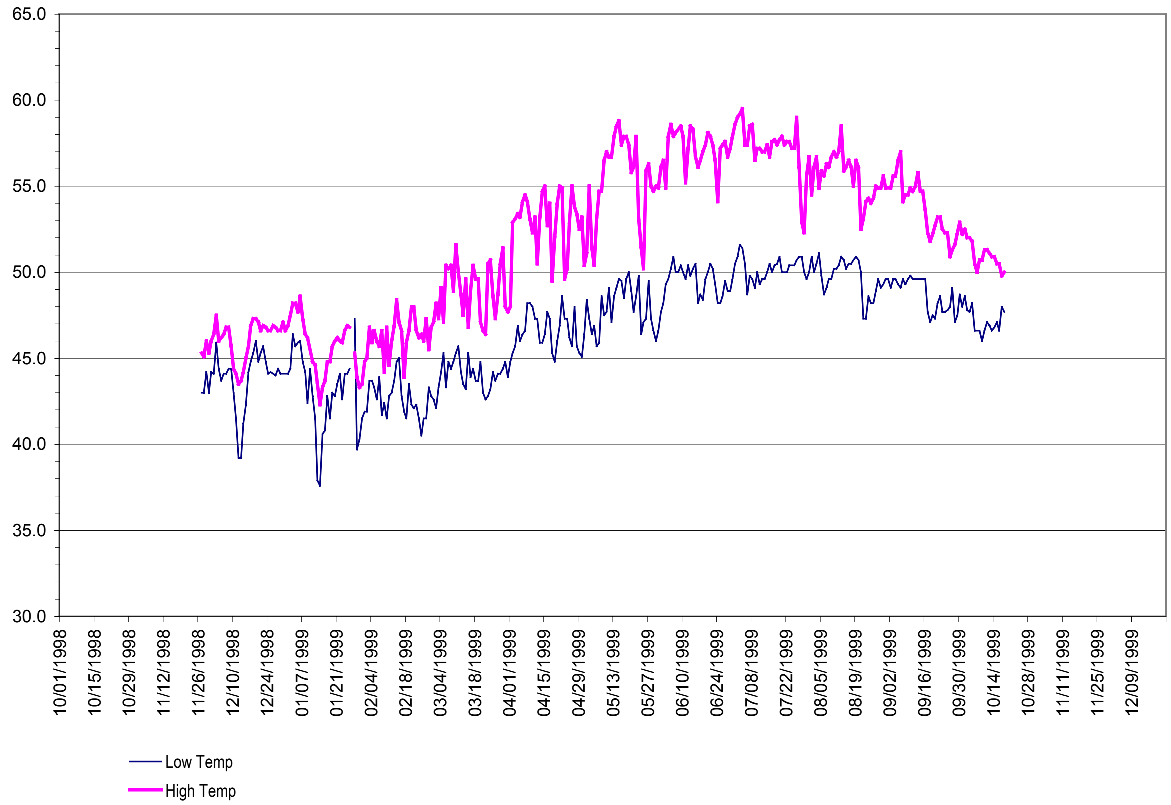

Figure 7.9-10. Temperature (ºF), Fall Creek rearing ponds.
(Rushton, 2002)

At Fall Creek, water availability was determined by examining USGS gauge records, subtracting maximum water withdrawals by the City of Yreka, and assuming a minimum instream flow requirement. Flows in Fall Creek tend to be constant, especially in the summer, because of its spring water source.

Water availability was estimated as follows:

USGS Gauge No. 11512000
Location: 3,000 feet downstream of Fall Creek powerhouse

- Minimum monthly average flow: 25 cfs
- City of Yreka municipal water withdrawal (upstream of gauge): +15 cfs
- Minimum historical average monthly flow rate: 40 cfs

A minimum instream flow requirement in bypass reaches was assumed to be 30 percent of the mean annual flow based on the Tenent Method.

- Minimum discharge at gauge: 25 cfs
- Assume 30 percent instream flow: -12 cfs
- Available water for diversion to hatchery: 13 cfs

Currently, the CDFG diverts and uses 6 to 8 cfs for rearing yearling fall Chinook salmon at the Fall Creek fish hatchery. It is assumed in the calculations above, that the water is reused (i.e., the 6 to 8 cfs is included in the 13 cfs).

Based on the constraints of water temperature and water quantity, spring Chinook production would require the holding of adult Chinook at Iron Gate fish hatchery, incubating the eggs at either Iron Gate fish hatchery or Fall Creek fish hatchery, and rearing the fish at Fall Creek fish hatchery in a new facility.

Facilities Required

To determine the facility needs, both adequate space and water need to be considered. Space for a new facility at Fall Creek is available downstream of the existing hatchery. Stream gradient appears to be sufficient for a short water intake system and a short bypass reach.

Space is problematic at Iron Gate fish hatchery, but not a fatal flaw. Adult holding at the hatchery for spring Chinook would need new ponds. The existing ponds are too small to be practical. There is not enough space in the existing holding/spawning area for new larger holding ponds. Because spring Chinook need to hold for several months, it is vital that they be given a generous amount of space. Otherwise, they may injure themselves by abrasion or trauma from contact with pond walls, or by biting each other (mostly males) when in close proximity. Because of the long holding time, handling also needs to be minimal. The most practical solution would be to build new holding ponds near the settling ponds on the south side of Bogus Creek. The auxiliary trap could be modified to shunt fish in a flume over Bogus Creek into the new holding ponds.

Hypothetical Hatchery Production. The following hypothetical hatchery production description assumes that spring Chinook adult holding occurs at Iron Gate fish hatchery and juvenile rearing is conducted at Fall Creek fish hatchery. It is assumed in this calculation that all of the available water at Fall Creek is used at maximum capacity and that the 6 to 8 cfs currently used for fall Chinook rearing during the summer and fall will be reused at the new downstream facility.

Adult holding ponds at Iron Gate fish hatchery:

- Assume 5.8 cfs is the volume of water required for adult holding (for 2,000 adult spring Chinook). This is based on 1 gpm per 15-lb adult with a 30 percent addition for a 6 degree elevation from 50 degrees (Senn, 1984).
- Need at least 8 ft^2 per adult (Senn, 1990).
- Size: 15 feet x 100 feet x 5.5 feet = 8,250 ft^2 = 1,031 adults
- Flow: 2.9 cfs per pond = 1,000 adults per pond
- Maximum capacity: two ponds with 2.9 cfs each for 1,000 adults, 1.45 cfs for each of four ponds with 500 adults = 2,000 adults (more than needed)

Juvenile rearing capacity:

- Assuming adequate rearing space and uses all of the available water (13 cfs) at Fall Creek. Production performance is based on rearing performance of fall Chinook at Iron Gate fish hatchery.

- Assuming smolt production is at a rate of 3,600 lb/cfs, 13 cfs can produce 46,800 lb.

- At 90/lb, this equals 4.2 million fish

- Using the same grow-out pond configuration as Iron Gate fish hatchery, this would require five series of four ponds, each measuring 10 x 100 feet and with each series receiving 2.5 cfs.

Reality check:

The 5.8-cfs limit on adult holding water at Iron Gate fish hatchery is more limiting than the 13 cfs capacity at Fall Creek fish hatchery. This was checked by adhering to the following life cycle computation:

- 2,000 adults at a 50:50 sex ratio = 1,000 females
- 1,000 females with an average fecundity of 3,000 eggs = 3.0 million eggs
- 3.0 million eggs with a 75 percent survival to swim-up stage = 2.25 million fry
- 2.25 million fry with 96 percent survival to smolt = 2.16 million smolts
- 2.16 million smolts with a 1.0 percent ocean survival to the river mouth = 21,600 adults
- 20,000 adults harvested at a 75 percent rate = 5,000 adult escapement to the hatchery
- 5,000 adults with a pre-spawn mortality rate of 50 percent = 2,500 spawners

Clearly, the production from 2,000 spawners would be a substantial program. It would require 5.0 cfs at Fall Creek in two series of three ponds (six ponds total), each 10 x 100 feet. Additional incubation facilities would need to be about one sixth of that currently in place at Iron Gate fish hatchery. There is not enough water or space in the current hatchery building.

It may be advantageous to build a small incubation facility at Fall Creek fish hatchery instead of expanding the hatchery building at Iron Gate fish hatchery. The average temperature at Fall Creek fish hatchery is warmer in the fall and winter months than the average temperature at Iron Gate fish hatchery. Fish would hatch out earlier and rear longer before release. None of the production lots would need to be “pushed” to reach 90/lb.

<u>Operational Needs.</u> Additional facilities and production would require a proportionate amount of operational expenditure. Additional facilities would need electricity for light, heat, pumps etc., To produce fish in the maximum capacity as outlined above (2.16 million smolts), at least two additional full-time staff members would be needed. The cost of food for this production level would be about $13,000 per year.

<u>Biological Considerations</u>

<u>Stock Genetics.</u> Spring Chinook salmon, which historically were thought to have spawned in the tributaries to Upper Klamath Lake, were extirpated before about 1900 (Fortune et al. 1966). This “inland” stock most likely had a stream-type life history, as do all other spring Chinook stocks

east of the Cascade Mountains (NMFS, 1998) . Inland stocks also exhibit a much different ocean distribution, tending to migrate far from the coast out into the central north Pacific whereas the coastal ocean-type stocks tend to remain close to the coastline. Thus, if the intention of developing a spring Chinook salmon run at Iron Gate fish hatchery ultimately is to establish a stock that could again use the upper watershed (assuming fish passage is provided around Iron Gate and Copco dams), a suitable donor stock from the Klamath system would not be available. The introduction of another inland stock from the Columbia River basin would be possible, but not likely acceptable from a management standpoint, and its probability of success would be low given the transplant distance.

If the intent of producing spring Chinook salmon at Iron Gate fish hatchery simply is to develop a hatchery run for harvest, the use of a coastal stock from one of the tributaries to the Lower Klamath River (Trinity or Salmon rivers or Clear Creek) may be appropriate.

Straying. Straying will be an issue using either a Lower Klamath River stock or an out-of-basin stock. If Trinity River fish are used, straying is likely to stay in the Trinity/Klamath basin and most likely in the Trinity River basin. Out-of-basin (inland) stocks probably would stray at a greater rate and may stray to rivers outside of the Trinity/Klamath basin. Elevated straying rates likely would persist for at least one Chinook life cycle length (4 years in salt water). Seed stock would need to be donated for at least 4 years. Additional years of transfer may be needed if initial returns are poor. Straying rates would be expected to decline over time.

Disease Transmission. If the Trinity River fish hatchery spring Chinook is the donor stock, disease transmission will be a significant issue. The Trinity River stock is infected with IHN, although there have not been any serious problems in the last 10 years. Iron Gate fish hatchery and wild stocks in the Klamath River above the Trinity River have been found to be clean of IHN. Bill Cox, a CDFG pathologist, is concerned about infecting Iron Gate fish hatchery with IHN from transferred fish or eggs (Cox, pers. comm., 2003). To reduce the chance of this from occurring, eggs at Trinity River fish hatchery would need to be quarantined and tested for IHN before shipment to Iron Gate or Fall Creek fish hatcheries. Eggs from individual females would need to be isolated, initially, in this way, which would require a new, small incubation facility at Trinity River fish hatchery. IHN is transmitted to eggs by the female's ovarian fluid. It usually stays on the surface of the eggs and can be killed with a disinfectant. There is a small risk that IHN can get into an egg and resist the disinfectant. For this reason, all infected lots would have to be destroyed or returned to the Trinity River production lots. If IHN screening is ineffective at identifying all of the infected egg lots, infection of Iron Gate fish hatchery is possible. The risk may be less if the eggs were incubated at Fall Creek fish hatchery because this would put an inhospitable reservoir between the eggs and Iron Gate fish hatchery. There is evidence, however, of upriver fish with IHN infecting a down-river hatchery stock (Feather River fish hatchery). An ultraviolet (UV) sterilization system of incubation effluent water would further reduce the risk.

The risk of introducing IHN, and perhaps other diseases, to the Iron Gate area would be even more of a concern if anadromous fish passage ultimately is provided at Iron Gate and the Copco dams. No viral diseases are known to infect fish in the upper basin, and the native fish populations there, including redband trout, have no natural resistance to these organisms. The likelihood of introducing IHN to the upper basin was one the major reasons given by the Klamath River Basin Fisheries Task Force (1992) for not supporting the reintroduction of anadromous fish above Iron Gate dam. Similarly, the ODFW (1997) listed the risk of disease introduction as one of the major concerns of any attempt to reintroduce anadromous salmonids to the Upper Klamath basin in Oregon.

Fall Chinook Hatchery Production. Peak water use for adult spring Chinook at Iron Gate fish hatchery would overlap with high water needs for yearling fall Chinook. To alleviate competing water demands, some of the yearling fall Chinook production would need to be moved to the new Fall Creek fish hatchery to make room for adult spring Chinook in the Iron Gate fish hatchery water budget.

Hatchery/Wild Fish Interaction. Tribal, state, and federal biologists that participated in the Hatchery Subgroup are concerned about the interaction between hatchery fish and wild fish. The focus for concern is competition for thermal refugia space in June in the lower river. Adding hundreds of thousands or millions of new hatchery spring Chinook may exacerbate the situation. This may be minimized if the spring Chinook rearing were accelerated at Fall Creek fish hatchery to allow earlier release, but this may lead to new and different problems. Spring Chinook spawn a month or so earlier than fall Chinook. If they were incubated in the relatively warm water at Fall Creek fish hatchery, they could be ponded in December. Iron Gate fish hatchery Chinook, by comparison start to be ponded in mid-January. This jump on growth may allow for these fish to be released in the beginning or middle of May, ahead of all other hatchery production in the system. This may allow them to pass through the lower river before thermal refugia competition is an issue. Unfortunately, it is unknown how they will behave in terms of migration. Thermally manipulated production of this type runs a risk of poor smoltification and may result in fish holding in the river for physiological reasons thus negating the potential benefits of early release.

Survival. Adult Holding: Temperatures at Iron Gate fish hatchery are marginal for holding spring Chinook salmon for 3 to 4 months. Previous experience by Iron Gate personnel indicated potential problems holding adult spring Chinook at the facility (Marshall, pers. comm., 2003). The problems probably were the result of high water temperatures, but the small size of the adult holding pond also may have contributed. While larger ponds and new technology are available, adequate adult spring Chinook holding performance cannot be guaranteed at Iron Gate fish hatchery.

Post-Release: The calculations of fish numbers above (to define facility and water needs) were based on the assumption that spring Chinook would have a similar smolt-to-adult survival as fall Chinook currently do at the hatchery. However, limited efforts in the late 1960s and early 1970s failed to produce spring Chinook returns to the hatchery. From 1970 to 1974, between 9,300 and 48,900 spring Chinook smolts were released. No adult returns were seen at Iron Gate fish hatchery after 1974. The reason for the poor smolt survival is not known. Nevertheless, the failure of these earlier efforts raises uncertainty as to how well a downriver stock would perform at Iron Gate fish hatchery. Any serious consideration to start a spring Chinook program at Iron Gate fish hatchery would need to be preceded by a limited test production to evaluate whether smolt-to-adult survival rates would be high enough to sustain the program.

7.9.4.5 Expanded Yearling Fall Chinook Production

The Joint CDFG and NMFS Hatchery Review Committee Report (2001) recommended that the desirability of expanding the yearling fall Chinook component of Iron Gate fish hatchery production be investigated. Expanding yearling production presumably could be done in a variety of scenarios, with variable corresponding reductions in Chinook smolt (subyearling) production. The rationale for considering greater yearling production (and less subyearling smolt production) was to take some of the competition pressure from hatchery smolts off of wild fish in the lower river during June. This is a period of high temperature stress in the lower river. A shift to more yearling production means shifting more releases to November when there are fewer wild fish in the lower river and the temperatures are lower.

Currently, the yearling program is conducted at two locations. Approximately 900,000 yearlings are produced at Iron Gate fish hatchery. An additional 180,000 yearlings are reared at Fall Creek fish hatchery. Iron Gate is operated at capacity in terms of rearing space and available cool water. The Fall Creek facility is old and in need of repair or complete rebuild. Fall Creek is the City of Yreka's municipal water supply, which limits the availability of water for expanded fish production. The city's diversion of up to 15 cfs is located upstream of the existing rearing facility discharge.

Approach

There are several alternatives to increase production of yearling fall Chinook at Iron Gate fish hatchery. Each alternative uses different assumptions regarding water use, smolt/yearling ratios, and level of commitment (status quo or increase). Four alternatives are considered here, one of which is the existing operation. Showing the existing production operations is useful for comparative use. The four alternatives are as follows:

- Alternative 1: Leave production as it is. Smolt and yearling releases remain the same.
- Alternative 2: Shift production with 2 million smolts and 300,000 more yearlings being produced. It is assumed that the number of pounds of fish produced remains the same as it is now. This alternative requires a small new facility at Fall Creek fish hatchery (hereafter referred to as Fall Creek 2).
- Alternative 3: Shift all production at Iron Gate fish hatchery to yearling production. This alternative requires a new moderate-sized hatchery at Fall Creek.
- Alternative 4: Shift production numbers similar to Alternative 2, but integrate with a spring Chinook production program. This would require a new hatchery at Fall Creek of a size similar to Alternative 2.

Detailed Description of Alternatives

Alternative 1. The current production program at Iron Gate fish hatchery uses 25 cfs for incubation and rearing. Up to 50 cfs are used at times, most of which go to the fish ladders. The 25 cfs in the rearing facility are used fully at two periods: at the time of smolt releases (and smolt transfer), and at the time of yearling releases. Each series of four raceways receives 3.125 cfs. One raceway series is dedicated for coho and one is dedicated for steelhead. The remaining six raceways are dedicated for Chinook rearing, using 18.75 cfs.

Chinook are reared in Iron Gate fish hatchery raceways until May 31. At this time, the Chinook dedicated raceways are at capacity. On May 31, 4.6 million smolts are released, 200,000 smolts are moved to Fall Creek fish hatchery, and about 1 million are retained at Iron Gate for yearling production (Table 7.9-8). The 200,000 smolts moved to Fall Creek are reared to the yearling stage and released on November 15 at 8/lb, with the expectation of 180,000 survivors at release. The retained 1 million smolts at Iron Gate are reared to the yearling stage with an expected release of 900,000 fish at 8/lb on November 15. Again, the rearing capacity at this point is used to the maximum possible. The total production for the season is 165,722 lb, with no more than 112,500 lb at any one time.

Table 7.9-8. Present fish production methods at Iron Gate fish hatchery.

Number	Stage	Fish size (number/lb)	Pounds Produced	Release or Transfer	Date
4.6 million	Smolt	90	51,000	Release	May 31
200,000	Smolt	90	2,222	Transfer (Fall Creek 1)	May 31
900,000	Yearlings	8	112,500	Release	Nov. 15
5.7 million total			165,722		

Chinook production by weight increases through the season to 64,444 lb on May 30, drops to 11,111 lb on June 1 after releases and transfers, then increases to 112,500 lb by November 15 when the yearling releases are made.

<u>Alternative 2.</u> In this alternative, the proportion of smolts and yearling production is altered while keeping the weight of fish produced the same, at approximately 170,000 lb. Smolt production is reduced to 2 million and yearling production is increased to 1.2 million. The number of fish transferred to Fall Creek fish hatchery remains the same (Table 7.9-9). Total numbers of fish are reduced, but total weight is increased slightly (only to keep round production numbers). This would require an additional facility at Fall Creek (Fall Creek 2) of sufficient size to accommodate 300,000 fish using approximately 6.2 cfs.

Table 7.9-9. Fall Chinook production metrics for Alternative 2.

Number	Stage	Fish size (number/lb)	Pounds Produced	Release or Transfer	Date
2.0 million	Smolt	90	22,222	Release	May 31
200,000	Smolt	90	2,222	Transfer (Fall Creek 1)	May 31
900,000 (Iron Gate)	Yearlings	8	112,500	Release	Nov. 15
300,000 (Fall Creek 2)	Yearlings	8	37,500	Release	Nov. 15
3.4 million total			174,444		

<u>Alternative 3.</u> Production under Alternative 3 would shift all Chinook production at Iron Gate fish hatchery to yearling releases. This is an extreme deviation from the current program to illustrate the trend of outcomes when shifting away from smolt production in favor of yearling production. A new rearing facility of moderate size would be required at Fall Creek using 8.4 cfs. Table 7.9-10 shows the resulting production numbers while maintaining the current production weight.

Table 7.9-10. Fall Chinook production metrics for Alternative 3.

Number	Stage	Fish size (number/lb)	Pounds Produced	Release or Transfer	Date
0	Smolt	90	0	NA	NA
200,000 (Fall Creek 1)	Smolt	90	2,222	Transfer (Fall Creek 1)	May 31
900,000 (Iron Gate)	Yearlings	8	112,500	Release	Nov. 15
408,000 (Fall Creek 2)	Yearlings	8	51,000	Release	Nov. 15
1.5 million total			165,722		

Alternative 4. In this alternative, the production scenario of Alternative 2 is modified to accommodate a spring Chinook program (see Section 7.9.4.4)**.** In that analysis, it was determined that adult pre-spawn holding at Iron Gate fish hatchery was more limiting than juvenile rearing at a Fall Creek fish hatchery (Fall Creek 2). For the sake of discussion, the figures in the reality check computation in the spring Chinook section (7.9.4.4) , 2,000 spawners, will be used. The progeny produced from 2,000 spawners conservatively could be 2 million subyearling smolts at 90/lb. There is enough water at Fall Creek to rear this many subyearlings. However, the holding requirements for 2,000 adults at Iron Gate fish hatchery, would be about 10 cfs. Because adult spring Chinook holding (May through September) overlaps the water demand for yearling fall Chinook (May 15 through November 15), yearling production would need to be reduced correspondingly (Table 7.9-11).

Table 7.9-11. Fall and Spring Chinook production metrics for Alternative 4.

Number	Stage	Fish size (number/lb)	Pounds Produced	Release or Transfer	Date
2.0 million	Fall Chinook smolt	90	22,222	Release	May 31
200,000	Fall Chinook smolt	90	2,222	Transfer (Fall Creek 1)	May 31
640,000 (Iron Gate)	Fall Chinook yearling	8	80,000	Release	Nov. 15
260,000 (Fall Creek 2)	Fall Chinook yearling	8	32,500	Release	Nov. 15
2.0 million	Spring Chinook smolt	90	22,222	Release	May 15
5.12 million total	Composite	8/90	159,166	All releases at Iron Gate	May 15, 31, and Nov.15

To compute the amount of lost yearling production, the following assumptions were made:

- Yearling growth was assumed to be linear.
- All spring Chinook were spawned on September 15.
- 6,048 lb of Chinook yearlings can be produced for each cfs of water when supplied at 3.1 cfs per pond series, as they are at Iron Gate fish hatchery.

If 10 cfs is used for adult holding, only 640,000 yearlings can be produced at Iron Gate fish hatchery without transferring additional fish to Fall Creek fish hatchery. To compensate, enough fish could be transferred to a new facility (Fall Creek 2) to make up the difference (i.e., 260,000+). The results of this scenario are the following:

- Total production weight is reduced by 6,500 lb.
- Smolt production is reduced from 4.6 to 4 million.
- A spring Chinook run of 15,000 fish is produced.

Production sequence for Alternative 4 is as follows:

- Sequence starts with 3 million spring Chinook eggs at Fall Creek 2 fish hatchery and a yet-to-be-determined number of fall Chinook eggs at Iron Gate fish hatchery (less than current numbers).
- Spring Chinook all are reared at Fall Creek 2 fish hatchery to be released as 90/lb smolts.
- Between May 15 and May 31, 2 million spring Chinook are transferred to Iron Gate fish hatchery where they are released into the river.
- Between May 15 and May 31, about 280,000 fall Chinook smolts are transferred to Fall Creek 2 fish hatchery to make room for the now arriving adult spring Chinook. The number of juveniles will reduce, by attrition, to 260,000 at the time of release as yearlings.
- On May 15, the spring Chinook holding ponds receive 2.9 cfs of water flow.
- On May 31, 2 million fall Chinook smolts are released at Iron Gate fish hatchery.
- On May 31, 200,000 fall Chinook smolts are transferred to the Fall Creek 1 fish hatchery, for the ultimate production of 180,000 yearlings.
- On June 1, adult spring Chinook holding pond flow is increased to 5.8 cfs.
- On June 1, about 680,000 fall Chinook smolts are retained at Iron Gate fish hatchery to ultimately produce 640,000 yearlings.
- Between September 15 and 30, spring Chinook are spawned at Iron Gate fish hatchery and transferred to incubation facilities at Fall Creek 2 fish hatchery.
- On November 15, all yearling fall Chinook (1.08 million) are released (including CDFG Fall Creek fish). The 440,000 fish reared at Fall Creek fish hatcheries 1 and 2 are trucked to Iron Gate fish hatchery and released into the river.

Facilities Required

Alternative 1. No new facilities are needed.

Alternative 2. With this alternative, a small new rearing facility would be needed at Fall Creek (Fall Creek 2). The facility could consist of a single pair of raceway series identical to those at Iron Gate fish hatchery. Each series would receive 3.1 cfs of water and sequentially flow through four 10- by 100-foot-long raceways. This would consume about half of the 13 cfs of water available to use at Fall Creek (see Section 7.9.4.4). The water supply would be diverted from a weir structure a short distance upstream. This water would be conveyed in a pipeline or open channel, through a sedimentation pond, and gravity fed into the rearing ponds.

Additional facilities needed to support this operation would be a maintenance and storage shed, office, and fish food storage shed or silo. A sedimentation pond would be required downstream of the facility to remove suspended solids before discharge into Fall Creek. The transportation of 500,000 fish to Fall Creek 2, in addition to the current 200,000 fish, may require another transport truck or use of one.

Alternative 3. With this alternative, a new facility at Fall Creek (Fall Creek 2) would need to be much larger. To rear 408,000 additional yearling fall Chinook at Fall Creek 2, 8.4 cfs out of 13 cfs of water available would be used. If 9.3 cfs were used, they would correspond with three series of four standard CDFG 10- by 100-foot-long raceways identical to those at Iron Gate fish hatchery. Each series would receive 3.1 cfs as they do at Iron Gate. At Iron Gate, each series produces 150,000 yearlings. The same would be true at Fall Creek 2 with a little added buffer.

The water supply and effluent system would be the same as described above except sized larger. Other facilities would include an office, maintenance building, garage, and food storage building or silo. A hatchery of this size may require a residence because the operation would be a full-time commitment for at least one employee. A residence would require a domestic water supply. The transportation of 640,000 fish to Fall Creek, in addition to the current 200,000 fish, may require another transport truck or use of one.

Alternative 4. Alternative 4, like Alternative 2, would require a new modest-sized hatchery facility at Fall Creek (Fall Creek 2). It would need to accommodate 32,500 pounds of fish. First in the production sequence, it would rear 22,222 pounds of spring Chinook (2 million fish at 90/lb). When these fish were released in mid-May, about 280,000 fall Chinook smolts (to eventually produce 260,000 fish) would be transferred from Iron Gate fish hatchery to allow the use of 10 cfs of water for arriving adult spring Chinook. The 260,000 yearling Chinook would weigh 32,500 pounds. Thus, the design needs to revolve around the fall Chinook yearling needs rather than spring Chinook needs, at least for rearing space and water supply.

The facility would need to divert and use 5.4 cfs for rearing and about 0.2 cfs for egg incubation for a total of 5.6 cfs. This corresponds closely with two standard series of four 10- by 100-foot-long raceways each receiving 3.1 cfs. Going with this standard, 6.4 cfs is needed out the 13 cfs available at Fall Creek.

Additional facilities would be the same as described for Alternative 2 with one exception. The spring Chinook would need a small incubation building housing about 22 Heath® stacks. There are two reasons for this. First, the incubation building at Iron Gate fish hatchery cannot accommodate 22 more Heath® stacks. Second, and more importantly, the spring Chinook would need to be isolated from Iron Gate during the start-up phase as a quarantine measure. The donor stock, probably from Trinity River fish hatchery, has IHN (see spring chinook section 7.9.4.4).

Operations Cost

Alternative 1. Status quo. No changes.

Alternative 2. More staff may be needed to operate the additional satellite facility at Fall Creek 2. There is a small increase in the weight of fish produced, so food cost would be increased accordingly. There would be a minor use of electricity and heat.

Alternative 3. With 408,000 fish being reared at Fall Creek 2 in this alternative, extra staff members likely would be needed. No additional food would be required. With the potential for a residence, there could be a corresponding use of electricity and heat.

Alternative 4. This is by far the more complicated operation with multiple transfers of fish in large numbers. However, fewer raceways of fish would need tending compared with Alternative 3. Additional staff members likely would be required. No additional food would be required. In fact, less food would be needed. Because a residence likely would be needed at Fall Creek, a corresponding consumption of electricity would result.

Biological Considerations

The most important biological consideration is the reasoning behind the suggested production shift. The rationale is that by releasing fewer smolts, there will be less competition for space and food resources in the lower river during June when most wild Chinook smolts are migrating. The basis for this concern is that the river warms considerably at this time and there is a perception that thermal refugia may be a limiting factor for wild fall Chinook smolts.

A shift in production to more yearlings, with a corresponding reduction in smolt poundage, will lead to a reduction in adult return numbers. This will be the case even though it is known that hatchery yearling fall Chinook produced at Iron Gate fish hatchery return at a rate that is approximately three times greater than smolts. The numbers can be computed and compared as follows:

- For each 100 lb of smolts at 90/lb = 9,000 fish. If the return rate is 1 percent, then 90 adults return.
- For each 100 lb of yearlings at 8/lb = 800 fish. If the return rate is 3 percent, then 24 adults return.

All of the alternatives that increase the proportion of yearlings would require additional facilities at Fall Creek. The present facility footprint is too small to expand. A new hatchery site downstream (Fall Creek 2) would need a separate water supply. The reach between the intake and outlet would be affected from the water diversion. The historical monthly average low flow is about 40 cfs. Using the Tenent Method for setting minimum flows results in 12 cfs, leaving 13 cfs, which could be diverted. The various alternatives considered would require flows ranging from 5.4 to 8.4 cfs. Although these flows fall well within the historically acceptable range, there still will be environmental impacts from flow diversion.

Water quality in Fall Creek also will suffer. Hatcheries discharge water with low dissolved oxygen and a loading of BOD, ammonia, suspended solids (even with a settling pond), and other compounds.

7.10 BIOLOGICAL MODELING OF FISH PASSAGE OPTIONS

Given the complexities and interactions among multiple variables affecting fish survival and population recovery, the stakeholders recommended that PacifiCorp use two modeling approaches as tools to assess and prioritize mitigation strategies and options. The models needed to incorporate all of the life history uncertainties experienced by fish populations including habitat quality and quantity as well as upstream and downstream fish passage efficiencies at Project facilities.

7.10.1 Methods

Two separate modeling approaches were identified to address the information needs noted above. The first model, PASRAS (now revised and named KlamRAS), focuses on dam/reservoir passage efficiencies so that passage options (operations, facilities) can be assessed. The KlamRAS model incorporates both habitat data and fish passage survival through Project structures to estimate fish production in user identified reaches or areas of the basin. The model allows the user to vary a wide range of input variables to explore how different assumptions affect model results. Thus, this model is being used primarily as a tool to assess the effects various fish passage options have on fish production.

The second model, EDT, provides a tool to incorporate detailed habitat features and biological productivity into the analysis of fish passage options. It provides a more comprehensive tool to address the success of restoring anadromous fish runs to the upper Klamath River basin above Iron Gate dam. This model is being used to assess existing and potential fish capacity and productivity in the Upper Klamath River basin by reach and tributary where reintroduction of anadromous fish may occur.

The use of these models is based on the premise that KlamRAS evaluates different fish passage options and allows larger “gaming” alternatives, while EDT can be used to evaluate what habitat awaits fish when they get past the projects and the implications of the habitat on productivity.

The following is a discussion of the two modeling efforts and a list of steps involved in developing and implementing the models.

7.10.1.1 Overview of KlamRas Model

PasRAS (Passage Risk Assessment Simulation) is a family of stochastic risk assessment life history models of Pacific salmon species. Previous versions have been developed for spring Chinook (stream type and a limited ocean-type life history), sockeye, and coho (CoRAS). A new version, called KlamRAS, has been developed for fall Chinook and ocean-type spring Chinook life history types that can be used to simulate these life history types in the Klamath River basin.

KlamRAS runs under Windows 98 through XP, as a stand-alone, user-friendly installable program written in Microsoft Visual Basic 6.0. The model is an age-structured life cycle model that incorporates as many of the life history characteristics of the species as could be documented in the published and unpublished (gray) literature. The species models (fall versus spring) differ because of life history differences, assumptions about hatchery fish interactions, and the extent to which passage (juvenile and adult) may be simulated through the Klamath hydroelectric developments in the mainstem and tributaries.

Risks to salmon survival through a sequence of life-cycle stages are modeled as a modified Markov chain of events (Figure 7.10-1). Monte Carlo methods are used to simulate uncertain events at each life-cycle stage (Burgman et al. 1993; Law and Kelton, 1991; Vose, 2000). Most events are represented as binomial, uniform, gamma, or normal probability distributions. The spring Chinook and sockeye structural models were developed by a Fisheries Technical

Subcommittee (FTS) as part of efforts to develop a decision structure for evaluating the feasibility of fish passage through PGE's Pelton Round Butte project (Oosterhout 1998, 1999). The coho structural model was based on a model developed by Tom Nickelson and Pete Lawson (Nickelson and Lawson, 1998), and later modified to include interactions with hatchery fish (Oosterhout et al. 2003). More information about these models is available in reports that can be downloaded from www.decisionmatrix.net.

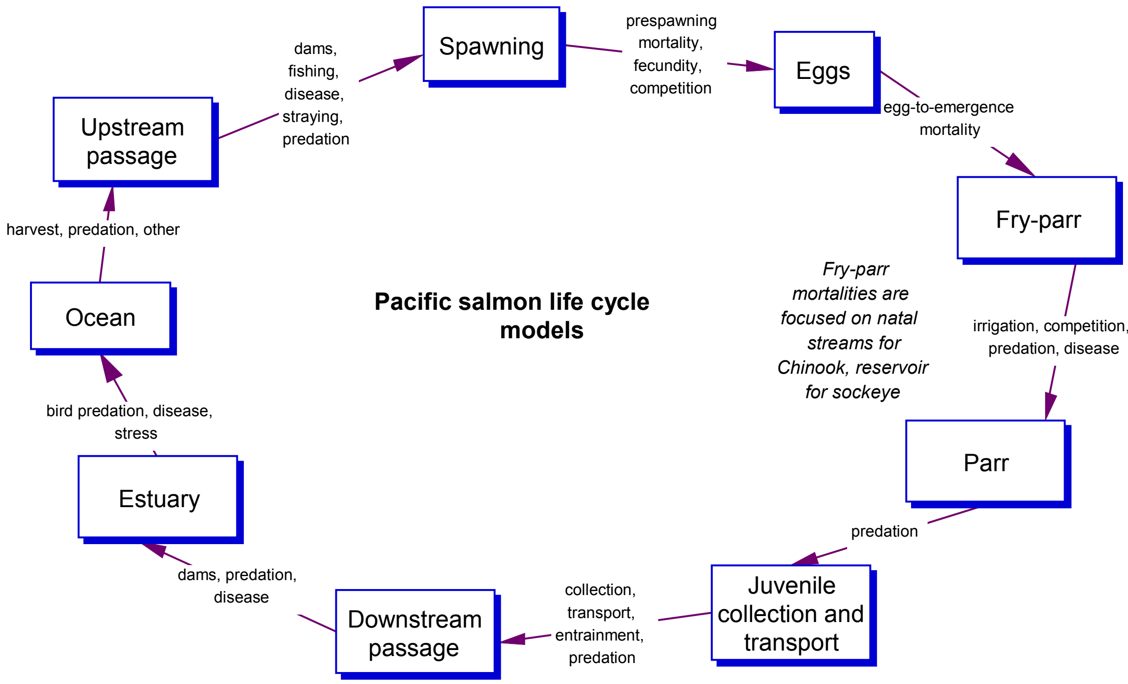

Figure 7.10-1. Life cycle schematic.

The following description for KlamRAS is extracted from Oosterhout (1999). The model name has been changed to KlamRAS in the text below.

Using typical Monte Carlo simulation methods, KlamRAS sets up and executes independent replicates of simulated life-cycle survival over many years. A typical replicate might simulate the life of the population over 100 years. In a Monte Carlo simulation like KlamRAS, whenever the simulation needs a new value for some parameter, it samples from the appropriate statistical distribution (binomial, normal, exponential, uniform, etc.), which is defined by the appropriate parameters (mean, standard deviation [s.d.], coefficient of variation [C.V.], discrete probabilities, etc.) defined by the user. To achieve statistically meaningful results, it is typically necessary to run hundreds or thousands of replicates.

Each independent replicate of a Monte Carlo simulation is analogous to an independent sample drawn for a designed experiment. If properly conducted, a Monte Carlo simulation can be evaluated using statistical tools that could be applied to any designed experiment (Fahrig, 1991). Just as with a designed experiment, the number of replicates required depends on the variance of the inputs (i.e., the range of uncertainty for each of the variables), and the sensitivity and power desired for the analysis. KlamRAS produces results in several formats: probability density graphs for time to extinction and final population size; tables showing numbers of spawners, recruits, and recruits per spawner for each replication; and graphs showing mean, median, minimum, and maximum population sizes year-by-year for each replication. Text files of key data are produced that can be opened in spreadsheet or statistical programs for further analysis.

KlamRAS also allows the user to increase stochasticity and/or conduct multivariate sensitivity analyses by representing the probabilities themselves as ranges. For example, with the sensitivity analysis option turned on, instead of assuming a nominal 0.6 survival fraction at some life-cycle stage, the user can define survival as a range of, say, 0.4 to 0.8. Then, whenever KlamRAS needs to use this parameter, it first randomly picks a value from the defined range, and then samples from the appropriate distribution using that value instead of the nominal value. To conduct a factorial experiment, the user can have KlamRAS flip a coin rather than sample from the full range of a parameter: instead of sampling from a range of 0.4 to 0.8, KlamRAS would use either 0.4 or 0.8, with a probability of 0.5 of using either. Sensitivity analysis can be conducted for up to nine parameters at a time. Even when the sensitivity analysis option is turned off, KlamRAS still uses Monte Carlo sampling tools to represent all variables by their appropriate statistical distributions.

The Fish Passage Work Group (FPWG) identified a list of key questions that it hoped to answer using KlamRAS:

- Should fish be reintroduced (if so, then which, where, how…)? What is the likelihood of success, given different assumptions and scenarios?
- What are the potential benefits and risks of passage? How much habitat is available, what quality, opportunities for restoration, how likely would it be "successful"?
- Rank-order potential benefits as a function of assumptions
- Rank-order uncertainties as they affect results
- Which potential actions might have greatest impacts on resources in general (fisheries, other, and hydroelectric facilities)? Operations, PM&E measurers, upstream restoration actions independent of relicensing?
- Actions PacifiCorp can take to mitigate Project effects

KlamRAS is not the only tool being used to investigate these questions, of course. The primary purpose of other versions of PasRAS always has been to provide a "thinking" tool, for helping people reach agreement on the relative importance of risks, possible impacts of management activities, and prioritization of research and habitat improvement efforts. Because ecological systems are complex and poorly understood, and the impacts of human actions on those systems are also complex and poorly understood, the output of any single species, basically linear life history models, may be heuristic at best (Burgman et al. 1993; Fieberg and Ellner 2000; Hilborn and Mangel 1997; Ludwig 1999 #320; Mode and Jacobson 1987; Pace 2001; Pascual et al. 1997). Hence, using such models for predictive purposes may be useful in a relative sense, to compare strategies and investigate key system drivers; but there is little if any evidence that any such models have performed credibly as absolute prediction tools. That said, PasRAS has proven useful in a structured decision context (e.g., see PGE's FERC draft and final license applications) to help prioritize uncertainties, frame discussion, and evaluate habitat restoration options; and those are the purposes for which it was used on the Klamath Project.

KlamRAS Modifications to PasRAS

The specific tasks taken to modify the previous Chinook version of PasRAS are listed in Table 7.10-1

Table 7.10-1. Tasks taken to develop a fall Chinook version of PasRAS for the Klamath Project.

Task	Details
Develop baseline	Remove parts not needed for subyearling migrant types
Modify juvenile survival variables	Develop probability distribution input screen for water year type (WYT)
	Define emergence-to-migration survival as function of WYT, spawning habitat
	Add location to reach definitions
	Review and possibly modify density dependent survival functions
	Add juvenile migration survival through seven nodes of the Project
Modify ocean variables	Modify/verify marine maturation rates
	Replace current ocean cycle variability (ALPI) with appropriate ocean cycles (PDO)
Modify adult migration variables	Modify adult migration survival to model seven Project nodes and catastrophic events (fish kills below Iron Gate dam)
Set up for initial Spencer Creek runs	Get reach productivity, capacity parameter settings
	If necessary, run Habrate for Spencer Creek, using stream survey data
Distribute	Develop beta 1 and beta 2 installation CDs
	Provide setup help and simple user's manual
Training	Develop and run half- to full-day workshop to train users
Initial validation	Determine plan for developing "transferable confidence"
	Parameterize and review scenario(s) to run for validation
	Run validation scenarios
	Prepare results materials and distribute
Review with subcommittees	Prepare materials for meetings
	Attend meetings: 2, all-day
Review with external experts	Periodic reviews as needed with external experts

Reporting of Model Outcomes

KlamRAS, like PasRAS, provides output in a variety of formats, including the following:

1. Graph of spawners over time, showing average, minimum, and maximum over all Monte Carlo replications.

2. Spawner count statistics, averaged over all replications.

3. Counts of spawners, recruits, smolts, and R/S in tables for each simulated year, each replication.

4. Number of reaches populated at the end of each replication, size of ending population, and running mean and standard deviation to enable evaluation of how many replications are needed.

5. Probability distribution graphs of ending population size and time to extinction.

6. Average final spawners for each reach simulated.

All the table outputs can be exported to Excel for further analysis, and the graphical outputs can be copied and pasted into Word or other Windows programs. KlamRas also provides a multi-variate sensitivity analysis capability. If activated, the sensitivity analysis writes simulation details to a text file that can be opened in Excel or statistical analysis package, to investigate relative impacts of parameter settings. Using this tool appropriately requires a good understanding of multi-variate statistics, and the results of any such analysis should be carefully reviewed to ensure that the results are appropriately analyzed (Oosterhout, 1999).

The products to be provided include the installation CDs for the software and a training session to enable members of the FPWG to parameterize the model for different scenarios, run the model, and interpret the outputs.

7.10.1.2 Overview of the Ecosystem Diagnosis and Treatment (EDT) Methodology

PacifiCorp and the stakeholders agreed to use the EDT Methodology and the inherent modeling tools to assist the development of a strategy for reintroducing anadromous salmonids to stream reaches both within and above Project facilities. The EDT model provides the means necessary to assess fish performance under various fish passage scenarios and stream habitat conditions. In the paragraphs below the EDT Methodology is described along with the tasks completed as part of the analysis for the Project relicensing.

EDT is an analytical tool relating habitat features and biological performance to support fish and wildlife planning (Mobrand Biometrics, 1999). The model has been developed over a number of years primarily by state, tribal, local, and private interests in the Pacific Northwest involved with watershed restoration and salmon recovery[1]. It captures a wide range of information and makes it accessible to planners, decisionmakers and scientists as a working hypothesis of the ecosystem. EDT acts as an analytical framework that brings together information from empirical observation, local experts, other models and analysis.

An EDT analysis has six basic steps:

1. Identify Basin Fisheries Goals and Objectives
2. Perform Analysis and Diagnosis
3. Formulate Treatments (Actions)
4. Describe Benefits and Risks
5. Refine Project Objectives
6. Develop Treatment Application, Monitoring, and Evaluation Program

[1] The Northwest Power Planning Council is currently in the process of web-enabling the ETD Model and data entry tools. The model will be available for public use in late summer 2004.

These six steps form the EDT conceptual framework. The framework states that salmon enhancement actions are designed to affect specific environmental attributes in a manner that changes biological performance to meet basin goals and objectives. Based on discussions in the FPWG, the step of analysis and diagnosis will be addressed after the FPWG has the opportunity to be confident in the parameters that are being used to describe habitat conditions and factors of mortality.

EDT often is misunderstood because of confusion surrounding the term “model.” Although EDT is indeed a model, it is a scientific model, not a statistical model. A scientific model explains the mechanisms behind phenomena to form an overall hypothesis; a statistical model provides correlation-based predictions without necessarily explaining the underlying mechanism. As a scientific model, EDT constructs a working hypothesis of a watershed and a population, which enables understanding of complex ecological systems well enough to design effective enhancement strategies. This working hypothesis also provides metrics to monitor progress and testable hypotheses to refine knowledge. A statistical model, on the other hand, seeks to reduce complexity to a small number of predictive or correlated variables.

EDT draws on an environmental database of 46D, and a set of mathematical algorithms to compute productivity, capacity, and diversity parameters for the targeted salmonid population. Because it is completely deterministic, issues such as statistical power, precision, or “overparameterization” are not relevant. A detailed matrix of EDT habitat attributes is provided in Appendix 7D.

At a more fundamental level, EDT is not inductive and predictive so much as it is deductive and explanatory. That is to say, it does not attempt to discover some fundamental property of population performance from other observations or relationships. Rather, it assumes all such relationships are known, states them explicitly, and then uses computer power to integrate many individually simple premises and deduce their combined implications. As mentioned above, these “combined implications” are reduced to just three indices, productivity, carrying capacity, and diversity.

The tasks that have or will be completed (modeling is ongoing) as part of the Klamath River basin EDT analysis are described below.

Task 1.0: Technical Workshop To Discuss EDT Model Assumptions, Biological Rules, and Algorithms

PacifiCorp held a workshop in the spring of 2003 with members of the FPWG to review the EDT model. The review included a detailed overview of input assumptions, the biological rules that translate habitat conditions to fish performance, and the algorithms used to calculate modeling parameters such as productivity, capacity, and diversity. The primary goal of this workshop was to ensure that the FPWG has a clear understanding of how the model works as well as its strengths and weaknesses.

Task 2.0: Establish Fisheries Goals and Objectives for the Basin (EDT Step 1)

A key step in the EDT Methodology is the establishment of the fisheries goals for the basin. As noted above, the EDT conceptual framework states that actions are designed to affect specific environmental attributes in a manner that changes biological performance (in this case, salmon performance) to better meet basin goals. Thus, to come up with effective actions, the FPWG should have a clear understanding of fisheries goals for the basin. Goal statements should address such topics as the following:

- Species of interest
- Species distribution
- Abundance
- Harvest
- Other topics important to each stakeholder

In EDT, fisheries goals are not expressed as actions. For example, the establishment of fish passage facilities at all project structures would be an action not a goal. Fish passage is one of many actions that may be used to meet the goal of say, increasing fish abundance in a basin. Increasing hatchery production would be an alternative action that may achieve the same objective. Fish passage, therefore, is a means to an end, while a goal defines the end.

As EDT and KlamRAS modeling is completed, it is anticipated that stakeholders will use this information to set fisheries goals for the basin. Any future actions developed by the FPWG would be evaluated on the basis of their ability to achieve these goals. This task has yet to be completed.

Task 3.0: Perform Analysis and Diagnosis (EDT Step 2)

This task deals with all modeling components of the EDT Methodology. Data for running the model fall into two categories, biological and environmental. Model outputs include estimates of fish performance expressed by the indices of productivity, capacity and diversity, and the reach, preservation, and restoration analyses are described below.

The Habitat Modeling Subgroup (HMG) was formed to act as the technical group responsible for acquiring biological and environmental data used to populate the model attributes. This group included federal, state, tribal, NGO, and PacifiCorp personnel. Data have been entered that describe the habitat within the Project area, including key tributaries. These data are still being reviewed by the HMG. Ongoing efforts of the HMG will provide habitat data for the Upper Klamath River basin including tributaries of Upper Klamath Lake.

Task 3.1 Enter Biological Data

The EDT model requires a wide range of biological data including stock-specific information on fish fecundity, sex-specific age distributions, relative hatchery/wild fitness, hatchery program information, spawning sites and times, terminal harvest rates, and basic life history patterns. Specific parameters and information that will be collected for this task include the following:

- Species of interest. The species to be modeled as part of this effort is currently Chinook salmon. Future work by the HMG will incorporate steelhead trout and coho salmon into the modeling effort.

- Population name. A unique name used to identify the race and approximate area used by the population for spawning (e.g., upper Cedar River spring Chinook). All ESUs and all spawning populations known to be genetically distinct from other populations automatically will constitute a distinct population for which an independent EDT analysis will be performed. Other populations will be defined by geographic distribution.

- Spawning distribution. A complete list of the reaches in which the natural population is known to spawn (or to be restored to) as well as the reaches it is believed to have spawned in historically. Populations as modeled are defined by spawning reaches and, therefore, may not have overlapping spawning areas. All life histories (see below) subsequently modeled will originate from these reaches.

- Adult run and spawn timing. The weeks in which spawning typically begins and ends. If spawning is significantly earlier in the upper portions of a drainage than the lower portions, two (non-overlapping) populations will be created with different spawning dates.

- Life history patterns. In EDT modeling, a "life history pattern" consists of a distinct combination of juvenile and adult age distributions for different components of the same population. More specifically, it consists of a set of proportions (summing to 1.0) describing the prevalence of a number of such alternative patterns.

- Marine distribution. An indication of whether a given population has a far north oceanic distribution or an offshore distribution. For Chinook salmon, this will be done by indicating whether the population has an ocean-type or a stream type migration pattern.

- Harvest rates. Estimated in-river and ocean harvest rates for each population (both commercial and sport). For initial model runs, harvest will be turned off. In this way, the full potential of the habitat to support anadromous salmonids can be estimated.

- Sex-specific age distribution. Age-specific sex ratios and age-specific fecundity.

- Hatchery data. Baseline data also will be compiled for the hatchery parameters listed below. Hatchery data are used in the model for determining competition with naturally produced fish. However, as was the case with harvest, and for the same reason, initial model runs will not include hatchery releases.

  - Hatchery location (tributary and RM)
  - Species reared
  - Fish size and weight at release
  - Total number of fish released by species
  - Release locations (tributary and RM)
  - Donor stock (local, adjacent drainage, distant drainage)
  - Release date(s)
  - Survival information if available (smolt-to-adult survival, smolts/spawner, catch/escapement, etc.)
  - Mean number of adult returns

- Stray rates if known
- Proportional contribution of hatchery fish to the natural spawning escapement
- Number and location of hatchery carcasses returned to the river

- Stock Genetics. The successful reintroduction of anadromous fish to the Upper Klamath River basin depends on the availability of genetic stocks that would be suitably adapted to the local environments where reintroduction would occur. Therefore, the HMG will review existing data and information to assess the ecological and evolutionary basis for the stocks that historically used the upper basin and identify the opportunities and risks associated with the use of lower basin or out-of-basin stocks for potential introduction. Specific activities associated with this review include the following:
  - Provide an overview of the importance of stock genetics and associated life history characteristics as related to re-introducing anadromous salmonids to the Upper Klamath River basin (above Iron Gate dam). Various documents prepared by NMFS, supporting its status reviews and ESA listings for several west coast salmon stocks (e.g., Wapples 1991), provide good discussions of the importance of genetic diversity as related to stock adaptations to local ecological conditions.
  - Summarize previous assessments of the feasibility of re-introducing anadromous fish to the Upper Klamath River basin. Reports include Fortune et al. (1966), Klamath River Basin Fisheries Task Force (1992), ODFW (1997) and Chapman (1981).
  - Review and summarize available information on the historical use of the Upper Klamath River basin by anadromous salmonids. Sources of information will include Fortune et al. (1966), Snyder (1931), and Land & Lane Associates (1981).
  - Explore general ecological conditions in the Upper Klamath River basin as they relate to probable life history characteristics of historical and current salmonids. Because salmon runs have been extirpated from the upper basin above Upper Klamath Lake (Nehlsen et al. 1991), it will be necessary to draw inferences from information on stocks downstream of Iron Gate dam and from other interior stocks east of the Cascades. A comparison will be made of the ecological adaptations (life histories) for ocean-type and stream-type Chinook salmon as influenced by environmental conditions (primarily hydrology and water temperature regime).
  - Prepare a technical memorandum for FPWG review.

Task 3.2 Enter Environmental Data

The approach used for assembling environmental data for the analysis has three basic steps:

1. Identify geographic scope
2. Define stream reaches
3. Enter and document environmental attributes

The first step in the process is to identify the geographic scope of the EDT analysis. The following streams/reaches will be modeled as part of this analysis:

- Klamath River Reaches
  - Klamath River downstream of Iron Gate dam
  - Iron Gate and Copco reservoirs
  - J.C. Boyle peaking reach (broken into three reaches)
  - J.C. Boyle bypass reach
  - J.C. Boyle reservoir
- Klamath River Tributaries (within Hydroelectric Project area)
  - Jenny Creek
  - Shovel Creek
  - Spencer Creek
  - Fall Creek
- Upper Klamath River above J.C. Boyle reservoir and Upper Basin Tributaries (above Upper Klamath Lake)
  - Currently being assessed for modeling inclusion.

Only stream reaches historically accessible to each anadromous species will be modeled. Stream reaches above impassable waterfalls or other natural barriers will not be modeled. The exact stream reaches modeled will be developed in consultation with the HMG (see below).

Modeling will be conducted in two phases. In Phase 1, only stream reaches downstream of Spencer Creek to Iron Gate dam will be modeled. This first phase has been limited to allow the EDT model to be quickly populated so that a working version can be demonstrated to the FPWG. After review by the FPWG, it is envisioned that additional reaches both above and below the Phase 1 reaches will be modeled.

In Phase 2, fish-bearing steams will be broken into "environmentally homogenous" reaches that reflect the hydrography of the basin. The goal of this exercise is to assess environmental conditions from the perspective of the target species and to identify areas within which rearing conditions are, as nearly as possible, indistinguishable to a fish.

PacifiCorp will be responsible for coding the hydrography of the basin, that is, indicating the direction of water flow and the spatial relationship of tributaries such that it can be understood by the EDT program. This reach structure is needed to ensure that the confluences of all fish-bearing streams are identified, and to include coding by which the model can determine upstream from downstream, and thus possible migration routes for juveniles and adults.

Obstructions (e.g., dam, culvert, cascade) that significantly restrict adult or juvenile passage, or cause mortality to adults or juveniles will be identified in the model. Hatcheries, acclimation sites, lakes, and reservoirs also will be identified as separate reaches or multiple reaches depending on feedback received from members of the FPWG and HMG.

The third phase is entering and documenting environmental attributes. There are 46 environmental attributes that will be entered into the EDT model, if data are available, on a reach-by-reach basis. The 46 attributes are listed in Appendix 7C, and can be classified roughly into the following categories:

- Hydrology
- Water temperature
- Channel/streambed
- Community richness
- Riparian conditions
- Meso-habitats
- Water Quality
- Miscellaneous (pathogens, hatchery outplants, etc.)

PacifiCorp is working in collaboration with the HMG to compile, analyze and enter the attribute data into the EDT model. At the March 2003 FPWG meeting, it was agreed that PacifiCorp will populate the EDT model then share the data and sources of information with the FPWG via the Stream Reach editor. It will be important to have FPWG members to both review work products and incorporate the basin specific knowledge of the group regarding stream conditions into the EDT model. PacifiCorp is continuing with this task in 2004.

All available biotic and abiotic environmental information will be entered into the EDT model using the existing EDT Stream Reach Editor. The Stream Reach Editor is an ACCESS-driven database that allows the user to input and rate stream data over time and space.

Baseline environmental information will be summarized along three axes. The first axis is spatial, reflected in the reach structure described above. The second axis is temporal, because some information will refer to the Template (the normative, historical watershed and native fish populations), some to the Patient (the contemporary, non-normative watershed and fish community), and some to a specific season. The third axis captures the justification or level of proof for a piece of information. A thorough understanding of this sort of metadata is essential in the later stages of analysis, when it will be necessary to choose between alternative strategies with comparable potential benefits.

The environmental attributes will be entered into the model systematically and with "the appropriate perspective." The appropriate perspective recognizes that the goal is not so much to describe every reach precisely, as it is to produce a reasonable description that can be shown to be consistent with documented observations and widely accepted relationships found in the scientific literature. A determined effort to maintain consistency with observations and accepted relationships will result in meaningful ecological inputs. Moreover, each attribute will be associated with a rationale and a level of proof assessment. The latter will flag potential errors for future revision, and the former will indicate exactly how an erroneous evaluation might be corrected (e.g., additional data collection).

Researchers will ensure consistency among reaches in terms of environmental ratings by developing and applying the best possible set of local "benchmark reaches" for every high priority attribute. Benchmark reaches are reaches in which an attribute or set of attributes are estimated as accurately as possible based on quantitative data. If quantitative data do not exist, then ratings based on biologists knowledgeable with the stream will be relied upon (i.e., the HMG). This qualitative approach will have to be used for many reaches because the number of reaches even in data-rich basins always exceeds the number of high-certainty, reach-specific observations. All data sources will be documented clearly in the model.

The source and scientific strength of each attribute entered in the model will be documented clearly. This task will be performed through the use of the "Level of Proof" data entry form found in the EDT Stream Reach Editor. A screen capture of the Stream Reach Editor used for entering both the environmental data and the Level of Proof information (captured in the Ratings Comments field) is shown in Figure 7.10-2.

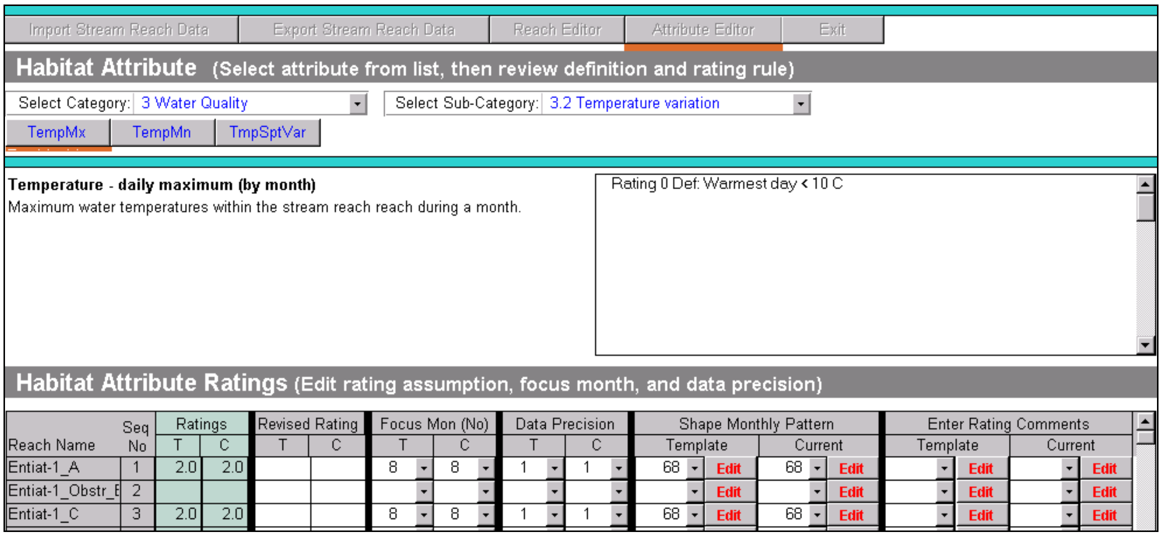

Figure 7.10-2. Screen capture of EDT Stream Reach Editor.

Task 3.3 Run EDT Model

After all biological and environmental data have been entered into EDT; the model will be run to produce the following outputs:

- Model runs estimating current (Patient) and historical (Template) fish productivity (adult recruits per spawner and smolts per spawner), carrying capacity (adults and smolts), life history diversity (percent life histories with productivity greater than 1.0), and equilibrium abundance (adults and smolts) indices.

- An analysis in which reaches will be prioritized in terms of their potential impact on salmon productivity, capacity, equilibrium abundance, and life history diversity if fully restored (i.e., basin pre-settlement) (Restoration Analysis).

- A Reach Analysis in which reaches will be prioritized in terms of their current contribution to sustaining existing salmon productivity, capacity, equilibrium abundance, and life history diversity (Preservation Analysis (Protection)).

- A series of graphics displaying the relative impact of specific environmental factors (not all environmental factors) on population performance indices for each reach for all defined fish populations (Reach Analysis).

An example of the output for the Reach Analysis is shown in Figure 7.10-3.

Species/Component:	Spring Chinook
Restoration Potential:	Current conditions versus Historic Potential
Restoration Emphasis:	0

Stream(s) / Water(s):	Sandy River	**Sub-Watershed:**	
Reach:	Sandy1 extends from confluence with Columbia River upstream 5.4 miles (near Dabney Park)	**Reach Length (mi):**	5.4
		Reach Code:	Sandy1

Restoration Benefit Category:	A	**Life History Diversity Rank:**	4	**Potential % change in diversity:1/**	5.6%
Combined Performance Rank:	2	**Productivity Rank:**	9	**Potential % change in productivity:1/**	7.6%
% of Total Life History Trajectories Affected:	100%	**Average Abundance (Neq) Rank:**	2	**Potential % change in Neq:1/**	28.2%

Life stage	Relevant months	% of life history trajectories affected	Productivity change (%)	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatc	Competition (other sp	Flow	Habitat diversity	Harvest	Nutrient load	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	% Key habitat (quant
					Change in attribute impact on survival															
Spawning	Sep	2.6%	-89.9%	3							•							⬤		
Egg incubation	Sep-Apr	2.6%	-100.0%	1													⬤	⬤		
Fry colonization	Mar-May	5.3%	-7.3%	10						●										
0-age resident rearing	Mar-Oct	12.9%	-10.7%	5					•	●					●	●		●		
0-age transient rearing	Mar-Aug	14.8%	-2.2%	11						●										
0-age migrant	Oct-Nov	13.8%	-3.2%	9						•					•	●				
0,1-age inactive	Oct-Mar	6.4%	-35.4%	4,2	●				●	●					•	●	⬤			
1-age migrant	Mar-Jun	68.9%	-0.7%	8						●						●				
1-age resident rearing	Mar-May	6.4%	-3.7%	12						•										
1-age transient rearing																				
2+-age transient rearing																				
Prespawning migrant	Apr-Aug	100.0%	-0.9%	6						●	●							●		
Prespawning holding	May-Sep	2.6%	-24.3%	7					•	●	•							●		

Page 1

1/ Value shown is for overall population performance.

Notes: Changes in key habitat can be caused by either a change in percent key habitat or in stream width.

Potential % changes in performance measures for reaches upstream of dams were computed with full passage allowed at dams (though reservoir effects still in place).

<HP> indicates highest priority given due to fragmentation of habitat by dam or reservoir.

KEY

NA = Not applicable

	Loss	Gain
None		
Small	•	○
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

Figure 7.10-3. Reach analysis output for Sandy River spring Chinook.

Results of a typical Preservation and Restoration analyses is shown in Figure 7.10-4. Degradation refers to the percent loss in each population parameter if the reach were degraded further. Restoration refers to the percent change in these same parameters if the reach were restored to historic conditions.

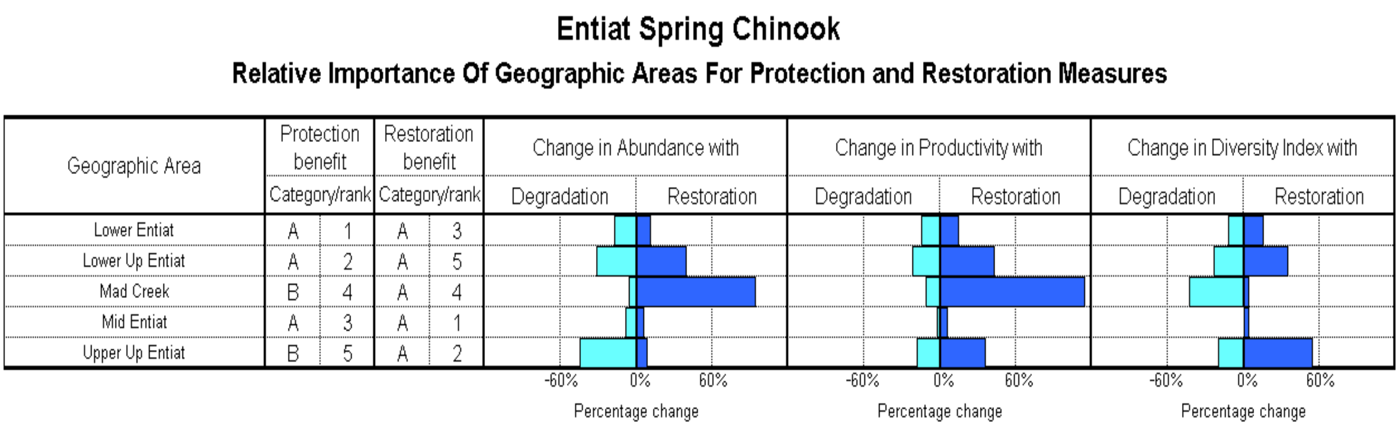

Figure 7.10-4. Entiat spring Chinook preservation and restoration modeling results.

Where possible the outputs of the model will be summarized in tabular format by reach so that they may be used as input to GIS for graphical display purposes.

Task 4.0: Formulate Treatments (EDT Step 3)

In this step, members of the FPWG will be tasked with identifying the set of fish passage actions that will be modeled as possible future conditions. Most of the fish passage actions already will have been identified as part of the initial fish passage options modeling work described earlier using KlamRAS (see above), and through the efforts of the Engineering Subgroup. These two groups also will be tasked with combining fish passage actions into coherent fish passage plans that are internally consistent and meet all or a subset of the fisheries goals identified by the stakeholders.

Data inputs that will need to be supplied to model the fish passage plans include the following:

- Reservoir survival (each reservoir treated separately)
- Fish guidance efficiency (FGE) at each facility
- Turbine survival at each dam
- Bypass survival at each facility
- Juvenile transport survival (if applicable)
- Bypass outfall survival at each facility
- Transport (adult or juvenile) sorting survival (if applicable)
- Smolt-to-adult survival rate (SAR)
- Bypass effect (if applicable)
- Transport effect (if applicable)
- Adult volitional passage efficiency

7. Adult trap and haul survival (if applicable)

Possible fish passage options that will be modeled as part of this task include the following:

- Without Project (remove all dams)
- Partial Project removal (one or multiple dams)
- Trap-and-haul (various locations)
- Volitional fish passage at all projects
- Volitional fish passage at a subset of facilities

The EDT model then will be re-run to produce indices of productivity, capacity, and diversity for all options, by species and population of interest.

Task 5.0: Describe Benefits and Risks (EDT Step 4)

A benefit risk analysis will be conducted for all actions and fish passage options examined through modeling. The objective of the EDT benefit risk analysis is to describe how the proposed actions and fish passage options could effect the following:

- Fisheries goals
- Project facilities and operations
- Project economics
- Aesthetics
- Recreation
- Flood control

8. Water quality and quantity

The primary goal of the benefit risk analysis is to clearly identify the possible trade-offs being made under each action or option to all basin values. This step is necessary to inform decision makers as to the possible consequences and uncertainties (assumptions etc.) associated with each action or option. Because not all stakeholders will be in agreement as to what should be considered a benefit or risk, the benefit risk statements will be presented in list format to allow each stakeholder to judge whether the outcome has positive or negative impacts on their goals.

Decisionmakers then can use this type of information to eliminate actions that do not meet identified fisheries goals, have unacceptable risks associated with them, or result in too large an impact on other identified resource goals and values.

Task 6.0: Refine Basin Objectives (EDT Task 5)

After the completion of the benefit risk analysis, the FPWG will need to re-examine whether basin goals or the actions needed to meet the goals should be revised. If new actions or combinations of actions are proposed, the EDT model will be re-run to produce the model outputs described previously. This process may continue until such time as an agreed upon set of actions are defined by the stakeholders.

Task 7.0: Treatment Application, Monitoring, and Evaluation

After an agreed-upon set of actions are defined, the FPWG will work to prioritize actions and define the monitoring program for the basin. Action implementation plans and performance criteria will be developed for each action to ensure that it is both effective and implemented in a cost-effective manner. Again, this task would not be completed until such time as an agreed-upon plan has been developed for the basin.

7.10.2 Results and Discussion

Given the complexities and interactions among multiple variables affecting fish survival and population recovery, PacifiCorp has developed two models to use as tools to assess and prioritize mitigation strategies and options associated with anadromous fish. The models incorporate life history uncertainties experienced by fish populations including habitat quality and quantity as well as upstream and downstream fish passage efficiencies at Project facilities.

Development and use of these two models is well underway, but only preliminary runs of the models have been completed to date. Because the models are intended to be used as gaming tools to evaluate alternatives for anadromous fish passage and potential re-introduction, use of the models will continue following submittal of the Final License Application. A Habitat Modeling Group (HMG), a sub-group of the Fish Passage Work Group, is continuing to meet monthly to evaluate the anadromous fish reintroduction and fish passage issue via use of the models.

A discussion of each model's purpose and modeling progress to date is presented below.

7.10.2.1 KlamRAS

KlamRAS is being used to focus on dam/reservoir passage efficiencies so that passage options (operations, facilities) can be assessed. The KlamRAS model incorporates both habitat data and fish passage survival through Project structures to estimate fish production in user-identified reaches or areas of the basin. The model allows the user to vary a wide-range of input variables to explore how different assumptions affect model results. Thus, this model is being used primarily as a “gaming” tool to assess the effects various fish passage options have on fish production.

The HMG is in the process of parameterizing the KlamRAS model. They are using a combination of data collected in other basins and the opinion of both fish passage engineers and biologists to set modeling values (and ranges) for fish screen collection efficiency, percent screen, bypass, reservoir and turbine survival, as well as juvenile and adult survival rates through various fish ladder and trap-and-haul scenarios.

After completing the parameterization process, the HMG will be examining five different project configurations to estimate impacts on anadromous fish production and survival. The scenarios include full project and selected development dam removal, volitional passage through fish ladders and screens, and trap-and-haul systems located at various locations in the Project area.

The outputs of these model runs will also be used to identify those critical uncertainties that drive model results. If possible, data collection efforts will be implemented to reduce the uncertainty around these input values to the extent possible.

One major uncertainty that has already been identified by the HMG and stakeholders is juvenile survival through Project reservoirs.

To address this issue, PacifiCorp will be implementing a reservoir survival study in 2004. The study will incorporate both coho and Chinook salmon smolts and will be conducted at Copco 1 and Iron Gate reservoirs using Iron Gate hatchery smolts. Both of these reservoirs are located in the California portion of the Project area. Studies will not be undertaken in Oregon waters until permits can be obtained from the ODFW. Currently, the ODFW does not want tests to be conducted in Oregon waters because of concerns about disease and impacts on resident fish populations (November 19, 2003 letter from Amy Stuart, ODFW).

Although not possible in 2004, the testing of juvenile survival through Lake Ewauna and Upper Klamath Lake is a critical uncertainty that must be addressed as it may have the greatest effect on fish production potential upstream of Iron Gate dam. Of the new areas being modeled for anadromous fish reintroduction, the majority of this habitat is located in the Upper Klamath basin above these two lakes. Previous reviews of anadromous reintroduction have all been concerned that due to such physical constraints as lake length, depth, flow patterns and poor water quality, juvenile survival through the two lakes may be quite low. Further difficulties include the absence of native fish stocks adapted to the specific environmental conditions from which to start the reintroduction effort.

PacifiCorp estimates that KlamRAS modeling will continue through the completion of the reservoir survival study in 2004. The data from this study will be incorporated into the KlamRAS alternatives modeling exercise, at which time the results will be summarized and sent to the stakeholders for review and comment.

7.10.2.2 Ecosystem Diagnosis and Treatment (EDT)

The second model being used to explore the anadromous fish reintroduction issue is EDT. This model provides a tool to incorporate habitat features and biological productivity into the analysis of fish passage options. It provides a comprehensive habitat based tool to address the success of restoring anadromous fish runs to the upper Klamath River basin above Iron Gate dam. This model is being used to assess existing and potential habitat capacity and productivity in the Upper Klamath River Basin by reach and tributary that may be considered for the reintroduction of anadromous fish. The habitat quantity and quality outputs from EDT are being used as inputs into KlamRAS.

The habitat inputs used in EDT modeling are being developed from various sources, including:

1. Results of water quality, geomorphology, and project operations studies conducted as part of relicensing.

2. Studies conducted by other parties in the Upper and Lower Klamath River Basin, including information on juvenile emigration timing, migration speed and survival in the Lower Klamath River, effects of disease on native fish populations, run-size estimates, estuary conditions and mainstem habitat quality and quantity.

3. Historical fisheries literature developed both within and outside the Klamath River Basin.

4. Expert opinion of HMG members familiar with Klamath River habitat and fish reintroduction efforts in other basins.

For the most part, the EDT model has been fully parameterized (draft) for the river reaches extending from Iron Gate dam to Keno dam. Efforts to fill-in the habitat data needed to evaluate the 236 miles[2] of stream reaches above Keno dam are on-going and are expected to be completed by mid- 2004.

Data entered into the EDT model to date tend to confirm that the habitat/environmental problems identified in the previous reviews of anadromous reintroduction still exist in the basin today. Two of the more important and highly related problems include:

- Water Temperature: Water temperature data collected in juvenile traps in the lower Klamath River show that stream temperatures after July 1st often exceed 24 degrees Celsius (Klamath River Fisheries Assessment Program, Juvenile Salmonid Monitoring on the Trinity and Klamath Rivers, 1994). Stream temperatures above 21 degrees Celsius are known to cause severe stress and mortality to anadromous salmonid species.

- Disease: Diseases such as *ceratomyxosis* cause substantial mortality to juvenile Klamath River Chinook salmon when temperatures exceed 16 degrees Celsius. Studies conducted on juvenile Chinook salmon by the US Fish and Wildlife Service in the Upper Klamath River Basin showed that after three-days exposure time 100 percent of the test specimens were infected with *Ceratomyxa shasta* and 83 percent died within 17 days (*Ceratomyxosis* resistance in juvenile Chinook salmon and steelhead trout from the Klamath River, USFWS

[2] Preliminary estimate of habitat in the Upper basin above Keno dam.

2003). As stream temperatures in the Klamath River regularly exceed 16 degrees Celsius during the peak migration period for Chinook salmon (May-July), impacts from this disease on fish survival are assumed to be severe. In contrast, steelhead exposed to the same conditions showed virtually no mortality. The results of an investigation of *Ceratomyxa shasta* in the Klamath River, prepared by PacifiCorp in 2003, is included as Section 9.0 of the Fish Resource Final Technical Report.

Initial, and very preliminary EDT model runs show that even when passage survival through reservoirs and dams is assumed high, self-sustaining runs of fall Chinook salmon could not be achieved in the Project area (Iron Gate dam to Spencer Creek). EDT estimates of adult fall Chinook salmon returns to the spawning grounds under three scenarios were as follows:

- <u>487 adults</u>: Adult returns to the spawning grounds with 100 percent dam survival, model predicted reservoir survival, and current ocean and freshwater harvest rates (see below).

- <u>1,356 adults</u>: Adult returns to the spawning grounds with 100 percent dam survival, model predicted reservoir survival, and no harvest.

- <u>4,500 adults</u>: Adult returns to the spawning grounds with 100 percent dam and reservoir survival, and no harvest.

Besides the dam related assumptions presented for each scenario, other factors responsible for the model results include; the quality of the free-flowing habitat available in the Project area, high water temperatures, disease, predation from introduced fish species, and harvest. These results point out the importance of including habitat in the Upper Klamath River basin in future model runs to determine if an increase in habitat quality and quantity can increase fall Chinook salmon production to sustainable levels, based on modeling.

In regards to harvest, Klamath River fall Chinook salmon are harvested in the ocean and freshwater at approximately 15 percent and 30 percent, respectively (Ocean Abundance Projections and Prospective Harvest Levels for Klamath River Fall Chinook salmon, 2003 Season. Klamath River Advisory Team, March 9, 2003). These data indicate that to re-establish self-sustaining Chinook salmon runs upstream of Iron Gate dam may require the implementation of selective fisheries for hatchery fish in both recreational and commercial freshwater and ocean fisheries. This would not only require a change in harvest policy but also that all hatchery fish be marked prior to release into the basin.

7.10.2.3 Continuing Modeling Efforts

The Habitat Modeling Group (HMG) will continue working in 2004 to investigate the reintroduction of anadromous salmonids in the Project area and the upper basin. PacifiCorp and stakeholders commit to completing in 2004 correspond with both modeling issues, and finding solutions to the issues identified in previous anadromous fish reintroduction reviews. A description of the tasks and a time frame for completing each is presented below:

- Conduct a parameter-by-parameter review of the habitat and fish passage inputs used in modeling stream habitat in both the Project area and the Upper Klamath River Basin (above Keno dam). As can be seen from the preliminary EDT results presented above, the accuracy of key assumptions regarding harvest, dam and reservoir survival have tremendous influence on resulting estimates of production. The parameter review is expected to be complete by April 2004.

- Identify and model other anadromous species that could be candidates for reintroduction to the Project area and upper basin. (Complete by June 2004)

- Develop criteria for modeling a “restored condition” for habitat in the upper basin. Based on these criteria, develop a suite of actions that would meet habitat objectives and goals. Different actions and approaches would be combined and modeled as separate scenarios to determine the best reintroduction strategy. Information on expected benefits, when these benefits are likely to be achieved, and how they may effect the implementation of different fish passage facilities and their location would be described. This task would start in June 2004 and continue until completed.

- Identify reintroduction strategies including broodstock source, stocking strategy, numbers of fish released, their location, and the facilities needed. Also, identify the parties that will need to be contacted to assist in this effort (start in May 2004)

- Identify those issues that parties outside of the HMG will need to address before reintroduction can take place. For example, parties outside of the HMG will need to provide input (both policy and technical) on issues such as candidate introductory stocks, anadromous fish impacts on disease prevalence, and competition with resident trout populations. (May 2004)

- Identify critical data gaps and uncertainties that will need to be addressed through data collection or other methods (modeling etc.). Priority would be given to those data gaps that are needed for decision-making. This task would be on-going throughout the process.

PacifiCorp will be submitting the results of the HMG efforts to the stakeholders for review and comment as they are completed. PacifiCorp expects to use the work performed by the HMG to better define PacifiCorp’s role in any proposed anadromous fish reintroduction effort. As the above tasks are completed, PacifiCorp will review this additional information, and revise as appropriate the Project Operations and PM&E measures included in this License Application.

7.11 REVIEW OF ADULT TROUT PASSAGE AT J.C. BOYLE DAM

7.11.1 Methods

The purpose of this section is to review and summarize various sources of information related to the upstream passage of adult rainbow trout at the J.C. Boyle dam on the Klamath River. The need for the review was prompted by concerns about the decline in trout use of the fishway since 1959.

Several sources of information have been reviewed related to the J.C. Boyle fish passage issue to address some of the hypotheses of why the use of the ladder has declined since construction of the dam. This information includes: (1) trout passage estimates at the J.C. Boyle fish ladder, (2) streamflow records for years when ladder counts were made, (3) fish planting records, (4) stream temperature data, (5) results of previous tagging studies associated with trout movement at the ladder; and (6) design drawings of the ladder as constructed compared to contemporary design criteria.

7.11.2 Results and Discussion

7.11.2.1 Background

Construction of J.C. Boyle dam on the Klamath River was completed in October 1958. A fish ladder designed primarily for rainbow trout was built as part of the Project. To verify that the fish ladder performed as intended, the ODFW monitored fish use of the ladder in 1959 starting in mid-May. At the end of 1959, it was estimated that 5,529 rainbow trout had moved upstream through the fish ladder (Table 7.11-1). This estimate did not include January through mid-May 1959, when many more fish probably moved upstream during the spring spawning run. In general, the large number of fish using the fish ladder in 1959 indicated that the ladder performed well.

Table 7.11-1 Expanded monthly estimates of upstream passage of rainbow trout at J.C. Boyle dam.

Month	Year							
	1959	**1960**	**1961**	**1962**	**1988**	**1989**	**1990**	**1991**
January	--	--	0	0	--	0	0	0
February	--	--	99	0	0[1]	0	0	0
March	--	580	1,075	308	20	5	51	0
April	--	165	1,459	742	92	135	207	35
May	289[1]	55[2]	766	430	20	64	12	5
June	532	--	21	165	11	15	16	7
July	48	--	0	63	5	5	5	0
August	333	--	0	63	18	46	27	6
September	1,980	--	14	0	67	147	59	2
October	2,252	--	448	517	227	166	33	15
November	95	--	0	7	47	8	2	0
December	0	--	0	0	0	0	0	0
TOTAL	**5,529**	**800**	**3,882**	**2,295**	**507**	**588**	**412**	**70**

1 Estimates were made for the second half of the month only.

2 Estimates were made for the first half of the month only.

Sources: 1959, 1961, and 1962 estimates – Hanel and Gerlach (1964). 1960 estimates – Toman (1983).
1988 through 1991 estimates – ODFW Progress Reports (1992).

Estimates of fish movement through the ladder in 1960 were made only for the March through May period corresponding to the spring spawning migration. The estimated passage for the three months was 800 trout (Toman, 1983). Monitoring throughout 1961 and 1962 provided estimates of 3,882 and 2,295 trout per year, respectively, with most of the movement occurring in the spring (See Table 1, in Toman, 1983.). The fish ladder was not monitored again until 26 years later, starting in 1988 and continuing through the end of 1991. The numbers of fish passing through the ladder each of these four years was 507, 588, 412, and 70, respectively (Table 7.11-

1). It is important to note that the number of fish using the ladder from 1959 through 1962 is based on extrapolations while the data on fish using the ladder from 1988 to 1991 are the actual numbers of fish sampled. Consequently, direct comparisons of data should be viewed with caution.

The seasonal pattern of fish movement through the fish ladder was similar in all years. Most of the movement occurred in the spring, peaking in April, and again in the fall, mostly September and October (Table 7.11-1). The spring movement probably is associated with an upstream spawning migration. The autumn movement may be a redistribution response to the cooler stream temperatures at that time of year or an early movement to preferred wintering areas upstream of the dam.

The number of fish using the fish ladder annually in the 1988-1991 period was considerably smaller than what was estimated in the1959-1962 period.. The exact reasons for this decline in use of the ladder are unknown. Possible reasons may include: (1) water coming down the spillway at the dam may be providing a false attraction to the migrating fish such that many fish may be unable to find the entrance to the ladder; (2) differences in water temperature between the 4-mile bypass reach (consisting mostly of spring water) and the peaking reach downstream of the powerhouse may discourage fish from moving into the bypass reach and hence to the ladder; (3) the relatively high number of fish observed using to ladder in the 1959-1962 period may have been the result of the large numbers of hatchery trout planted below the dam in that and previous years, and (4) the ladder itself may not be performing efficiently.

Because of the decline in use of the fish ladder, the ODFW recommended that PacifiCorp conduct a radio-tracking study to assess the movement of trout as they approach the J.C. Boyle bypass, dam, and fishway entrance in an effort to determine if fish are passing through the ladder effectively. (See section 5.0.)

7.11.2.2 Spillway Flows

To determine whether false attraction to the spillway could explain the drop in fish counts between 1959 and the later period from 1988 through 1991, it was necessary to look at actual flow conditions at the dam for the years when fish counts were made. In reviewing the flow data (see Figures 7.11-1 through 7.11-6) it is assumed that spill occurred at the dam only when flows below the powerhouse (USGS Gauge No. 11510700) exceeded 3,350 cfs, which is the powerhouse capacity of 3,000 cfs plus a bypass flow of about 350 cfs.

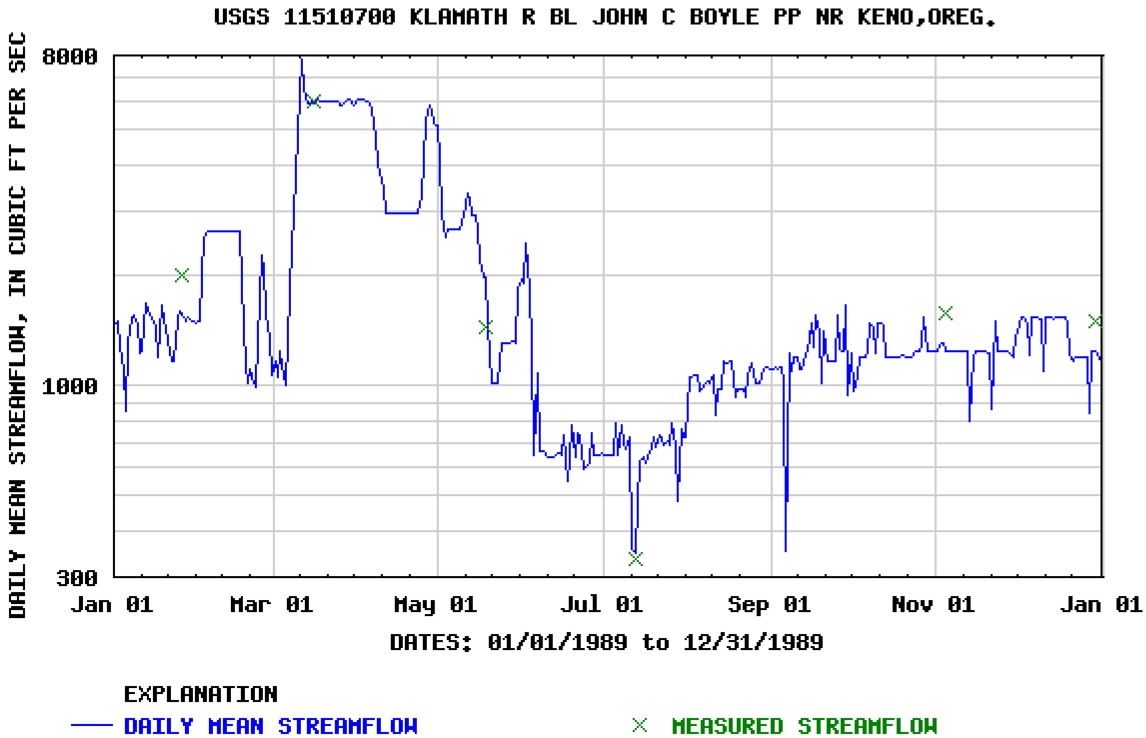

Figure 7.11-1. Flow conditions 1/1/1989 to 12/31/1989.

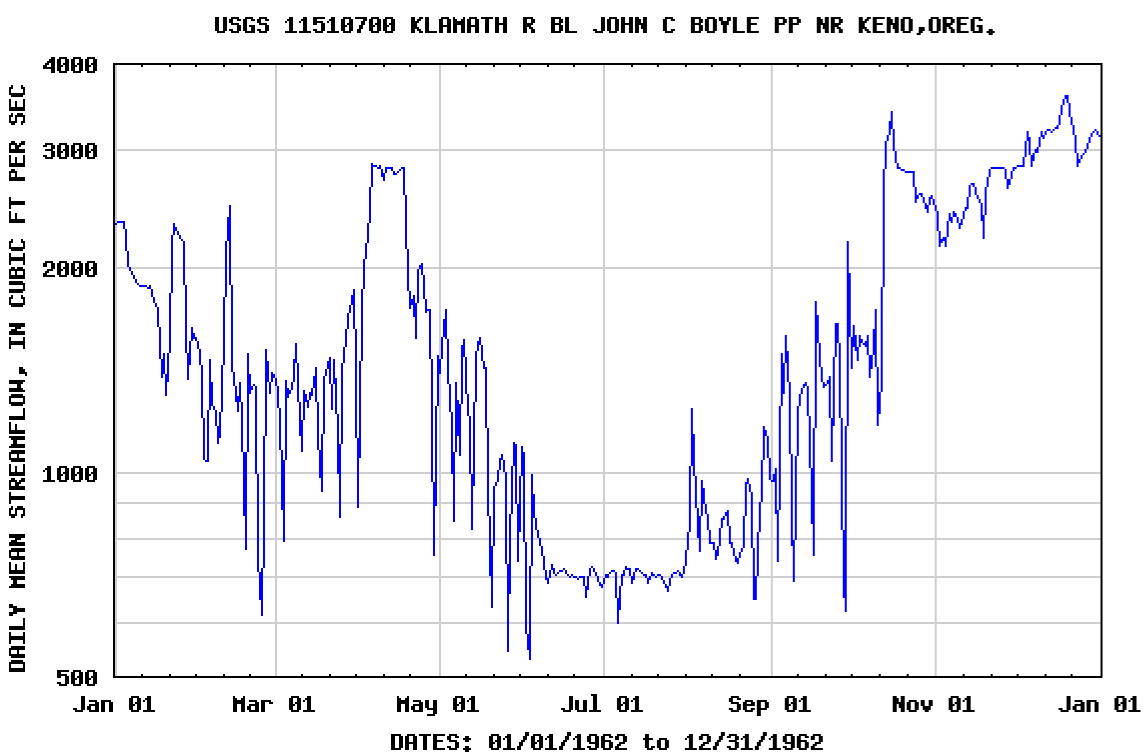

Figure 7.11-2 Flow conditions 1/1/1962 to 12/31/1962.

Figure 7.11-3. Flow conditions 1/1/198 to 12/31/1988.

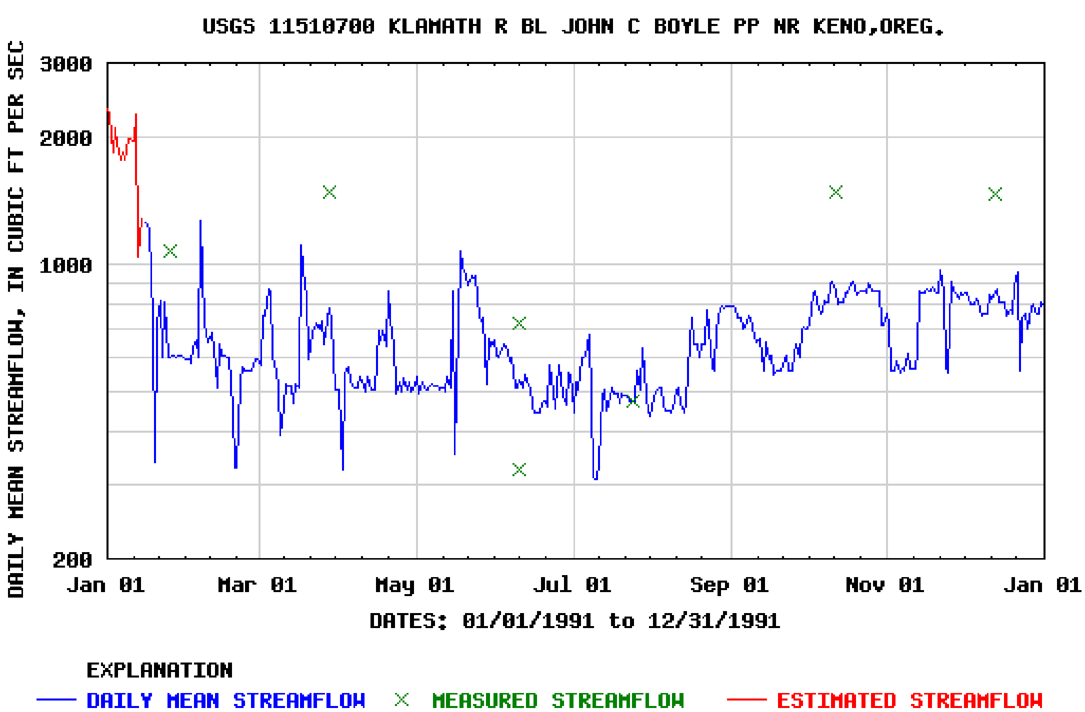

Figure 7.11-4. Flow conditions 1/1/1991 t0 12/31/1991.

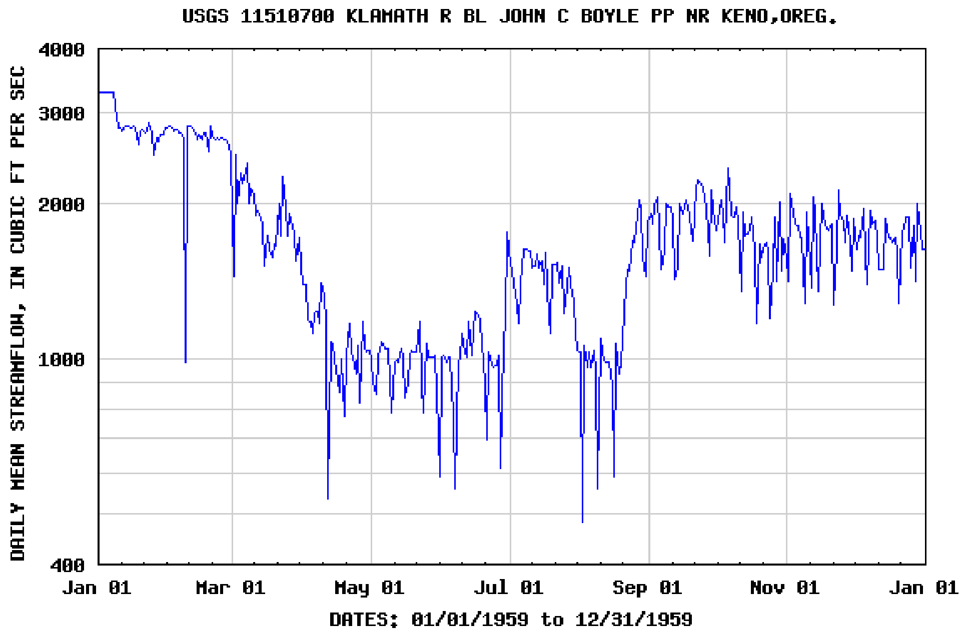

Figure 7.11-5 Flow conditions 1/1/1959 to 12/31/1959.

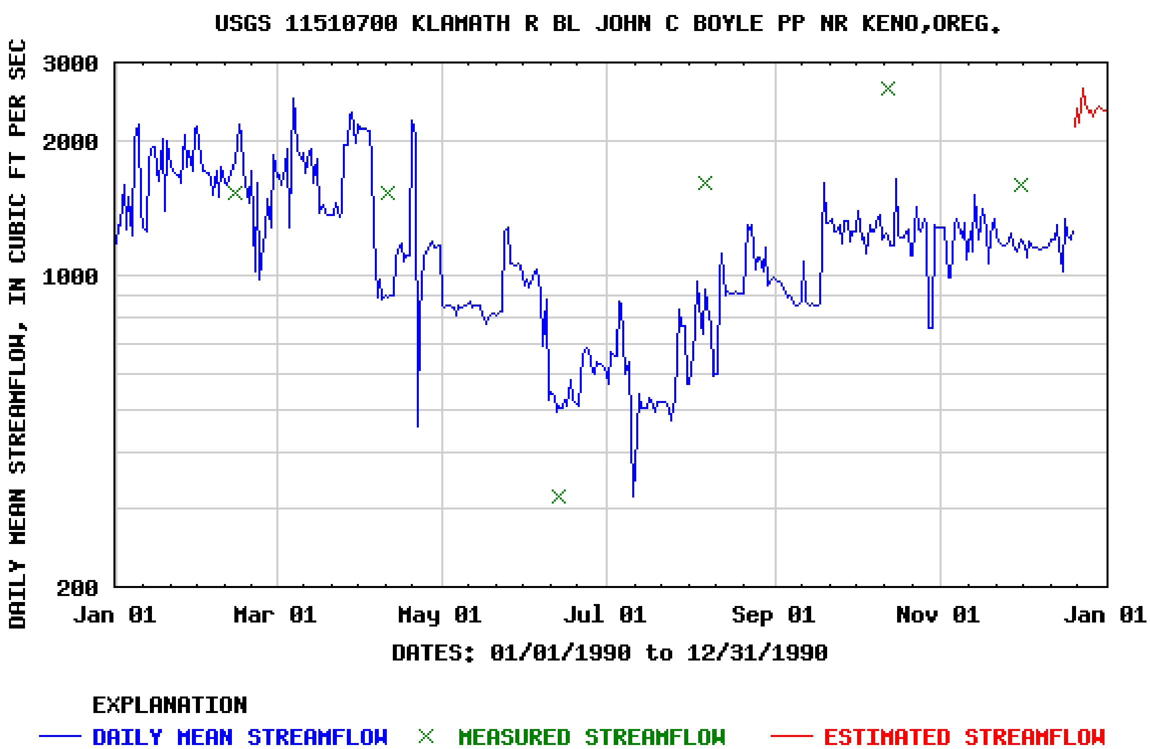

Figure 7.11-6. Flow conditions 1/1/1990 to 12/31/1990.

In 1959, the first year after dam construction, there was no spill at the dam except in the first week of January. River flows from mid-May (when fish ladder monitoring began) through the end of the year were generally between 1,000 and 2,000 cfs. Therefore, it can be assumed that there was little or no water passing over the spillway. The only flow at the base of the dam would have been the combined discharge through the fish ladder system (80 cfs) and the fish screen bypass (20 cfs) needed to meet the 100 cfs minimum flow requirement. Thus, there was no significant flow at the dam spillway to have created a false attraction in 1959, and the high fish use indicated that the ladder itself performed well under these nonspill conditions.

In 1961 and 1962, when annual fish estimates had dropped to 3,882 and 2,295, respectively, streamflows were similar to those in 1959 (i.e., they remained below the powerhouse capacity thus indicating that there was no spill at the dam). For years 1988 through1991, when the trout passage numbers were lowest, flow records reveal that there was no spill in 1988, 1990, or 1991. During these years, flow conditions at the dam were similar to those of 1959. Therefore, the hypothesis that spillway flows accounted for the significant drop in fish use of the ladder cannot be supported.

In 1989, spill occurred only for a short period of about 6 weeks. However, the spill coincided with the peak of the spring spawning migration in late March and April. Even with spills exceeding 3,000 cfs during most of April 1989, spring-run fish counts were still highest in that month, consistent with other nonspill years. These data suggest that the considerable spill that occurred during most of April 1989 did not dissuade the movement of fish through the fish ladder.

7.11.2.3 Water Temperatures

The ODFW monitored water temperatures in the J.C. Boyle fish ladder coincident with the trout movement studies between 1959 and 1962 (Toman, 1983). The vast majority of the fish moved up the ladder when water temperatures were between 45º and 60ºF. This period corresponded to the spring spawning migration, primarily in March and April, and the fall migration in late September and October. Although the bypass reach downstream of the dam is heavily influenced by springwater, water temperatures in the bypass are similar to those being discharged at the powerhouse at the times of year that the trout are moving upstream (City of Klamath Falls, 1989). During the summer, when there is a large temperature differential between the bypass and peaking reaches, trout do not tend to move upstream. The near lack of trout movement during the warm summer months also has been observed at Keno dam and tributaries in the Upper Klamath River basin with warm water temperatures (ODFW Progress Reports 1988 – 1993; Toman, 1983). Therefore, it does not appear that water temperature differential could be causing a decreased use of the J.C. Boyle ladder because there is little differential at the times of year when the fish normally migrate.

7.11.2.4 Hatchery Fish

ODFW annually planted 15,000 to 32,000 catchable-sized (8+ inches) rainbow trout downstream of J.C. Boyle dam in the 1959-1962 period (ODFW file date summarized in Toman, 1983). These hatchery fish may have contributed to the number of trout observed passing through the J.C. Boyle ladder during this period. ODFW continued to plant hatchery trout in the Klamath River until 1978 when the river was reclassified for wild trout management. The fact that counts of trout in the J.C. Boyle ladder dropped from approximately 2,000 - 4,000 per year in the early

1960's to about 500 per year by the late 1980's could be explained, in part, by the elimination of stocking of hatchery trout.

7.11.2.5 Tagging Studies

In 1990, the ODFW conducted an upstream and downstream trapping study in Spencer Creek, which enters the upper end of J.C. Boyle reservoir. As part of the study, 300 adult trout that passed upstream through the J.C. Boyle fish ladder were tagged (ODFW, 1990). Most of these fish were tagged in March and April 1990. The Spencer Creek trap collected 926 adult rainbow trout from March 4 through May 8, 1990. Of these fish, only eight were from the group that had been tagged at the J.C. Boyle fish ladder. On the basis of these results, the study concluded that nearly all of the adult trout migrating to Spencer Creek originated from the Keno reach upstream of J.C. Boyle reservoir. The destination of the majority of the trout that passed over the dam is unknown. No suitable spawning habitat other than in Spencer Creek is known to exist upstream of J.C. Boyle dam to Keno dam.

During the fall of 1988, BEAK Consultants tagged 453 rainbow trout more than 200 mm FL from the Klamath River downstream of the J.C. Boyle powerhouse (City of Klamath Falls, 1989). The ODFW monitored fish passage at the J.C. Boyle fish ladder in late 1988 and throughout 1989. None of the tagged fish was observed in the fish ladder.

In the winter-summer of 2003, PacifiCorp conducted a trout movement study at the J.C. Boyle Development using radio-tagged adult rainbow trout. An objective of the study was to assess movement to and through the J.C. Boyle fish ladder of trout previously captured and tagged downstream of the dam in both the bypass and peaking reaches. During the February through mid-May monitoring period, only one of 42 radio-tagged fish approached or ascended the fish ladder. The fish had been captured and tagged on February 13 approximately 1 mile downstream of the dam in the bypass reach. The fish ascended the ladder on April 2 in about a 3.5-hour period. It was later detected in Spencer Creek. The successful passage of this fish after it entered the fish ladder indicates that it was not delayed or deterred by the ladder at the dam. The lack of upstream movement toward the dam for 41 of the 42 tagged fish is consistent with the results of the 1988 tagging study noted above.

The results of these tagging studies provide concurring evidence that only a small fraction of the trout originating from downstream of the dam actually use the upstream fish passage facilities at J.C. Boyle dam, and that most trout from below the dam presumably spawn below the dam.

The complete results of the Adult Rainbow Trout Movement Study is presented in Section 5.0 of the Fisheries FTR.

7.11.2.6 Ladder Design

The upstream fishway at J.C. Boyle dam is a pool and weir type fish ladder with submerged orifices and an auxiliary water supply system to help attract fish to the ladder's entrance. It was designed and constructed in 1958 in accordance with criteria prescribed by the state of Oregon at that time. The primary criteria included 12-inch drops between pools and a vertical-to-horizontal slope of 1:8.5. Contemporary criteria for resident trout fishways are 6- to 9-inch drops between pools and a 1:10 slope.

It is unknown whether reconstructing the fish ladder in accordance with contemporary design criteria would noticeably improve fish passage efficiency. It is conceivable that a new facility would allow the fish to move through the ladder more quickly after they enter the ladder. However, it is doubtful that the non-contemporary design of the existing ladder could explain the decline in its use over the years To argue such would require the unlikely assumption that the ladder efficiency became progressively worse through the years, yet the ladder has remained unchanged.

7.11.2.7 Discussion

The fact that the number of fish passing J.C. Boyle dam in the 1959 – 1962 period was higher than in the more recent years indicates that there has been a change in the way rainbow trout are using the area near the dam. However, the evidence summarized above does not indicate that the current fish passage facilities or Project operations have contributed to the declining use of the ladder. A more plausible explanation for the reduced trout use of the ladder is that the trout population has modified its movement behavior over the years in an adaptive response to new conditions with the dam in place. The construction of J.C. Boyle Dam inundated nearly four miles of riverine habitat. The fish observed moving upstream over the dam in the first few years after dam construction would have been following their homing behavior to natal spawning or over-wintering areas, much of which may have been inundated by construction of the dam. It is known that Spencer Creek, which enters the reservoir, is a good spawning stream and still supports spawners from the upstream Keno reach. However, it is also likely that there was good spawning habitat at the mouth of Spencer Creek in the 4-mile section of the Klamath River that is now inundated. This reach of the Klamath River was relatively low gradient (15 ft/mi), and thus likely was a depositional area for spawning gravel originating from Spencer Creek and the upstream Keno reach.

7.12 RESIDENT FISH ENTRAINMENT AND TURBINE INDUCED MORTALITY

J.C. Boyle, Copco, and Iron Gate reservoirs support populations of resident fish including both native and non-native species. Popular sport fisheries occur in each reservoir targeting primarily bass, perch, and catfish. Rainbow trout, resident lamprey species, and Lost River and shortnose suckers also occur in the reservoirs. Of these three reservoirs, only J.C. Boyle reservoir has a fish screen, which does not meet current criteria; therefore, fish species that occur in these reservoirs can enter the powerhouse turbines.

Site-specific field studies to estimate fish entrainment and turbine survival rates are costly and often subject to considerable uncertainty (Eicher and Associates, 1992; FERC, 1995). PacifiCorp is addressing this issue of entrainment and turbine mortality by reviewing existing fisheries information for the Project reservoirs and tailwaters, coupled with other entrainment and mortality studies at projects with similar fisheries and environments. The purpose of the evaluation is to characterize the potential for entrainment and to estimate turbine-induced mortality of the fish most likely to be entrained. This information then can be used in conjunction with other fisheries information for the Project area to determine if entrainment is adversely affecting fish populations. It is expected that the AWG and FPWP will revisit this issue at a later date

The objectives of this review are as follows:

- Characterize the potential magnitude, size composition, species composition, and seasonal distribution of the annual fish entrainment at J.C. Boyle, Copco, and Iron Gate dams.
- Develop estimates of potential turbine-induced mortality at each powerhouse by applying relevant study results from other projects with turbine types and operating characteristics similar to those at the Klamath Project.
- Evaluate whether the probable degree of entrainment mortality is adversely affecting fish populations of concern in the Project area (i.e., do screening Project intakes or other mitigation measures appear biologically supportable).
- Use results of evaluation to determine need for additional study.

7.12.1 Methods

7.12.1.1 Fish Entrainment

The general study approach for assessing fish entrainment was to apply existing study trends and data from similar projects and interpret this information in conjunction with known fisheries data for the Project reservoirs and dam tailwaters. In the past 20 years, there have been many entrainment studies conducted at dams in cool water and warm water environments similar to those conditions in the Klamath Project reservoirs. Although highly variable, common trends and correlations with a number of biological, environmental, and physical site conditions have been noted (FERC, 1995). Potential physical factors affecting entrainment that will be addressed include reservoir size, dam height, forebay configuration, depth of intake, and water flow through the reservoir or powerhouse. Biological factors will include fish species present and those most likely to be entrained, fish size, seasonal and diurnal movements, and density dependent influences on fish movement.

7.12.1.2 Turbine-Induced Mortality

A considerable amount of literature is available on the causes of injury and mortality to fish as they pass through hydroelectric turbines. Factors affecting mortality relate to the probability of physical contact with moving turbine blades, pressure changes and cavitation, and shear forces and turbulence. Information that will be used to estimate mortality rates of entrained fish at each powerhouse will include: turbine design, number of turbine runner blades, hydraulic head, peripheral runner velocity, intake depth, operating efficiency, and size of fish entrained.

7.12.2 Results and Discussion

7.12.2.1 Characterization of Fish Entrainment

A first step in characterizing potential fish entrainment is to identify the species of fish and their relative abundance in the reservoirs being evaluated. Extensive fish sampling was conducted in J.C. Boyle, Copco, and Iron Gate reservoirs in 1998 and 1999 by Oregon State University (Desjardins and Markle, 1999). The sampling covered spring, summer, and fall seasons and included the use of six types of collection gear. Results of these studies are summarized below.

In J.C. Boyle reservoir, more than 6,000 fish representing 19 species were collected (Table 7.12-1). Ten species were native; nine were non-native. The five most abundant taxa collected were chub spp. (native), bullhead spp. (non-native), fathead minnow (non-native), pumpkinseed sunfish (non-native), and tui chub (native).

In Copco reservoir, more than 26,000 fish were collected (Table 7.12-2). Yellow perch (non-native) made up 81.5 percent of those collected. Other most common taxa included sucker spp. (native), golden shiner (non-native), bullhead spp.(non-native), and tui chub (native). Ten of the 18 identified species were native.

Table 7.12-1. Species counts and percentage of total catch for fish sampled in J.C. Boyle reservoir in 1998 and 1999 by seine, trawl, trammel, and trap nets (Desjardins and Markle, 1999).

Common Name	Native/Non-Native	Number Caught	Percent of Total
Chub spp.	Native	1,700	27.4
Bullhead spp.	Non-native	771	12.4
Fathead minnow	Non-native	722	11.6
Pumpkinseed	Non-native	572	9.2
Tui chub	Native	506	8.2
Sunfish spp.	Non-native	383	6.2
Sucker spp.	Native	269	4.3
Sacramento perch	Non-native	221	3.6
Crappie spp.	Non-native	198	3.2
Blue chub	Non-native	196	3.2
Smallscale sucker	Native	187	3.0
Speckled dace	Native	170	2.7
Largemouth bass	Non-native	95	1.5
Redband trout	Native	61	1.0
Shortnose sucker	Native	49	0.8
Yellow perch	Non-native	47	0.8
Cottid spp.	Native	40	0.6
Lamprey spp.	Native	9	0.1
Blue gill	Non-native	2	0.0
Golden shiner	Non-native	2	0.0
Lost River sucker	Native	2	0.0
Largescale sucker	Native	1	0.0
Total		**6,203**	**100.0**

Table 7.12-2. Species counts and percentage of total catch for fish sampled in Copco reservoir in 1998 and 1999 by seine, trawl, trammel, and trap nets (Desjardins and Markle, 1999).

Common Name	Native/Non-Native	Number Caught	Percent of Total
Yellow perch	Non-native	26,742	81.5
Sucker spp.	Native	3,077	9.4
Golden shiner	Non-native	1,123	3.4
Bullhead spp.	Non-native	600	1.8
Tui chub	Native	247	0.8
Chub spp.	Native	197	0.6
Crappie spp.	Non-native	187	0.6
Largemouth bass	Non-native	175	0.5
Shortnose sucker	Non-native	158	0.5
Pumpkinseed	Non-native	85	0.3
Unidentified spp.	Non-native/Native	84	0.3
Blue chub	Non-native	70	0.2
Centrachid spp.	Non-native	29	0.1
Smallscale sucker	Native	17	0.1
Speckled dace	Native	10	0.0
Cottid spp.	Native	3	0.0
Redband trout	Native	3	0.0
Fathead minnow	Non-native	2	0.0
Lamprey spp.	Native	2	0.0
Largescale sucker	Native	2	0.0
Lost River sucker	Native	2	0.0
Sacramento perch	Non-native	1	0.0
Total		**35,816**	**100.0**

In Iron Gate reservoir, more than 4,000 fish were collected representing 16 species, eight of which were native (Table 7.12-3). The five most commonly collected taxa were chub spp. (n), yellow perch (nn), bullhead spp. (nn), largemouth bass (nn), and golden shiner (nn).

Table 7.12-3. Species counts and percentage of total catch for fish sampled in Iron Gate reservoir in 1998 and 1999 by seine, trawl, trammel, and trap nets (Desjardins and Markle, 1999).

Common Name	Native/Non-Native	Number Caught	Percent of Total
Chub spp.	Native	1,316	32.0
Yellow perch	Non-native	562	13.7
Bullhead spp.	Non-native	471	11.5
Largemouth bass	Non-native	413	10.0
Golden shiner	Non-native	399	9.7

Table 7.12-3. Species counts and percentage of total catch for fish sampled in Iron Gate reservoir in 1998 and 1999 by seine, trawl, trammel, and trap nets (Desjardins and Markle, 1999).

Common Name	Native/Non-Native	Number Caught	Percent of Total
Crappie spp.	Non-native	222	5.4
Tui chub	Native	201	4.9
Pumpkinseed	Non-native	193	4.7
Sucker spp.	Native	118	2.9
Blue chub	Native	98	2.4
Centrarchid spp.	Non-native	44	1.1
Smallscale sucker	Native	22	0.5
Redband trout	Native	17	0.4
Shortnose sucker	Native	13	0.3
Speckled dace	Native	9	0.2
Green sunfish	Non-native	5	0.1
Lamprey	Native	4	0.1
Unidentified spp.	Non-native/Native	4	0.1
Channel catfish	Non-native	1	0.0
Fathead minnow	Non-native	1	0.0
Total		**4,113**	**100.0**

A second step in characterizing entrainment is to consider physical features of the reservoirs and dams that may affect entrainment rates. FERC (1995) conducted exploratory analysis of a number of physical characteristics of hydroelectric projects in an attempt to identify trends or associations between these characteristics and entrainment rates. Although the analysis indicated no strong statistically significant trends or correlations, in part because of the varying sampling methods and fish population vagaries among sites, some general trends were apparent for reservoir size, flow through the reservoir (or plant), and hydraulic head (or reservoir depth). These variables seem to relate to the potential fish abundance in the reservoir. Physical characteristics associated with the Klamath reservoirs are shown in Table 7.12-4.

Table 7.12-4. Characteristics of J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate reservoirs and hydroelectric intakes.

Characteristics	J.C. Boyle	Copco No. 1	Copco No. 2	Iron Gate
River mile (RM)	224.7	198.6	198.3	190.1
Dam height	68	126	33	173
Reservoir area (ac)	420	1,000	40	944
Reservoir length (mile)	3.6	4.5	0.3	6.8
Total storage (acre-ft)	3,495	46,867	73	58,794
Intake ceiling depth (ft)	10	22.5	0	23

The potential magnitude of annual entrainment at the Klamath Project developments was evaluated by first reviewing trends from entrainment field studies completed at hydropower projects from the late 1980s to the present (FERC, 1995, 1996a, 1996b, 1997). Of about 50 projects, 26 projects were selected for review. Projects were included that had dam heights greater than 20 feet, reservoir surface areas greater than 100 acres, and reservoirs that did not contain major populations of pelagic fish, such as alewives and gizzard shad (which are known to dominate entrainment counts where they exist, but are not present in the Klamath Project reservoirs). These physical characteristics were considered potentially important in covering a realistic range of conditions representing the Project reservoirs.

The 26 projects range in size from about 1.7 to 102 MW total generating capacity (Table 7.12-5); the Klamath Project developments range in size from 18 to 80 MW (see Table 7.12-1). All of the projects selected from the entrainment database were located on warm water or cool water river systems and most exhibit substantial overlap in the species composition of dominant resident fishes, which typically include largemouth bass, a variety of sunfishes, walleye, yellow perch, minnows, and catfishes/bullheads. Although entrainment sampling methods and analytical approaches varied considerably among the projects, all of the study plans were developed in consultation with, and in most cases approved by, state and federal resource agencies.

Table 7.12-5. Estimates of fish entrainment at 26 hydropower projects (FERC, 1995a, 1996a, 1996b, 1997a, 1997b; RMC Environmental Services, Inc., 1995).

Project/River System	State	Reservoir Size (acres)	Dam Height (feet)	Total Hydraulic Capacity (cfs)	Total Generating Capacity (MW)	Operating Mode[1]	Total Annual Entrainment (fish)
Brule/Menominee	WI	545	63	1,377	5.3	PK	25,296
Grand Rapids/Menominee	WI	300	28	3,870	7.02	ROR	91,646
Park Mill/Menominee	WI	539	22	2,500	4.6	ROR	46,138
White Rapids/Menominee	WI	435	29	5,188	8	PK	144,554
Crowley/NF Flambeau	WI	422	28	1,480	1.74	ROR	66,920
Caldron Falls/Peshtigo	WI	1,180	80	1,430	6.4	PK	78,335
Sandstone Rapids/Peshtigo	WI	150	42	1,400	3.8	PK	81,303
Centralia/Wisconsin	WI	250	23	3,640	3.2	ROR	834,377
Rothschild/Wisconsin	WI	1,604	29	3,300	3.64	ROR	212,720
Wisconsin River Division	WI	240	29	5,120	1.8	ROR	705,804
Cooke/Au Sable	MI	1,320	48	3,600	9	PU	222,423
Five Channels/Au Sable	MI	250	40	3,000	6	PU	426,906
Foote/Au Sable	MI	1,800	52	4,050	9	PU	154,779
Loud/Au Sable	MI	790	31	2,600	4	PU	162,526
Mio/Au Sable	MI	860	36	2,700	5	ROR	120,323
Kleber/Black	MI	270	44	400	1.2	ROR	63,145
Tower/Black	MI	102	20	360	0.56	ROR	30,295
Cataract/Escanaba	MI	180	70[2]	450	2	PK	31,094
Escanaba Dam 3/Escanaba	MI	182	31	1,250	2.5	ROR	21,762
Moores Park/Grand	MI	240	21	1,200	1.08	ROR	85,848

Table 7.12-5. Estimates of fish entrainment at 26 hydropower projects (FERC, 1995a, 1996a, 1996b, 1997a, 1997b; RMC Environmental Services, Inc., 1995).

Project/River System	State	Reservoir Size (acres)	Dam Height (feet)	Total Hydraulic Capacity (cfs)	Total Generating Capacity (MW)	Operating Mode[1]	Total Annual Entrainment (fish)
Croton/Muskegon	MI	1,209	40	3,700	8.8	ROR	219,761
Hardy/Muskegon	MI	3,902	100	4,500	30	PU	25,947
Rogers/Muskegon	MI	610	39	2,400	6.8	ROR	55,875
Buchanan/St. Joseph	MI	423	20	3,798	4.1	ROR	70,006
Prickett/Sturgeon	MI	773	57	642	2.2	ROR	115,979
Hawks Nest/New	WV	243	56	10,000	102	ROR	48,269

1 PK = peaking; PU = pulsed (intermittent operation to maximize turbine efficiency); ROR = run-of-river.

2 Dam height represents vertical head between diversion dam and powerhouse.

Potential fish entrainment at the Klamath Project reservoirs was characterized by reviewing trends from these other entrainment studies as follows:

- Magnitude of Annual Entrainment: To provide a reasonable expectation of the magnitude of entrainment that could be occurring, the entrainment database presented in Table 7.12-5 was queried for median annual entrainment values for all projects combined and for several categories of projects with similar physical features. Median entrainment values were examined rather than mean values for each category to minimize the influence of outliers. To examine the relationship between annual entrainment and dam height, reservoir size, and total hydraulic capacity, each of these variables was broken into several ranges for comparison.

- Size Composition: The likely size composition of entrained fish was inferred by reviewing data from entrainment studies where size information was available.

- Species Composition: Likely species composition was evaluated by characterizing trends in the top five species entrained at ten projects for which there was available species composition data and comparing these trends against the relative species abundance data available for the Klamath reservoirs.

- Seasonal Distribution: Potential monthly variation and seasonal peaks in entrainment rates were evaluated by summarizing trends reported for dominant species at the projects reviewed for which there were seasonal data available.

Magnitude of Annual Entrainment

The median annual number of fish entrained at the 26 projects reviewed is 83,576 (Table 7.12-6). The 25 percent and 75 percent values are 48,269 and 162,526, respectively.

To further characterize potential entrainment occurring at the Klamath River facilities, the relationships among annual entrainment and reservoir size, dam height, and hydraulic capacity were examined.

Table 7.12-6. Ranges and medians of total annual entrainment for various categories of hydroelectric projects.*

Project Category	Number of Projects	Range of Total Annual Entrainment (fish)	Median Annual Entrainment (fish)
All	26	21,762 to 834,377	**83,576**
Reservoir Size (ac)			
< 500	14	21,762 to 834,377	**75,655**
500 to 1,500	9	25,296 to 222,423	**115,979**
>1,500	3	25,947 to 212,720	154,779
Dam Height (ft)			
<50	19	21,762 to 834,377	91,646
50 to 150	7	25,296 to 154,779	**48,269**
Hydraulic Capacity (cfs)			
<1,000	4	30,295 to 115,979	47,120
1,000 to 5,000	19	21,762 to 834,377	**85,848**
> 5,000	3	48,269 to 705,804	144,554

BOLD – Indicates range applicable to the Klamath Project reservoirs.

* Source: FERC, 1995a, 1996a, 1996b, 1997a, 1997b; RMC Environmental Services, Inc., 1995.

Reservoir size (surface area) of the Project developments are 420 acres for J.C. Boyle, 1,000 acres for Copco, and 944 acres for Iron Gate. Reservoir size determines in large part the habitat characteristics and turnover rates of the reservoir, which in turn can influence the species composition, abundance, and population attributes of the resident fisheries subject to the risk of entrainment. The categorization of entrainment by reservoir size suggests that greater entrainment might be expected with larger reservoirs (see Table 7.12-6). For the middle size category (500 to 1,500 acres), which encompasses Copco and Iron Gate reservoirs, median entrainment for the reviewed database was 115,979 fish. The J.C. Boyle reservoir is 420 acres, which falls into the less than 500-acre category with a median entrainment of 75,655 fish.

Most of the projects available in the reviewed database were low head dams; all were less than 100 feet. Therefore, the database was separated into projects less than 50 feet (but more than 20 feet) and those between 50 and 100 feet. This comparison suggests that entrainment potential is greater at the lower head projects. A possible explanation for the tendency of higher dams to have less entrainment potential is the fact that shallow water species, such as sunfish and minnows, which are the most commonly entrained species, are less likely to be occupying the deeper water habitat near higher dams. J.C. Boyle dam is 68 feet high and Copco No. 1 and Iron Gate dams are 126 and 173 feet high, respectively, suggesting that entrainment at these dams might be less than the entrainment at most dams in the database. For those dams higher than 50 feet, median entrainment was 48,269 fish.

Annual entrainment also may be related to hydraulic capacity of the projects. Therefore, annual entrainment estimates for the reviewed database were categorized by flows less than 1,000 cfs, 1,000 to 5,000 cfs, and more than 5,000 cfs (see Table 7.12-6). For the mid-flow-range projects, which encompass the Klamath powerhouses (1,735 to 3,200 cfs), estimated median annual entrainment is 85,848 fish. This estimate is similar to the median for all projects combined (83,576 fish).

Size Composition

Small YOY fish likely would comprise the majority of fish entrained by the Project powerhouses. In most studies at other hydropower projects, fish smaller than 4 inches in length represented the great majority of estimated annual entrainment (SWES, 1992; FERC, 1995, 1996a, 1997). Table 7.12-7 summarizes the proportion of entrainment as small or YOY fish at 12 projects for which size composition data were reported. The proportion of fish less than 4 inches long exceeded 75 percent at eight of the projects and 90 percent at three of the projects. Production of YOY fish in healthy reservoir systems is often high, and many of these small fish disperse from upstream habitats in response to changing habitat needs and density-dependent influences on resource availability. Compared to larger fish, YOY fish generally are more susceptible of being transported downstream during higher flow conditions and are less capable of escaping intake velocities.

Table 7.12-7. Proportion of entrainment as small or young-of-year fish and game fish/pan fish.[*]

Project	River	Proportion as Small or YOY Fish
Rothschild	Wisconsin	88% YOY game fish and pan fish
Wisconsin River Division	Wisconsin	98 %< 4 inches
Centralia	Wisconsin	97 %< 4 inches
Brule	Menominee	86 %≤ 6 inches
White Rapids	Menominee	82 %< 4 inches
Grand Rapids	Menominee	81 %< 4 inches
Park Mill	Menominee	79 %≤ 4 inches
Caldron Falls	Peshtigo	63 %< 4 inches 91 %< 6 inches
Sandstone Rapids	Peshtigo	93 %< 4 inches
Prickett	Sturgeon	84 %≤ 4 inches
Escanaba Dam 3	Escanaba	75 %≤ 6 inches
Crowley	North Fork Flambeau	78% ≤ 4 inches

[*] Source: FERC, 1995a, 1995b, 1996a, 1996b, 1997b.

Species Composition

Table 7.12-8 shows the relative abundance of the top five entrained species at ten of the 26 projects reviewed. Species most commonly entrained include black crappie, bluegill, yellow perch, walleye, and shiners. Channel catfish (as fry) were common at two of the Wisconsin River projects (Wisconsin River Division and Centralia). White suckers were commonly entrained only at the Sandstone Rapids Project in Michigan. By families, the centrarchidae (bass and sunfish), percidae (yellow perch, walleye, logperch, and darters), and cyprinidae (minnows and shiners) were most commonly entrained (Table 7.12-9). Species of these families also are well represented in the Klamath impoundments: percids (yellow perches), centrarchids (sunfishes, bass), ictalurids (bullheads), and cyprinids (chubs and fathead minnows).

Table 7.12-8. Percent relative abundance of the top five entrained species at ten hydroelectric projects in the Upper Midwest.*

Species	Rothschild	Wisconsin River Division	Centralia	Crowley	Brule	White Rapids	Grand Rapids	Park Mill	Caldron Falls	Sandstone Rapids
***Centrarchidae* (Sunfishes):**										
Black crappie	48.4	--	1.9	5.7	--	11.3	--	--	30.8	25.4
Bluegill	17.6	25.4	4.2	--	--	13.7	--	18.6	4.8	--
Sacramento perch	--	3.4	--	--	4.7	--	--	--	--	5.4
Largemouth bass	--	--	--	--	--	--	--	--	--	10.5
Rock bass	--	--	--	--	--	--	--	21.5	--	--
Pumpkinseed	--	--	--	--	--	--	--	--	--	--
***Ictaluridae* (Bullhead Catfishes):**										
Channel catfish	5.1	32.7	75.3	--	--	--	--	--	--	--
Yellow bullhead	--	19.2	3.0	--	--	--	--	--	--	--
Black bullhead	--	--	--	--	--	--	--	5.1	--	--
***Percidae* (Perches And Darters):**										
Yellow perch	--	--	--	15.6	43.3	11.0	--	--	41.2	4.2
Walleye	--	--	--	34.8	15.5	10.8	--	6.2	5.7	--
Logperch	7.0	--	--	17.9	5.1	--	9.3	--	--	--
Blackside darter	--	--	--	4.8	--	--	11.9	--	--	--
Banded darter	--	--	--	--	--	--	7.7	--	--	--
***Cyprinidae* (Minnows):**										
Common shiner	--	--	--	--	14.9	25.6	--	--	--	--
Emerald shiner	--	9.8	11.5	--	--	--	--	--	--	--
Fathead minnow	--	--	--	--	--	--	--	5.8	--	--
Golden Shiner	--	--	--	--	--	--	--	--	3.4	--
Rosyface shiner	--	--	--	--	--	--	--	--	--	--
Unidentified cyprinids	5.7	--	--	--	--	--	10.3	--	--	--
***Catostomidae* (Suckers):**										
White sucker	--	--	--	--	--	--	--	--	--	32.7
***Gasterosteidae* (Stickelbacks):**										
Brook stickleback	--	--	--	--	--	--	7.6	--	--	--

* Source: FERC (1995a, 1997b); Normandeau Associates, Inc., (1994).

Table 7.12-9. Species composition of J.C. Boyle, Copco, and Iron Gate reservoirs by family group as found by trammel net, trap net, trawl, and seine sampling in 1998 and 1999 by PacifiCorp and Oregon State University.

Family	J.C. Boyle (Percent)	Copco (Percent)	Iron Gate (Percent)
Cyprinidae (chubs, minnows, shiners)	53.1	5.0	49.2
Percidae (yellow perch)	0.8	81.5	13.7
Centrarchidae (bass, sunfish)	23.7	1.5	21.3
Ictaluridae (bullheads, catfish)	12.4	1.8	11.5
Catostomidae (suckers)	8.1	9.5	3.4
Salmonidae (trout)	1.0	0.0	0.4
Cottidae (sculpins)	0.6	0.0	0.0
Petromyzontidae (lamprey)	0.1	0.0	0.1

The comparison suggests that sunfish and yellow perch probably dominate entrainment at the Klamath hydroelectric developments. These species as YOY tend to reside in shallow water and, thus, may be more prone to becoming entrained at the relatively shallow intakes at the Project dams. Chubs also may be entrained at high rates because they are one of the most abundant species in the reservoirs. However, they are generally bottom dwellers and, thus, may not be as prone to entrainment as their relative abundance in the reservoirs might suggest. Similarly, bullheads and suckers are bottom dwellers and they too may be less prone to entrainment through the relatively shallow intakes especially at Copco and Iron Gate reservoirs. The intakes at both these reservoirs are shallow, but are above water that is deeper than 100 feet near the dam. The projects in the database indicating high entrainment rates of catfish and bullheads (and total entrainment as well) were Wisconsin River projects with reservoir depths less than 30 feet (see Table 7.12-5) and consequently with intakes drawing water from the bottom.

Most of the entrainment at the Project developments likely consists of non-native fish species, including yellow perch (Copco and Iron Gate), pumpkinseed, bluegill, crappie, other sunfish, and bullheads. The most abundant native species found in the Klamath reservoirs are chubs (tui and blue) and they undoubtedly would make up a significant proportion of the entrainment. Suckers have not been found to be a highly susceptible species to entrainment at most projects, especially those with shallow intakes.

In 1997 and 1998, an entrainment study was conducted at the Link River developments: East Side and West Side powerhouses. The results provide useful information regarding species susceptibility to entrainment in the Klamath River system (New Earth/Cell Tech and PacifiCorp, 1999). Although Upper Klamath Lake is much different than the downstream reservoirs in many ways, they share many of the same fish species. Minnow species (blue and tui chubs and fathead minnows) made up 78 percent of the entrainment at the powerhouse intake canals (Table 7.12-10). These were followed by yellow perch and sculpin (two species). Suckers (four species) made up 3.5 percent of the total entrainment.

Table 7.12-10. Relative abundance of fish entrained at Link River dam into the East Side and West Side canals.

Common Fish Name	No. of Fish	Relative Abundance(%)
Blue chub	214,204	48.99
Fathead minnow	67,577	15.46
Tui chub	57,675	13.19
Yellow perch	28,534	6.53
Klamath Lake sculpin	27,068	6.19
Marbled sculpin	11,931	2.73
Sucker unknown	8,690	1.99
Shortnose sucker	4,687	1.07
Sculpin unknown	4,413	1.01
Unknown species	4,345	0.99
Lamprey unknown	2,340	0.54
Lost River sucker	1,664	0.38
Unidentified partial remains	1,003	0.23
Slender sculpin	929	0.21
Rainbow trout	624	0.14
Minnow unknown	564	0.13
Speckled dace	333	0.08
Chubb unknown	298	0.07
Klamath largescale sucker	257	0.06
Brown bullhead	65	0.01
Sunfish	18	< 0.01
Total	**437,219**	**100%**

Source: New Earth/Cell Tech and PacifiCorp (1999).

Another line of evidence regarding the potential entrainment rates and species for the Project reservoirs is the fish community data available for the Klamath River downstream of the J.C. Boyle dam and powerhouse. Some of the species commonly found in J.C. Boyle reservoir, especially bluegill and pumpkinseed sunfish, also are found in the area immediately below the dam where the water consists primarily of that from the fish ladder and fish screen/bypass system (Table 7.12-11). However, the lower segment of the bypass reach contains much fewer of these reservoir species. In the 16-mile reach between J.C. Boyle powerhouse and Copco reservoir, none of the sunfish, perch, or bullhead species commonly found in the reservoir was observed in the river (Table 7.12-12). This suggests that entrainment rates of these reservoir species may be low, turbine mortality may be very high, the riverine habitat does not support such species, and/or that those fish that are entrained move quickly downstream to Copco reservoir.

Table 7.12-11. Percent of total CPUE (fish per-hour) by near-shore backpack shocking—J.C. Boyle bypass reach, upper and lower segments.

Fish Species Common Name	Relative Abundance Upper Segment All Seasons Combined (%)	Relative Abundance Lower Segment All Seasons Combined (%)
Redband/Rainbow trout	11.1	38.7
Blue chub	4.5	1.4
Tui chub	5.0	0.7
Chub spp.	--	--
Speckled dace	35.0	2.6
Sculpin (marbled)	15.5	53.3
Lamprey	0.5	--
Shortnosed sucker	--	--
Lost River sucker	--	--
Klamath sucker spp.[1]	--	--
Unknown sucker spp.	--	--
Largemouth bass	1.1	0.7
Sacramento perch	0.5	--
Bluegill	7.2	--
Pumpkinseed	7.2	1.4
Black crappie	0.5	--
White drappie	0.5	--
Fathead minnow	--	1.4
Yellow perch	--	--
Bullhead spp.	11.1	--
Unknown species[2]	--	--

1 Largescale and/or smallscale suckers.

2 Most likely fathead minnows and/or chubs.

Table 7.12-12. Percent of total CPUE (fish per-hr) near-shore backpack shocking—J.C. Boyle peaking reach.

Fish Species Common Name	Relative Abundance (%)[1]
Redband/Rainbow trout	4.2
Blue chub	1.0
Tui chub	1.2
Chub spp.	--
Speckled dace	63.5
Sculpin (marbled)	23.5
Lamprey	--

Table 7.12-12. Percent of total CPUE (fish per-hr) near-shore backpack shocking—J.C. Boyle peaking reach.

Fish Species Common Name	Relative Abundance (%)[1]
Shortnosed sucker	--
Lost River sucker	--
Klamath sucker spp.[2]	--
Unknown sucker spp.	6.7
Largemouth bass	--
Sacramento perch	--
Bluegill	--
Pumpkinseed	--
Black crappie	--
White crappie	--
Fathead minnow	--
Yellow perch	--
Bullhead spp.	--
Unknown species[3]	--

[1] Based on electrofishing CPUE.
[2] Largescale and/or smallscale suckers.
[3] Most likely fathead minnows and/or chubs.

Additional evidence regarding species vulnerability to entrainment can be inferred from downstream fish trapping that was conducted by the ODFW between 1988 and 1991 at the J.C. Boyle dam fish ladder. Although targeting trout, the trapping effort found that pumpkinseed made up nearly 90 percent of the non-trout species moving downstream through the ladder (Table 7.12-13). Tui chub and smallscale sucker were 5.4 percent and 2 percent of the non-trout species composition, respectively. The seemingly high susceptibility of pumpkinseed sunfish to entrainment comports with numerous other entrainment studies showing high entrainment rates for sunfishes.

Table 7.12-13. Number of identified non-trout species collected from downstream traps in the J.C. Boyle fish ladder.

Species	Number caught	% of Total
Pumpkinseed	263	89.5
Tui chub	16	5.4
Smallscale sucker	6	2.0
Fathead minnow	4	1.4
Blue chub	1	0.3
Brown bullhead	1	0.3
Largemouth bass	1	0.3
Speckled dace	1	0.3
Yellow perch	1	0.3
Total	**294**	**(99.8 - rounding)**

Source: ODFW (1988-1991).

Seasonal and Diurnal Distribution

Peak fish entrainment at the Project developments most likely occurs in spring and summer, following the spawning seasons of centrarchids, ictalurids, perch, and other species with high reproductive potential, when YOY fish are most abundant and tend to be dispersing into rearing habitats. Based on monthly variation in entrainment reported by FERC (1995), entrainment likely peaks between April and June, with entrainment of multiple-spawning species, such as bluegill and other sunfish, potentially showing secondary peaks in the fall. In the Link River study, most entrainment occurred in the late July through October period. Poor water quality conditions in Upper Klamath Lake during this period (high pH and temperature, and low dissolved oxygen) may be contributing to the downstream movement of fish through the East Side and West Side powerhouses. The lowest entrainment for most species would be expected to occur from late fall through winter when fish movements generally are suppressed by colder water temperatures.

Most entrainment studies of resident fish indicate there is little consistency in diurnal pattern among sites for the most commonly entrained species except for ichtalurids (catfish and bullheads), which show a much greater tendency for night movement. However, the East Side and West Side entrainment study found that the vast majority (more than 75 percent) of the total fish entrainment for all species combined, as well as for sucker species, occurred at night (New Earth/Cell Tech and PacifiCorp, 1999). Therefore, it is reasonable to assume that most fish in the downstream Klamath River reservoirs also would have a tendency to become entrained at night. This strong nighttime tendency is an important factor to consider when characterizing entrainment potential at J.C. Boyle, Copco No. 1, and Copco No. 2 powerhouses, all of which do not operate at night during most of the year because of power peaking operations. It may be too much to conclude that 75 percent of entrainment is avoided by not operating at night, but it is reasonable to assume that the nighttime shutdown would greatly minimize fish entrainment potential. In fact, the significant nighttime movement observed at Link River dam is the basis for the current summer shutdown of the West Side powerhouse and the requirement to minimize load (200 cfs) at the East Side powerhouse at night, per the USFWS 2002 BO to reduce take of endangered shortnose and Lost River suckers.

7.12.2.2 Turbine Mortality

Causes of Mortality

Injury and mortality of entrained fish passing through hydroelectric turbines principally occur by the following mechanisms (based on reviews provided by Cada [1990] and Odeh [1999]):

- Mechanical injury: Injury from direct strikes or collisions with turbine runner blades, abrading or rubbing against a turbine system component, and grinding when fish are drawn into small gaps with high-velocity zones.
- Pressure changes: Injuries caused by rapid pressure decreases that occur momentarily immediately behind the turbine blades. The main cause of pressure-related mortality is injury to the swim bladder from decompression.
- Cavitation: The rapid formation of vapor pockets or bubbles caused by subatmospheric pressures within a turbine. The bubbles collapse violently as they travel to areas with higher pressures, creating localized shock waves. Rapid exposure to hydrostatic pressures equal to the vapor pressure of water, followed by instantaneous return to atmospheric pressure, appears to be the principal cause of cavitation-related fish mortality.
- Turbulence and shear stresses: Fluid-induced forces that occur when two masses of water moving at different velocities are incident with each other. Fish encounter shear forces through the turbine system as they move from one velocity zone to the next. Shear forces are most pronounced along the leading edges of the runner blades, vanes, and gates. Shear forces and turbulence can spin or deform entrained fish.

Physical characteristics of turbine systems affecting the mortality rates of entrained fish include: head, turbine design, peripheral runner velocity, wicket gate openings, number of runner blades, gap sizes, flow through the turbine, passage routes through the turbine, turbine blade angle, and the size and species of fish entrained (Cada, 1990; Odeh, 1999; Cada and Rinehart, 2000). Many of these factors are sources of mechanical injury to fish and also produce turbulence, shear forces, and pressure changes that may injure fish (Cada and Rinehart, 2000).

Actual pressures experienced by entrained fish depend on turbine design, flow rate, and head. High-head turbines tend to be smaller units and generally have a higher rate of pressure change per unit time than low head turbines (Odeh, 1999).

Design factors affecting cavitation include hydraulic head on the turbine runner, net head, surface irregularities on the turbine blades, and abrupt changes in flow direction (Cada,1990; Odeh, 1999). Cavitation at hydroelectric facilities is difficult to predict, and turbine operators strive to minimize it through proper design to avoid costly damage to turbine surfaces (Cada, 1990).

Factors Influencing Mortality

The probability that an entrained fish will survive passing through a turbine depends on the size of the fish, the characteristics of the turbine, and the operational parameters of the hydroelectric facility. A review of the literature shows that the following factors should be considered:

- Turbine type
- Net head
- Peripheral runner blade speed
- Operating efficiency
- Depth of intake
- Fish length

Turbine Type. Francis units once were believed to show higher mortality rates than propeller-type (Kaplan) turbines. However, the Francis units generally were operated at higher heads, turbine settings, and blade speeds than were the propeller-type turbines. Tests comparing the two types of turbines at the same head, turbine setting, and blade speed showed no significant difference in fish mortality between Francis and propeller-type turbines (Cramer and Oligher 1964) . This suggested that mortality was the result of operating conditions, and not turbine design. Review of turbine-induced fish mortality tests by Bell et al. (1981), Turbak et al. (1981), and Eicher and Associates (1987), also indicated that at similar head, turbine setting, and blade speed no difference exists in fish mortality induced by Francis versus propeller-type units.

Net Head. A review by Eicher and Associates (1987) suggested that net head, by itself, was not a major factor affecting fish mortality induced by either Francis or Kaplan turbines. Heads varying from 40 to 410 feet were included in the review. Although greater mortality was shown to occur at higher head projects, the high runner speed and pressure were considered to be the actual cause of higher mortality at the higher head dams (Cramer and Oligher, 1964).

Peripheral Runner Blade Speed. Eicher and Associates (1987) found a correlation (r=0.73) between fish mortality and peripheral runner blade speed for Francis runners. They rated blade speed as the principal variable related to fish mortality in Francis units. They obtained a regression of Y=.52X-18.52 for percent mortality versus peripheral runner blade speed (fps) for 22 tests at 14 different Francis-turbine facilities. Most of the mortality estimates used in the Eicher regression were obtained from mark-recapture studies on anadromous salmonid smolts, and, thus, accounted for delayed mortality and any indirect mortality associated with predation in the tailrace. No correlation could be made between mortality and runner blade speed for Kaplan units.

Operating Efficiency. All studies reviewed indicated that mortality is lowest when turbines operate at peak efficiency. Peak turbine efficiency incorporates all operating parameters that produce low turbulence, low cavitation, and overall streamlined flow of water through the turbine. Parameters that are involved in peak efficiency are optimum wicket gate opening, optimum turbine setting, optimum runner blade speed, and optimum runner blade clearance. When units operate at high efficiency, cavitation is extremely low and a smooth flow is produced.

Intake Depth. Turbine intake depth can cause higher mortality if the intake is near the bottom of the water column in deep water. Mortality may occur from rapid decompression in the tailwater after fish are entrained from a deep water intake. The negative pressure behind the turbine blades can be substantially lower than the pressure to which bottom-dwelling fish are acclimated. Thus, bottom-dwelling fish may be more prone to pressure-related injuries. It also has been suggested that physostomous fish, such as trout and salmon, which have a pneumatic duct connecting the swim bladder to the esophagus, are more capable than physoclistous fish (lacking a pneumatic duct) of adjusting to rapid decompression by venting the swim bladder.

For fish that are entrained by shallow intakes, such as those at the Klamath Project, the pressure change experienced by the fish when passing through the powerhouse may be only slightly less than the pressure to which surface-dwelling fish are acclimated. Results of experiments with juvenile yellow perch showed mortality from rapid decompression occurred only when intake depths were greater than 33 feet (Cada 1990). Fish eggs and larvae are more tolerant to pressure change; their critical intake depth is about 160 feet.

<u>Fish Length.</u> Fish length has been found to be one of the most important variables affecting turbine mortality. Collins and Ruggles (1982), in testing trout of three size categories (65 to 99 mm, 100 to119 mm, and 120 to159 mm) that passed through a Francis turbine, found that mortality increased approximately proportional to fish length. A similar relationship was identified via multiple regression analysis of survival data from 95 tests of axial flow turbines (Headrick, 2001). Logically, the probability that an entrained fish will be struck by a turbine blade is a function of fish size as well as the characteristics of the turbine (runner velocity, number of blades, blade angle, and area of water passage). Formulas used to predict the probability of a blade strike incorporate fish length as a direct multiplier (Von Raben, 1957; DOE, 2003; Waporo, 1987; Bell, 1991).

The probability-of-strike equations have been used as surrogates to estimate mortality. While often the strike probability has closely matched empirically derived mortality estimates, technically, the strike formula alone does not account for all the variables known to affect mortality. On one hand, the formula underestimates mortality where other injury sources, such as hydraulic shear and pressure changes, are involved. On the other hand, the formula overestimates mortality because not all blade strikes result in mortality. Turnpenny et al. (1992) derived a regression equation that estimates the mortality-to-strike ratio (K) to the length of fish:

$$K=0.153(\ln l)+0.012$$

where l is fish length in centimeters.

Applying this formula to a 10-cm fish, for example, would result is a predicted turbine blade strike-to-mortality ratio of 36 percent. Therefore, to obtain an estimate of total mortality as a result of a blade strike would require multiplying the strike probability by the mortality-to-strike ratio.

<u>Mortality Estimates for Klamath Project Turbines</u>

All of the turbines at J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate powerhouses have Francis runners. The mortality rates of fish entrained through these turbines is best estimated using the Eicher (1987) regression formula depicted in Figure 7.12-1, which relates mortality to peripheral runner velocity (Table 7.12-14).

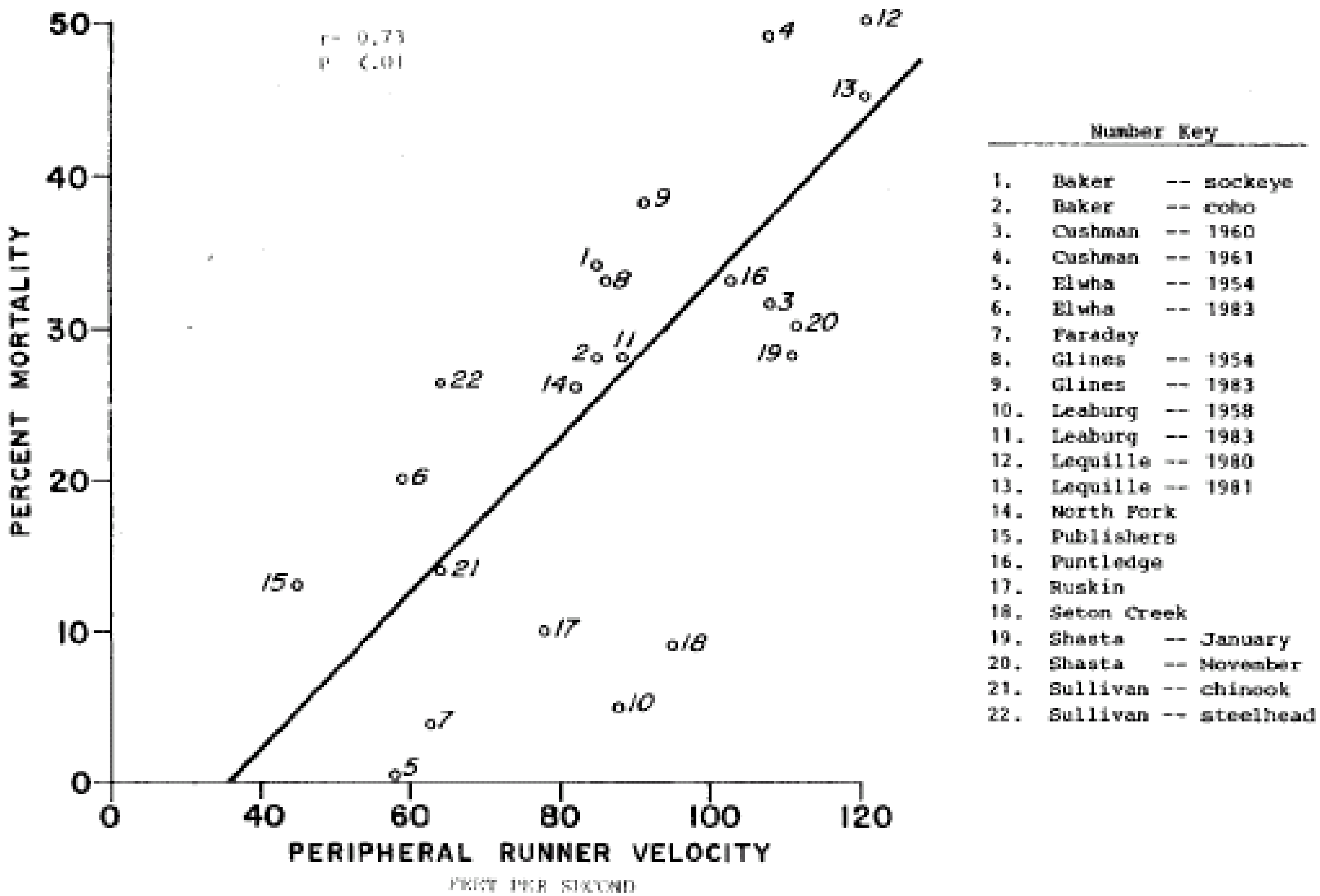

Figure 7.12-1. Relationship of peripheral runner velocity to mortality for Francis turbines.
Source: Eicher (1987).

Table 7.12-14. Turbine characteristics of J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate facilities.

Turbine Characteristics	J.C. Boyle		Copco No. 1		Copco No. 2		Iron Gate
	Unit 1	**Unit 2**	**Unit 1**	**Unit 2**	**Unit 1**	**Unit 2**	**Unit 1**
Turbine Type (e.g., Francis)	Francis	Francis	Francis	Francis	Francis	Francis	Francis
Orientation (vertical or horizontal)	Vertical	Vertical	Horizontal	Horizontal	Vertical	Vertical	Vertical
Hydraulic Capacity (cfs)	1,500	1,500	1,600	1,600	1,600	1,600	1,735
Generating Capacity (MW) (nameplate)	40	40	10	10	13.5	13.5	18
Head (ft)	463	463	123	123	152	152	158
Number of Runners	1	1	2	2	1	1	1
Number of Blades per Runner	15	15	17	19	17	19	15
Runner Diameter (in)	88	88	82	79.75	99.57	97.82	98.25
Runner Speed (revolutions per minute)	277	277	200	200	171.5	171.5	180
Peripheral Runner Velocity (fps)	**106.2**	**106.2**	**71.6**	**69.6**	**74.5**	**73.2**	**77.2**

In estimating turbine mortality using the Eicher formula it is critically important to account for the size of fish that are being entrained. Most studies used in the development of the Eicher regression equation were conducted on salmonid smolts between 100 and 200 mm in length. The average size of resident fish entrained at nearly all reviewed projects, and likely for the Project developments as well, is 50 to 75 mm in length. Thus, the mortality rate of the typical entrained resident likely would be about half or less than that of the fish used in the Eicher regression. Table 7.12-15 shows the estimated mortality rate for fish of various sizes for the J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate turbines. It was assumed that the fish used in the Eicher regression averaged 150 mm in length and that mortality for other sizes are directly proportional to length.

Table 7.12-15. Estimated percent turbine-induced fish mortality by fish size class at Klamath Project powerhouses.

Powerhouse	150 mm	100 mm	75 mm	50 mm
J.C. Boyle	36.6	24.4	18.3	12.2
Copco No. 1	17.9	11.9	8.9	6.0
Copco No. 2	20.0	13.3	10.0	6.7
Iron Gate	21.5	14.4	10.8	7.2

Turbine mortality at the two Copco powerhouses and at Iron Gate would be expected to be about 10 percent for the most likely size of fish (75 mm) to be entrained and about 20 percent for fish in the size range of 100 to 200 mm (see Table 7.12-14). Nearly all fish entrained at Copco No. 1

powerhouse would be expected to pass through the Copco No. 2 powerhouse, thus exposing those fish surviving the first powerhouse to the potential cumulative mortality at the second powerhouse. Potential mortality of fish passing through the high-head J.C. Boyle powerhouse would be 20 to 40 percent.

7.12.2.3 Potential Fisheries Impacts

A common understanding is that fish residing in hydroelectric reservoirs can become entrained through powerhouses and that a portion of them are killed as they pass through the turbines. The median number of fish entrained annually at the 26 FERC-reviewed projects summarized in this report is approximately 83,000 fish. However, it is likely that the J.C. Boyle and Copco powerhouse intakes entrain fewer fish than observed at the other reviewed projects because of the frequent shut down of these powerhouses at night (for load following) when most native species appear to move downstream (based on results from the East Side and West Side entrainment study). Also, the shallow intakes at the deep-water dam faces at Copco and Iron Gate may further reduce the likelihood of bottom dwelling species, such as suckers and bullheads, from becoming entrained. However, even considering these possible minimizing factors, it is likely that annual entrainment still is several tens of thousands of fish at each of the projects. Yellow perch, sunfishes, and chubs are likely to be the most commonly entrained species.

Even though entrainment may be less at the Klamath Project dams than observed at other sites, the rate of mortality associated with turbine passage is probably greater because of their relatively higher head (and thus greater turbine runner velocity).

The question as to whether entrainment mortality is causing a biologically significant impact to resident fish populations and whether this impact is great enough to require costly mitigation (typically in the form of fish exclusion/screen facilities) has been a significant challenge for resource agencies and hydropower licensees (FERC, 1995). While the need for downstream protection facilities for anadromous fish is rarely disputed, the need to install facilities for resident fish often is debatable.

The response of resource agencies to the entrainment mortality issue has varied by state. In the most conservative cases, resource agencies have stated that "biological significant impacts" to fish populations is not relevant, but rather that individual fish are being killed and that protection measures are needed to mitigate the losses (FERC, 1996a, 1996b). States that have taken this approach nearly always have recommended fish protection measures regardless of the results of site-specific entrainment mortality studies. FERC, in conducting their environmental analyses, generally has considered it important to review and interpret available information on potential impacts on fish populations because this could have a significant bearing on its balancing of developmental and nondevelopmental resources (FERC, 1996a, 1996b).

In the assessments of environmental effects of turbine entrainment mortality, the following factors have been considered:

- Native versus non-native fish: Entrainment at most of the Midwest and eastern projects reviewed by FERC (1995) consisted primarily of native fish species. However, reservoirs in the western United States, including those on the Klamath River, often are dominated by non-native species. Many of these non-native species, such as bass, catfish, perch, and sunfish, support popular sport fisheries. Resource agencies in the West often are confronted with management conflicts between protecting native species and supporting angler desires for game fish.

The Project reservoirs contain large populations of non-native species (see Tables 7.12-1, 7.12-2, and 7.12-3). Copco reservoir, in particular, contains more than 80 percent yellow perch. This species, as well as the sunfishes and catfish/bullhead species, likely would make up a majority of the fish entrained. Chubs, both blue and tui, would be the most likely entrained native species.

- Downstream habitat: Entrainment mortality removes fish that otherwise would contribute to recruitment to waters downstream of the dam. Therefore, it is important to consider the type of downstream habitat available to these fish and whether recruitment from upstream is important to the downstream populations. At J.C. Boyle dam, fish that pass the dam enter a 20-mile-high gradient stream reach. Nearly all of the species found in J.C. Boyle reservoir prefer slackwater lake habitat. The fact that few of these species are found in the river downstream of the powerhouse may attest to their strong lake preference and inability to remain in the riverine habitat. Those that pass the dam (via screen/bypass system) probably reside in the river pools just downstream of the dam before cool spring water inputs, or move quickly downstream and enter Copco reservoir.

  Fish that become entrained at Copco No. 1 enter the short (0.3-mile) Copco No. 2 foebay, which is essentially riverine in nature. These fish most likely quickly enter the Copco No. 2 powerhouse intake. Those that survive turbine passage at the Copco No. 2 powerhouse enter directly to Iron Gate reservoir, which provides habitat similar to Copco reservoir.

  Nearly all of the fish in Iron Gate reservoir are species that prefer lake habitat. Because there are no reservoirs downstream of Iron Gate, it is reasonable to assume that those fish that are entrained and survive through the turbines eventually will perish in the downstream riverine habitat.

- Compensatory mortality: Because the vast majority of fish entrained at hydroelectric projects consists of small YOY individuals, the principle of compensatory mortality has been applied to the interpretation of biological impacts associated with entrainment mortality on fish populations. Compensatory mortality refers to the fact that when the density of a fish population is reduced, the competition for population limiting resources, such as food or space, also is reduced thereby leading to higher survival rates of the remaining fish. Density-dependent compensation is important to fisheries management because it operates to offset the losses of individuals. It is the reality of this compensatory process upon which management of commercial and recreational fisheries is based (Ricker, 1975). When assessing impacts of entrainment mortality, it has been argued that compensation tends to regulate the population toward a long-term average supported by habitat availability, and, therefore, higher mortality at the YOY stage has little or no impact on the population as a whole, especially when there appears to be an abundance of YOY fish as indicated by high entrainment rates.

- Density-dependent dispersal: Most small fish that leave a reservoir may be "excess" fish from a habitat standpoint (i.e., as the rearing capacity of the upstream habitat becomes filled, the excess fish disperse downstream). High entrainment rates may be indicative of a healthy upstream population, which by definition would have surplus reproductive capacity.

PacifiCorp maintains that the results of this literature-based review, coupled with site-specific fisheries data, provides sufficient information t conclude that fish entrainment and associated turbine mortality are not likely to be causing significant adverse effects on resident fish populations in Project reservoirs.