Crater Lake Water and Power Project Feasibility Study

Feasibility/Conceptual Design Report

Revision No. 1

January 20, 2016

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Appendices

Appendix A Operations Modeling Charts (electronic model file delivered to client)
Appendix B Conceptual Design Drawings
Appendix C Canyon Hydro Budget Estimate – Turbine Generator
Appendix D Cost/Benefit Model Spreadsheets (electronic model file delivered to client)

Distribution

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Revision Log

Revision No.	Date	Revision Description
0	12/16/15	Issue for Client Review
1	1/20/16	Final Report Issue

Executive Summary

This report presents the results of a feasibility study of the Crater Lake Water and Power Project (CLWPP) performed by McMillen Jacobs Associates (McMillen Jacobs) for the Cordova Electric Cooperative (CEC) and City of Cordova (COC). This evaluation presents the fundamental geotechnical, engineering, construction, permitting and economic analyses required to make a Project feasibility determination. McMillen Jacobs analyzed the Project basis through a series of analyses, culminating in a Project conceptual cost estimate and cost/benefit analysis. These studies and conclusions are presented below.

Feasibility Study Focus	Conclusions
Geotechnical and Geohazards Analysis	No fatal flaw geotechnical or geologic hazards were identified, although significant field investigation will be required for design.
Baseline Hydrology Study	Crater Lake hydrology is sufficient to support a storage/hydro Project and represents both a water supply and renewable energy resource that could provide significant benefit to Cordova.
Water Supply System Evaluation and Penstock Sizing	COC of Cordova water system could benefit substantially from the additional, high quality water available through a storage resource. The existing water distribution pipeline can support this additional water.
Operations Modeling	The preliminary operations model showed multiple options for combined water/power supply and may offset as much as 25% of current diesel generation.
Initial Project Design Criteria and Conceptual Civil Design	The Project could employ conventional design and construction methods to develop a combined hydroelectric and water supply Project.
Permitting Evaluation and Strategy	No fatal flaws were identified in permitting. COC administers public lands and private land agreements could be negotiated. Permit requirements should be addressed early in the Project development cycle.
Constructability Review, Cost Estimate and Schedule	The Project is constructible with conventional and helicopter based methods. Cost estimates range from $12M to $26M, with a median cost of $17.2M for the base Project. Further design is required to narrow this range.
Cost/Benefit Analysis	The Project shows promise with an estimated cost/benefit ratio for CEC of 1.36 (AEA method) and 1.27 (inflation adjusted). The Project shows both negative and positive outcomes for COC, depending on assumptions, with an estimated ratio of 0.83 (AEA method) and 1.09 (inflation adjusted).

This very interesting Project appears to be feasible to construct and operate and would provide significant energy and water supply benefits to CEC and COC. The economic analysis strongly supports Project development for CEC and appears marginal on a purely economic basis for COC, with the assumption of approximately equal cost-sharing for development. A more balanced cost/benefit is possible through modified assumptions on cost sharing. It is important to acknowledge the feasibility-level nature of this evaluation and recognize that additional analyses will be required to support design, cost estimating, additional operations modeling and cost/benefit sharing. These analyses will lead to a more refined cost and value for the Project. Lastly, CEC and COC should recognize the unique challenges and uncertainties associated with construction and operation of any Alaska heavy civil works Project.

1.0 Introduction and Purpose of Study

The CEC and Cordova awarded a contract to McMillen Jacobs to evaluate the feasibility of the Crater Lake Water and Power Project (CLWPP or Project) and develop a Feasibility/Conceptual Design Report for the Project. McMillen Jacobs identified several Project configurations, narrowed the options to a single preferred alternative and provided detailed feasibility-level analyses of the preferred alternative.

1.1 Project Description

The Project is located approximately 2.5 miles northeast of Cordova, Alaska. The Project area is shown in Figure 1-1.

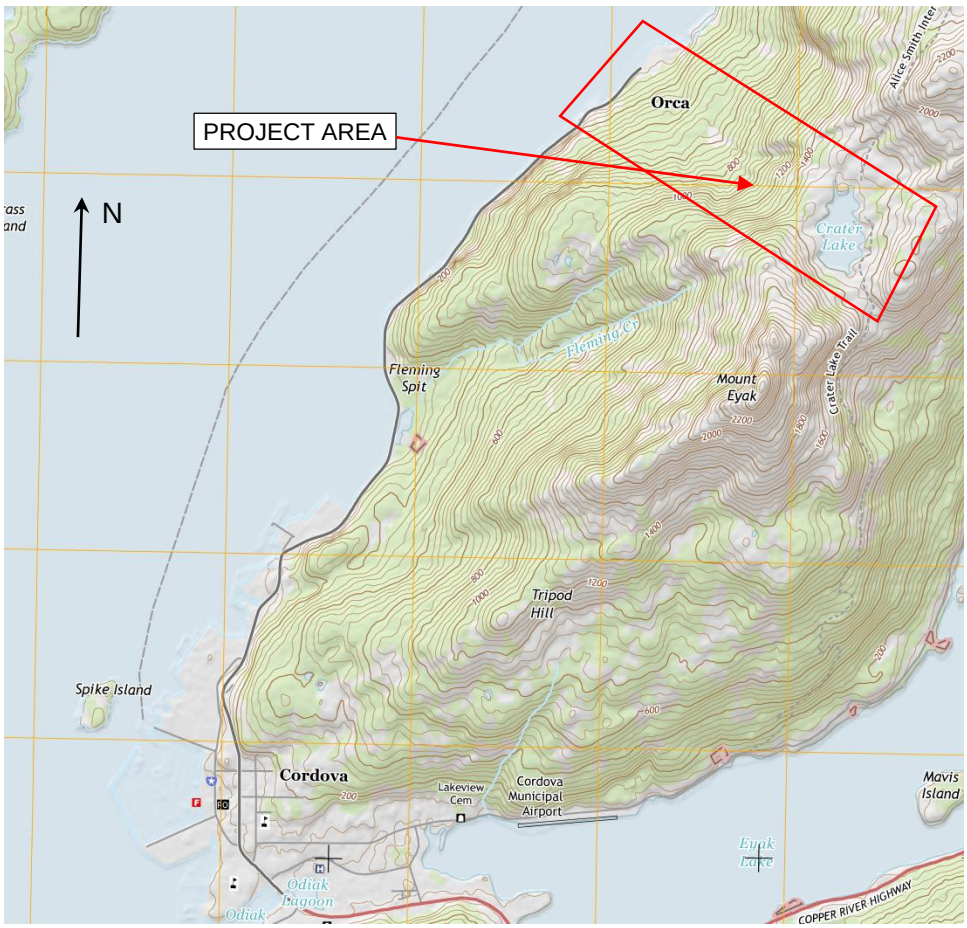


Figure 1-1. Project Area

The proposed Project will utilize the existing Crater Lake as a high head reservoir to generate hydropower and as an auxiliary water supply source to COC. The primary components of the Project include a small dam (on the order of 25 feet tall) at the existing Crater Lake outlet, a roughly 3,800-foot-long penstock, and a powerhouse/water treatment plant located near tidewater elevation. The general arrangement of the Project features is shown in Figure 1-2.

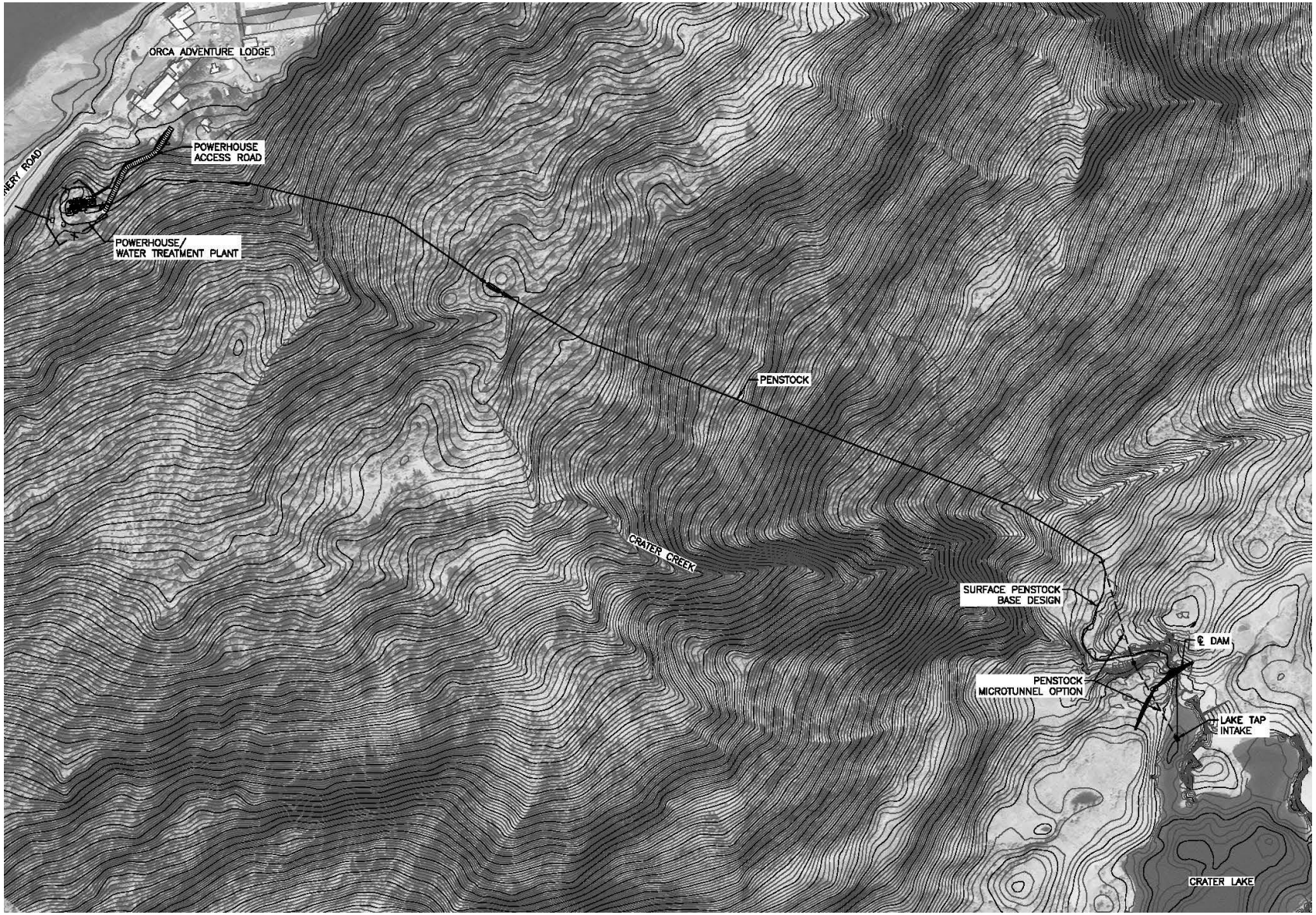


Figure 1-2. Project Features

1.2 Report Organization

This report describes the studies and relevant conceptual design for the Project at the feasibility stage, as well as a proposed constructability review, cost estimate and conceptual Project schedule. The report also includes an assessment of the cost-benefit of the Project in today's economic setting and a Projection of Project value given a set of future economic development scenarios. This report presents the results of all these feasibility-level analyses, organized as follows:

- Data Review and Compilation
- Geologic and Geotechnical Reconnaissance
- Hydrologic Evaluation
- Water Supply and Treatment Evaluation
- Generation and Operations Model
- Conceptual Civil Design Criteria
- Constructability, Cost Estimate and Schedule
- Permitting Scope and Planning
- Feasibility-Level Cost/Benefit Analysis
- Summary and Conclusions

The intent is that this report provide a conceptual design, cost estimate and economic analysis to determine overall Project feasibility. Based on the results of this analysis, CEC and COC may continue with more advanced engineering, economic and environmental studies leading to a build/no-build decision.

2.0 Data Review and Compilation Introduction

The purpose of this section is to summarize the information made available for the CLWPP feasibility study. This report functions as the original reference index for the Project. The report is organized based on either the water or power aspects of the Project and some of the available information (such as topographic map coverage) provides a data source for both focus areas. Table 2-2 at the end of this section provides a summary of the relevant data sources.

2.1 Previous Studies

Based on the historic data provided by CEC, the Crater Lake Project has been studied at the concept level since the early 1960s, beginning with a simple plan map of the Project for (then) Cordova Public Utilities (North Pacific Consultants, 1960). It appears that Crater Lake (called Summit Lake) was identified with a small dam, penstock to an area at the Orca Cannery, and connected to the COC through an existing 2400-volt (V) overhead transmission line. This study was followed by a number of reconnaissance-level studies in the following decades, with the most relevant being the "June 1982 Stone & Webster Report Technical Data Cordova Power Supply Interim Feasibility Assessment" (USACE, 1982), executed as a deliverable under the Coordination Act Report for the US Army Corps of Engineers (USACE), Alaska District. This 1982 report primarily identifies the biological resources that would be potentially impacted by the Project, referencing a 1979 reconnaissance report by CH2M HILL Company (not available). The report summarizes the generation from Crater Lake at 458 kilowatts (kW), not enough to meet (then) current Cordova Public Utilities peak demand of 3,150 kW.

Electricity and water use rate information was also retrieved from Internet access portals on the web for CEC (http://cordovaelectric.com/) and COC (http://www.cityofcordova.net/).

2.2 Land Ownership

Land ownership information was transmitted with the Request for Proposals (RFP) and included a general aerial photo with land ownership overlay. The Project may involve different landowners, depending on selection of the preferred penstock alignment, powerhouse/treatment plant location and access to transmission. The alignment and structure land ownership, as currently envisioned, is shown in Table 2-1.

Table 2-1. Land Ownership Potential by Project Feature

Feature	Potential Owner(s)
Dam Site	City of Cordova
Penstock	City of Cordova State of Alaska The Eyak Corporation (potentially)
Powerhouse	City of Cordova
Powerhouse Access Road	City of Cordova Orca Adventure Lodge (private)

At the completion of the feasibility study, the final list of affected landowners will be used to negotiate access agreements for the future geotechnical design investigation and may be used to negotiate long-term easements or land acquisitions as necessary if the Project moves forward.

2.3 Recent Topographic Data Acquisition

In late 2014, CEC contracted with for satellite-based photogrammetry on enough area to encompass all Project options (E-Terra, 2014). CEC also contracted with to provide field survey and Global Positioning System (GPS) based ground control and detailed topographic survey of the area within the anticipated dam footprint, several low-lying areas along the lake boundary (Edge Surveys, 2014) with emphasis on the drainage divide saddle to the south and on potential powerhouse locations near tidewater adjacent to Orca Inlet. More detailed penstock alignment and powerhouse site surveys will be required in the future, as design progresses on the preferred alternative, if warranted.

2.4 Hydrology/Meteorologic Data

A variety of hydrologic data sources for the Cordova area are variably relevant to the CLWPP. These include operational hydrologic data from the Power Creek Hydroelectric Project to the south, from the Snyder Falls Creek Hydroelectric Project to the east and a short-term record for Crater Creek outflows from Crater Lake for the last year (CEC, 2015). Each data set is variable in its detail and limitations, with the only directly relevant source from the Crater Lake outfall stream gage. At the time of RFP issuance, CEC was still in the process of acquiring the most recent data set from both Snyder Falls Creek and Crater Lake. The challenge to the Project is that Crater Lake is a distinct, limited geographic area of approximately 0.26 square-miles, with no glacial influence and minimal vegetation and soil.

The data from Power Creek does not directly measure overall basin runoff as a ratio of streamflow, because generation flows are not directly measured and bypass flows only capture a portion of the overall streamflow. Efforts to refine the interpretation of generation flow combined with bypass flow and site meteorology could be pursued, but the team made the decision to wait on the receipt of the most recent Snyder Falls Creek and Crater Lake outflow data before pursuing this option.

After the RFP was issued, CEC also provided additional meteorological data (NRCS, 2015) from the existing SnoTel weather station, located approximately 0.5 mile west of Crater Creek on the mountain above Cordova. This meteorological station is essentially the same elevation and microclimate as Crater Lake. It has a record of precipitation (snowfall and rainfall) for a continuous 10-year period and the data appears complete and reasonable.

Upon attempting to retrieve the last 2 years' data from Snyder Falls Creek, the CEC's hydrology consultant (Keta Engineering, 2015) reported that both the upper and lower stream gages had been subjected to natural geohazard events that may affect the quality of the record. An avalanche destroyed the equipment at the upper gage location and a rockfall deposited large debris in the stream cross-section for the lower gage, making the correlation between stream level and discharge flow subject to data smoothing techniques in post-processing. There were several other equipment maintenance and failure issues that eliminated the secondary redundant data acquisition measures in place at the lower gage site.

McMillen Jacobs' hydrologic staff ran some preliminary comparisons of the SnoTel and Crater Lake outflow gage data and there appears to be a solid correlation between data sets. The team elected to pursue more rigorous correlation of the complete Crater Lake outflow data set with the SnoTel data and used this data to develop a synthetic outflow record as the basis for the CLWPP reservoir sizing and water and power production estimates for the operational model.

2.5 Geology/Geotechnical Data

The existing geologic information was gleaned from the publically available resources such as the US Geological Survey (USGS)(Winkler et al., 1983 and others) and Alaska Division of Geological and Geophysical Survey(ADGGS) (Stevens et al., 2003). This was supplemented by the Humpback Creek geotechnical investigation report (R&M Consultants, 2008). Very little site-specific geologic data is available for Crater Lake. Most data sources focus on coastal Alaska geology in general, and more specifically on mineral resources and seismic activity.

2.6 Generation Data

CEC provided the annual power system report from the Alaska Center for Energy and Power (ACEP, 2014). This is an annual report that summarizes the contributions from both hydro and diesel generation for COC and provides a good graphic representation of overall seasonal demand trends.

2.7 Water Supply and Operations Data

The information provided by COC to date includes some recent photos of the Crater Creek intake structure and a general information summary of COC water usage for the years 2010 and 2014 from the Meals, Murchison and Orca treatment plants. A summary of the various data sources is presented in Table 2-2 below.

Table 2-2. Existing Data Sources for this Study

Existing Data Sources in Support of the CLWPP Feasibility Study			
Source Title	**Information Type** **Raw Data = D** **Report = R** **Other = O**	**Date or Date Range**	**Remarks**
Previous Studies			
Variety of sources. None provide real data, but are early indicators of Project potential.	O	Varies - from 1960 to present	CEC's most recent reconnaissance level reports and presentations are the most robust early level reports on record. Points to additional available detailed data that may have been used as early concept feasibility.
Land Ownership			
Land ownership figure from RFP	R Figure in RFP, general accuracy	2015	Good figure to illustrate variety of ownership. Line weights and location do not appear to be precise, e.g. Crater Creek thalweg does not appear to match underlying image very well.

Existing Data Sources in Support of the CLWPP Feasibility Study			
Source Title	**Information Type** **Raw Data = D** **Report = R** **Other = O**	**Date or Date Range**	**Remarks**
Various plat maps showing partial land ownership details and easements	O Plat map only	various	Some of the plat information masks potential alignment areas. Information incomplete or in "plat-speak", referring to other more detailed resources that were not provided.
Topography			
Edge Survey Surface Detailed Hand Topography	Topographic surface and maps in pdf format	10/14-16/2014	Covers the dam site and approximately 300 feet downstream with canyon walls along Crater Creek. Also includes southern saddle location at lake shore and several potential saddle dam locations.
E-Terra Satellite-based photogrammetry, entire Project area	D Geographic Information System (GIS) files and topographic surfaces	2014	The satellite photogrammetry was tied in with ground-based control provided by Edge Surveying. Control located near lake outlet at several locations and at sea level near Orca Lodge. Primarily in GIS format.
USGS topography	R Topographic maps	Various, outdated	Minimal detail, poor vertical resolution on forested sideslopes and within deep, incised channels.
Crater Lake Bathymetry	D Data files from Sonarmite, primarily SHP files	9/1/2015	Uncorrected for probe depth in water. Collected by Koplin in field.
Hydrology/Meteorology			
SnoTel Records	D SnoTel data records in Excel format	2005-2015	Daily precipitation totals (inches)
Crater Lake Outflow discharge data	D Stage-discharge data in Excel format	2014-2015	Daily discharge values. Good natural hard control with very little relationship shift potential.
Upper and Lower Snyder Falls Creek data	D Discharge curves in Excel format	2010-2015	Data has been post-processed to compensate for natural disturbances; some of the data has been "clipped". There are shifts in data with long periods between measurements.
Power Creek	D In Excel format	2011-2012	Please note there is long-term gage data for Power Creek at nearby location but discontinued. No overlapping data in hand with Crater Lake outflow

Existing Data Sources in Support of the CLWPP Feasibility Study			
Source Title	**Information Type** **Raw Data = D** **Report = R** **Other = O**	**Date or Date Range**	**Remarks**
Climate Records Cordova	O - Daily/Monthly Values	1949-2015	Archived Climate Data for long-term contextualization of local data.
Geology/Geotechnical			
USGS publications on regional geologic mapping (few)	R		Limited regional or specialized studies, primarily on minerals or hydrocarbon resources
Geotechnical Findings Report, Humpback Creek Hydroelectric Facility Reconstruction	R	12/18/08	Geologic investigation data report with limited geotechnical recommendations. Follow-on geotechnical basis report would be helpful.
Generation (CEC)			
Annual Power System Report for Cordova Electric Hydro-Diesel System	R with figures (pdf format)	April, 2014 covers calendar year October 2012 to 2013.	Automated data set produced from Supervisory Control and Data Acquisition System (SCADA) on Orca and Humpback Creek Projects. Diesel generation is presumably in response to shortfall on hydroelectric output, but hydro plant outages and operational variance can't be quantified from this data set. Report quantifies lost power generation with simplifying assumption that demand is not in place, but should check these "spill" periods against diesel generation to determine accuracy of assumptions. Spilled, lost or not-produced power is significant and 500kW reserve requirement significantly affects overall annual output.
Water Supply (COC)			
Annual water supply from COC's 3 water treatment plants from 2000 to 2014.	D	2000-2014	Monthly total production values (gallons) are provided from each plant.
Plans and specifications for the current system upgrades to attain Long Term 2 Enhanced Surface Water Treatment Rule (LT2) compliance.	D, R	2012-current	References include historic water usage by source and reports on ways to meet LT2 compliance and treatment equipment data and literature

3.0 Geologic and Geotechnical Reconnaissance

3.1 Field Reconnaissance

The McMillen Jacobs team consisting of Bryan Duevel, Matt Moughamian, and Kelly Tilford completed the site visit on August 27 and 28, 2015. On the first day, Mr. Tilford and Mr. Duevel were accompanied during the visit by Clay Koplin, Chief Executive Officer (CEO) of CEC, while Mr. Moughamian met with COC utilities department staff to gather water system data. On the second day, all four team members continued the reconnaissance. The reconnaissance team observed the following areas:

- The Crater Lake hiking trail between Eyak Lake and Crater Lake: The trail is considered a potential access route for construction equipment and materials to the lake.
- The eastern perimeter of Crater Lake and the lake outlet: The main dam site would be located at the lake outlet. The penstock intake would also be located in this vicinity.
- The slope between the Crater Lake outlet and tidewater along the preliminary surface penstock alignment: The penstock would be routed down this slope, with two alignments in consideration.
- The base of the slope near tidewater elevation: The new powerhouse would be located at one of two potential sites in this area.

The team accessed the site by foot and by helicopter. The objectives of the geotechnical reconnaissance were to identify significant geologic conditions; hazards and constraints; assess constructability concerns; and refine the penstock alignment.

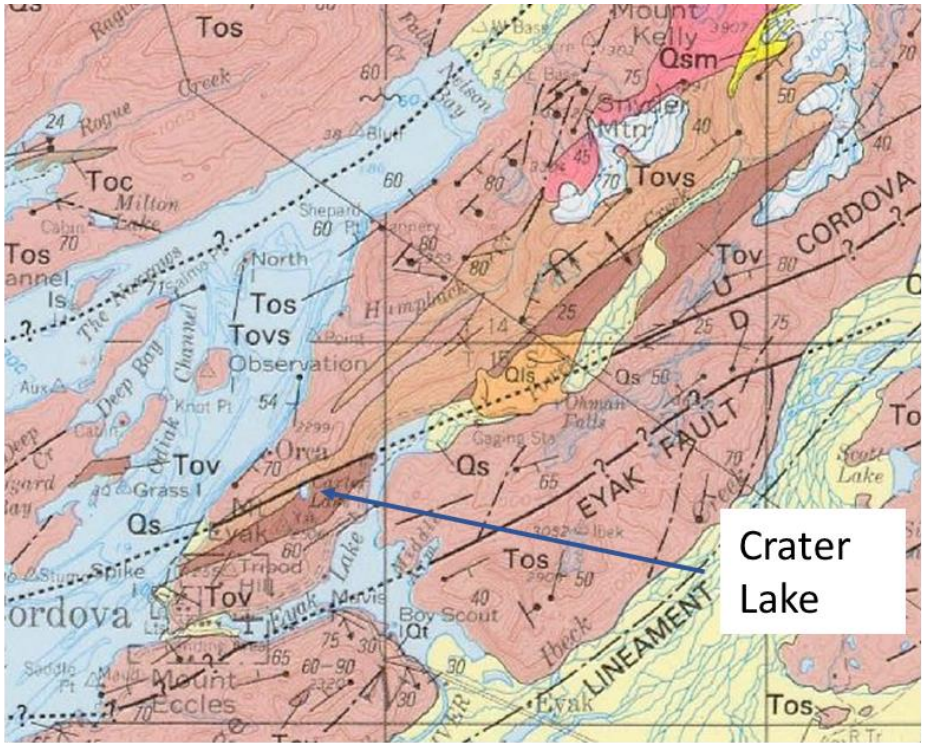
3.2 Site Description

3.2.1 General

Crater Lake is a natural lake located in the southeast portion of Prince William Sound on a northeast-southwest trending mountaintop ridge in the southern front of the Chugach Mountain Range. The mountains rise dramatically from sea level and are separated by geologically recent glacial troughs that form sea-level inlets to hanging glacial valleys above sea level. This varied geomorphology is widespread along the coast in this region. The lake rests at an elevation of approximately 1514 feet, approximately 2.5 miles northeast of Cordova. The lake appears to be a relict mountaintop glacial feature, interpreted to have been formed by glacial scouring that left behind this cirque (bowl) shape. There is no glacial activity in the drainage at present and no indication of glacial activity in the historic past, so this is probably a feature from the last glaciation period. The drainage area around the lake is relatively confined and covers an area of approximately 0.26 square-miles. The lake outlet (Crater Creek) spills rapidly down the steep mountainside immediately downstream of the lake as shown on Figure 1-2. Specific areas of the Project are described in more detail in the following sections.

3.2.2 Site Geology

The Project area is located at the boundary between the rugged Chugach Mountains to the east and the more subdued terrain of the Gulf of Alaska Coastal Province to the west. The Cordova area is characterized by a series of northeast-southwest trending ridges and islands, bounded by ocean inlets and deep glacial valleys (Winkler and Plafker, 1993). The regional geology is shown in Figure 3-1 below.



Tos **Sedimentary rocks, undivided**—Very thick, complexly deformed, monotonous sequence of thin- to thick-bedded turbidites consisting of sandstone, siltstone, and mudstone; metamorphosed to zeolite or prehnite-pumpellyite facies. Sandstone is feldspathic to lithofeldspathic. Abundant primary sedimentary features indicate deposition from sediment gravity flows, chiefly turbidity currents, on submarine-fan complex. Widespread, but minor amount of mudstone is hemipelagic and contains sparse planktonic foraminifers. Lenticular matrix-supported conglomerate, pebbly mudstone, and pebbly sandstone also are widespread. On the east side of Valdez Arm just north of Galena Bay, calcareous concretions in pebbly mudstone contain abundant fossil crabs and rare pelecypods and gastropods. The matrix-supported conglomerate, pebbly mudstone, and pebbly sandstone apparently mark distributary channels that fed midfan depositional lobes

Tov **Volcanic rocks, undivided**—Thick and thin tabular bodies of altered tholeiitic basalt consist chiefly of pillowed, massive, or crudely columnar flows, but also include pillow breccia, aquagene tuff, and diabase or gabbro sills; pillows have chilled margins that are palagonitic and amygdaloidal. Minor mudstone and siltstone that are interbedded with basalt are included locally. Commonly contains green, gray, or red chert in interstices between pillows, rarely includes interpillow clots of pink limestone or black mudstone. Radial cooling cracks in pillows commonly are mud-filled, especially near Ellamar. Metamorphosed to zeolite or prehnite-pumpellyite facies

Tovs **Interbedded sedimentary and volcanic rocks**—Variable proportions of interbedded, tholeiitic basalt and turbidites. Basalt consists of pillowed and massive flows, pillow breccia, and tuff. Turbidites, in most places, are mudstone, siltstone, and fossiliferous volcanogenic sandstone; in a few places nonvolcanogenic sandstone is interbedded. On Hinchinbrook Island and at Cordova, bioclastic limestone and pelagic limestone containing foraminifers are interbedded in several places, and on Ragged Mountain tuffaceous sandstone is common. Metamorphosed to zeolite or prehnite-pumpellyite facies

Figure 3-1. Regional Geologic Map (Winkler and Plafker, 1993)

Based on observations made during the site visit, the Crater Lake basin is primarily underlain by sheared and altered basalts and fine-grained metasedimentary rocks. The bedrock exposures indicate the presence of numerous small diabase or gabbro veins. The exposed rock outcrops away from the faults are moderately to closely jointed, with the majority of these fractures healed by a fine-grained white quartz or calcite filling. These rock types were primarily observed at the lake outlet, in the adjacent drainages in the immediate lake vicinity and east of the lake. The team also surveyed traces of the Cordova Fault and parallel and subparallel newly identified fault traces in the Crater Lake vicinity.

Existing mapping and tectonic history descriptions from the literature indicate that the western edge of the Chugach Range and accompanying Coastal zone are comprised primarily of complex accreted terrains associated with the northwest-trending subduction plate boundary between the Pacific Plate and the North American Plate. The bedrock types and condition are interpreted as indicative of a plate subduction boundary, where basaltic and gabbroic seafloor and fine-grained sedimentary rock has been sheared off the plate edge and pushed eastward into what is now the mainland. Description of the tectonic history indicates significant variation in the regional stress regimes as the tectonic plates shifted to accommodate changing structural dynamics from a pure subduction boundary to a transverse plate boundary with elements of both dip-slip and strike-slip faulting. Regional fault trends toward the northeast and southwest are coupled with glacial erosive features to create the fjord-like topography in the immediate Project area.

For the purposes of the Crater Lake geotechnical evaluation, it is sufficient to understand that the bedrock consists of both volcanic and well-cemented metasedimentary rock that is primarily closely to moderately fractured and fresh to moderately weathered. Minor thin, weathered clay zones were also observed within the shear zones associated with the faults.

3.2.3 Site Seismicity

The Project area is located in one of the most seismically active regions of the United States. Seismic activity is dominated by the Aleutian-Alaska megathrust zone which extends from the Aleutian Islands to south-central Alaska. The megathrust zone is the convergent plate boundary between the northwest-moving Pacific Plate which is being subducted below the North American Plate (Wesson et. al, 2007). The 1964 Prince William Sound earthquake was generated along this zone. This magnitude 9.2 earthquake was one of the largest ever recorded and caused severe ground shaking in the Cordova area. A number of active crustal faults are also located in south-central Alaska. Most notable of these is the Denali Fault, which generated a magnitude 7.9 earthquake in 2002.

Preliminary seismic design parameters have been developed based on 2012 International Building Code (IBC)/ASCE 7-10 which both make use of the 2008 USGS seismic hazard data (IBC, 2012). Based on soil and rock conditions at the site, a Soil Site Class B is appropriate for design. Recommended seismic design parameters are presented in Table 3-1. These parameters are appropriate for the design of all Project components. Seismic design parameters will be further refined in future design phases.

Table 3-1. IBC/ASCE 7-10 Seismic Design Parameters

Seismic Design Parameter	Value
Site Class	B
0-sec Period Spectral Acceleration	0.60
MCE Short Period Spectral Acceleration, SMS	1.512
MCE Long Period Spectral Acceleration, SM1	0.803
Design 0-sec Period Spectral Acceleration	0.40
Design Short Period Spectral Acceleration	1.008
Design Long Period Spectral Acceleration	0.535

Note: All values adjusted for Site Class B.

MCE = Maximum Credible Earthquake

3.3 Dam/Reservoir Geotechnical Observations

3.3.1 Site Description

Crater Lake is located in a bowl-shaped basin on top of the ridgeline extending northeast of COC of Cordova. The lake water surface elevation is approximately 1,514 feet. Topography within the basin is gently rolling, and rises away from the lake on all sides except at the outlet, which drops steeply off the mountainside within several hundred feet of the outlet. The perimeter of the bowl is formed by more prominent ridges that vary in elevation from about 1,550 feet along the northwest side of the lake to as high as 2,300 feet at minor peaks northeast and southwest of the lake. The outlet to Crater Creek is located at the northwest end of the lake, where the creek cuts a narrow channel through bedrock. A series of northeast-southwest trending lineaments (expressed at the surface in the form of shallow depressions) cross the bowl within the Project area.

The basin has been glacially scoured leaving a thin soil profile. Rock outcrops are prominent throughout the area. The basin is near the local tree-line elevation. Most of the area is covered in low shrubs and grasses, with localized areas of evergreen scrub up to 6 feet tall.

3.3.2 Geomorphology

As indicated above, the lake itself is interpreted as a geologically recent glacial scour feature remaining at the end of the most recent glacial period. This is also indicated by the presence of apparent glacial till (alluvium) within the lake, especially near the outlet channel as shown in Figure 3-2 below.

Figure 3-2. View of the Lake Outlet Area.

Note glacial till (sand and gravel) in the bedrock trench immediately upstream of the lake outlet.

The lake outlet drains to the northwest through a bedrock notch and most of the upper basin consists of bedrock outcrop with a thin veneer of rock talus and colluvium, typical of high Alaska mountain ranges. Within the basin, the lower reaches of the slopes decrease in steepness and are mantled by localized colluvial/alluvial fan deposits. Along the trace of the Cordova Fault on the east side of the lake, the lakeshore morphology consists of a wide fan that forms a terrace deposit indicating a higher lake level in geologic time as shown in Figure 3-3. The surface expression of the Cordova Fault is presented in Figure 3-4.

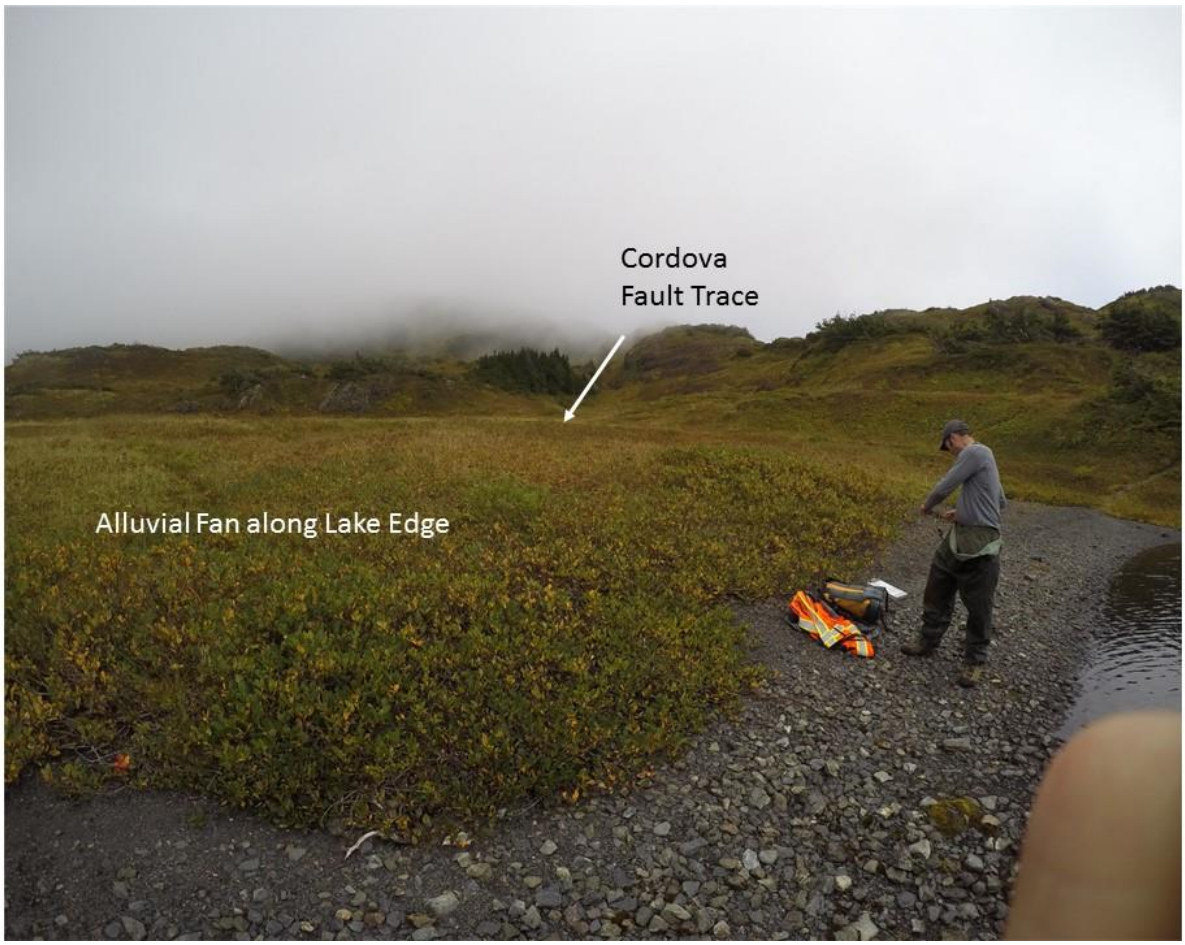


Figure 3-3. View east, Uphill toward the Cordova Fault from Crater Lake Shoreline.

Note alluvial fan and terrace deposit along the lake margin.

Figure 3-4. View of Cordova Fault on East Side of Crater Lake

The lake outlet is formed by a resistant bedrock notch, but the stream approach to the outlet consists of a deeper bedrock trench. This is interpreted as further evidence of glacial action within the basin. This upstream bedrock depression appears to be a suitable location for a laketap intake configuration, as shown in Figure 3-5. Bedrock appears to be approximately 15 feet below the lake surface at this location.

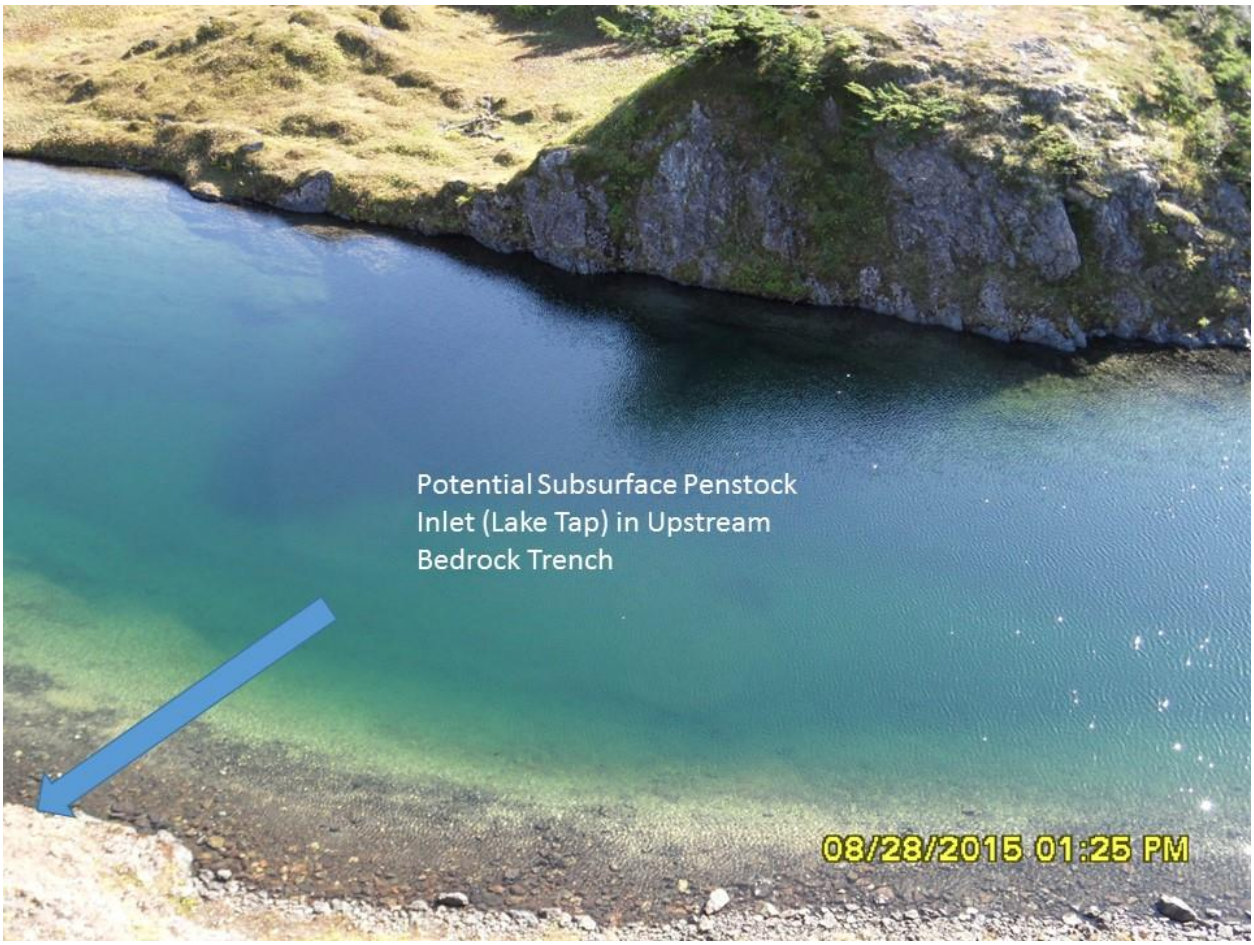


Figure 3-5. Bedrock Trench which Forms the Approach to the Elevated Lake Outlet

3.3.3 Geologic and Geohazard Observations

The exposed rock within the basin is predominantly basalt interspersed with dark gray bands of metasedimentary quartzitic shale. Although the geologic maps of the area indicate minor amounts of interbedded sedimentary turbidites consisting of mudstone and siltstone, none were observed during the site visit.

The basalt at the site is typically massive, moderately to slightly weathered, and strong (requiring more than one blow with a geologic hammer to break a hand sample). The most predominant joint set observed within the basalt is oriented approximately parallel with the faults that run through the Project area, at approximately 70/330 (dip/dip direction: Dip represents the planar angle from an imaginary horizontal surface within the planar feature and dip direction is the direction perpendicular to a horizontal line drawn through the plane of the feature). There is also random jointing present within the rock mass, much of it healed with mineral infilling.

Three prominent faults run through the lake basin. Each fault orientation follows the regional geologic trend, with dips ranging from 60 to 80 degrees and dip directions of 320 to 350. Each of the faults is

expressed by a watercourse drainage or depression in the rock exposure, as shown in Figure 3-6. Strong, intact basalt was observed on both sides of the fault zone. This is typical for a number of unmapped faults and shears observed during reconnaissance.

Figure 3-6. Geologic Mapping within Unnamed Fault Zone.

The largest of these features is the Cordova Fault (as shown on Winkler and Plafker, 1993), which crosses the northern half of the lake. The fault appears to be between 10 and 30 feet wide in the basin. Completely sheared sedimentary rock was observed within all of the fault zones. In one exposure uphill from the lake, one of the shear zones included a band of rock that had weathered to a dark green clay with intact relict sheared rock texture (Figure 3-7). The presence of this clay weathered zone should be taken into consideration during foundation design, as it is common for weaker, clayey foundation materials to wash out (pipe) over the life of a Project.

Figure 3-7. Dark Green Shear Weathered to Clay in Fault Zone

On the right bank immediately downstream of the proposed dam footprint, a shear zone was observed adjacent to the fault plane, expressed at the surface as a band of finely broken shaley rock with slickenside (fine shiny surfaces indicative of shear) as shown on Figure 3-8. These lesser faults trend parallel or subparallel to the Cordova Fault. Two of these faults appear to bound a bedrock island, which forms the current bedrock notch at the proposed dam site. The principal Project impacts related to the faulting include weaker foundation zones for the dam and laketap outlet and possible seepage paths associated with a raised Crater Lake. Careful mapping, core drilling and permeability testing will be required to further characterize these fault features for design purposes.

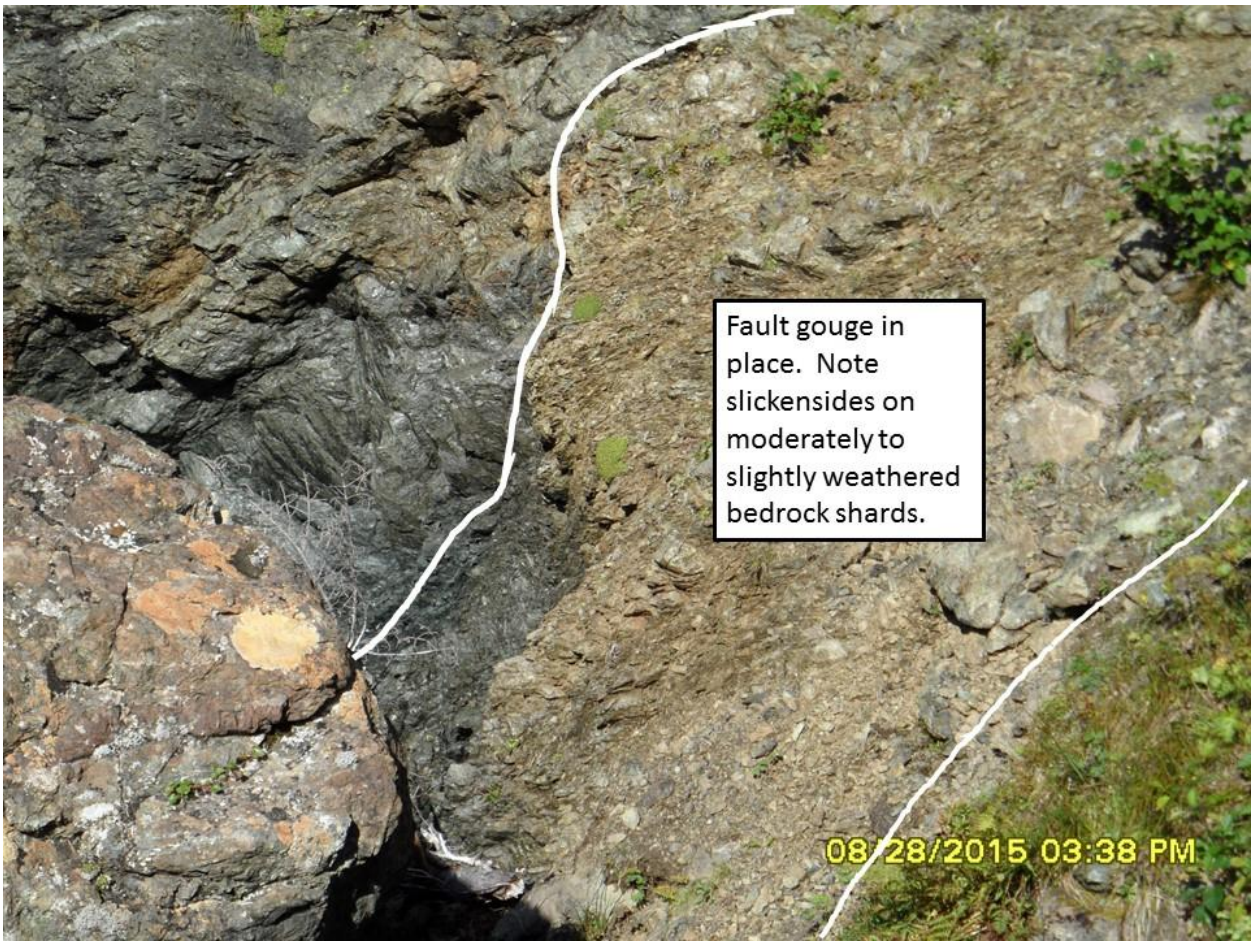


Figure 3-8. In-place Sheared Rock in Unnamed Fault Zone Downstream of Dam Site.

The observed and inferred faults and lineaments within the site vicinity are presented in Figure 3-9 below.

Due to time constraints, McMillen Jacobs staff were unable to field-check the apparent landslide complex below and west of Crater Lake, but have included this potential feature on the base map for reference. It is not anticipated that any of the Project features would traverse this area, so no further field investigation is required at the feasibility level.

The lack of mature vegetation to the north and east of the lake infers the presence of avalanche chutes in this area. Although this feature is indicated on Figure 3-9 as a geohazard to be avoided during design, discussion with Cordova-area long-term residents or people familiar with the Orca Lodge history may provide some historical information on this potential geohazard and possible activation frequency.

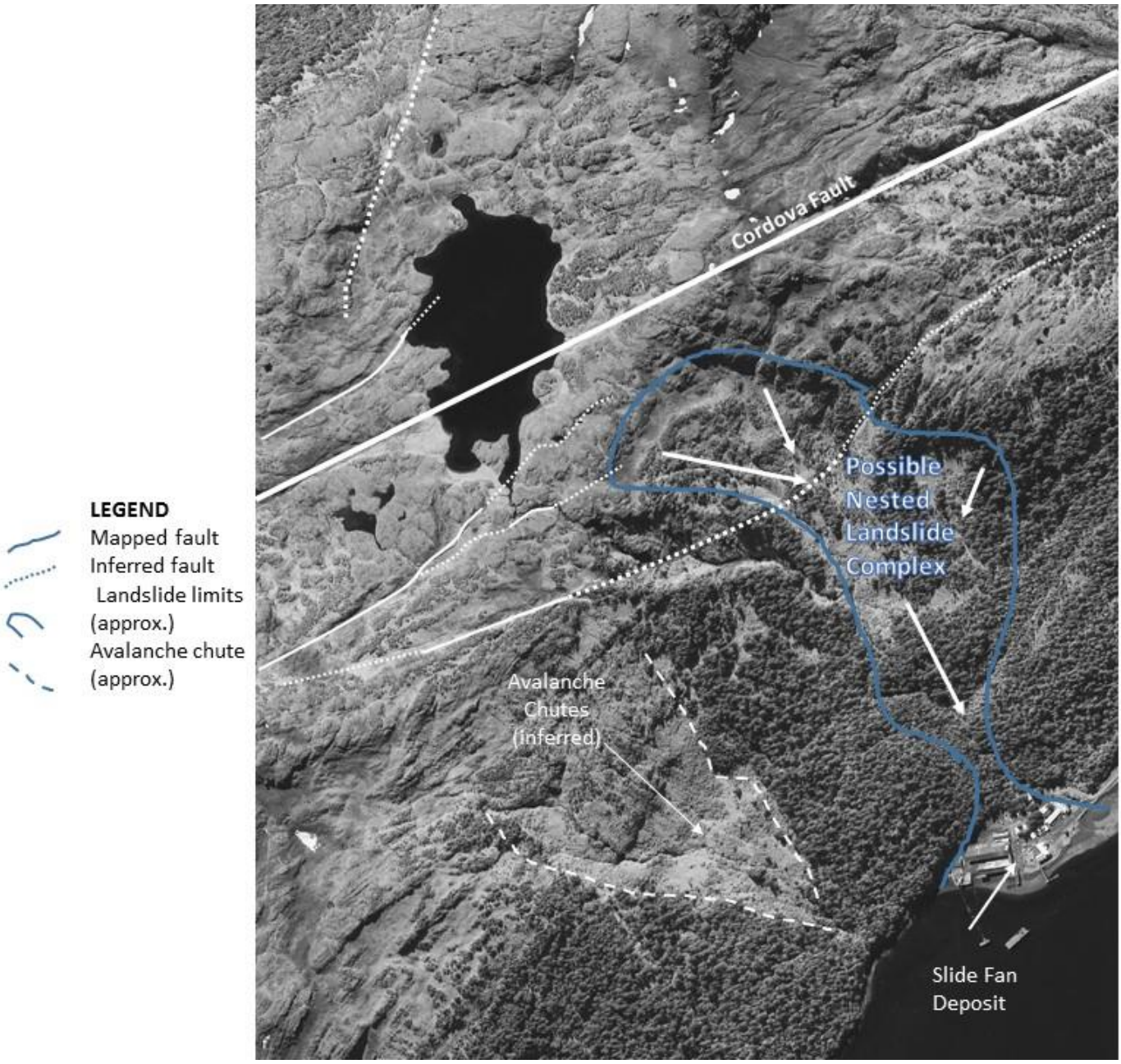


Figure 3-9. Faults, Shears and Geohazards

In general, it is anticipated that the rock mass at the basin site is anticipated to exhibit low permeability. Fluid flow through the rock would be primarily through fracture flow and fault/shear zones. There does not appear to be significant leakage through the rock mass based on the relatively stable lake elevation throughout the year even though at least three significant faults/shear zones cross through the lake.

3.4 Dam Site Considerations

The proposed Project concept involves raising the lake level on the order of 25 feet by constructing a small dam at the outlet. If greater storage is feasible and desired, a higher dam would require additional saddle dams at several locations around the lake perimeter and may not be justified based on basin

inflows. Depending on the final dam height, crest length of the dam may range from about 150 to 400 feet. It is anticipated that the dam would be designed as a concrete gravity structure.

3.4.1 Foundation Assessment

The rock present at the main dam site consists of strong basalt within the base and abutments. No adverse structure was identified in the rock within the anticipated footprint, but shear zones are present both upstream and downstream of the dam site. The maximum foundation loads imparted by the proposed dam structures are anticipated to be less than 10 kilopounds per square foot (ksf). The rock conditions present at the site are anticipated to adequately support loads of this magnitude and not cause structural instability within the foundation or abutments. This assumption must be confirmed with design-level site drilling, sampling and testing.

It is likely that the dam would need to be keyed into the foundation to provide passive resistance against lateral reservoir forces. The dam must be founded on competent rock, and any weak or highly weathered zones must be removed during foundation preparation to avoid performance issues such as differential settlement or foundation seepage.

3.4.2 Foundation and Reservoir Rim Seepage Assessment

The basalt rock at the dam site is not highly fractured and, where present, fractures were often healed with mineralization. Significant seepage within the basalt is not expected given the range of reservoir head pressures anticipated with this low structure (less than 20 pounds per square inch [psi]); however, fault zones are present approximately 50 feet upstream and 50 feet downstream of the dam site. The fault zones dip steeply to the north, and are expected to be present at depth below the dam foundation. The fault zones may act as conduits for seepage and should be thoroughly tested during the design investigation. If seepage is determined to be a design issue, a grout curtain may be required and additional drilling may be needed in the faulted areas around the reservoir to assess overall reservoir seepage potential.

3.5 Penstock Geotechnical Observations

3.5.1 Penstock Alignment Description

The penstock alignment would generally extend from the lake at an approximately northwestern orientation, following the fall line of the slope, east of the creek channel. The preferred surface alignment is shown on Figure 1-2, which also shows the topography of the slope. Crater Creek exits the lake at its northern edge and immediately drops into a narrow ravine, incised approximately 30 feet below the surrounding ground line. The creek flows through this gorge for about 300 feet and makes numerous sharp bends, eventually flowing to the west. The creek exits this upper ravine and enters into a steep canyon that drops down the slope in a north-northwesterly direction. The creek channel is formed by a series of faults and shear zones that parallel the predominant regional structural orientation.

In general, the terrain northwest of the lake is gently rolling to a point at approximate elevation 1370 feet elevation. This location is important because the topography forms a narrow landing between two steep drainages where it may be imperative to route the penstock alignment. This landing is formed by the intersection of two drainages with a significant fault zone, and the landing represents the only high

topographic spot to facilitate a penstock route between the two drainages. If the route varied to the west of this point, it would dive deep into the unstable landslide topography shown on Figure 3-9. If the route varied to the east of this point, it would enter the interpreted avalanche-affected zone to the east. Directly downhill from this location, the grade steepens as the slope drops between elevations 1,400 and 550 feet. In this reach, slopes typically range from about 30 to 45 degrees and numerous short cliff bands (on the order of 20 to 30 feet tall) are present, as shown on Figure 3-10. At elevation 550 feet, grades become gentler again, ranging between zero and 20 degrees to about elevation 400 feet. Below elevation 400 feet, slopes again steepen to 25 to 35 degrees, down to tidewater elevation.

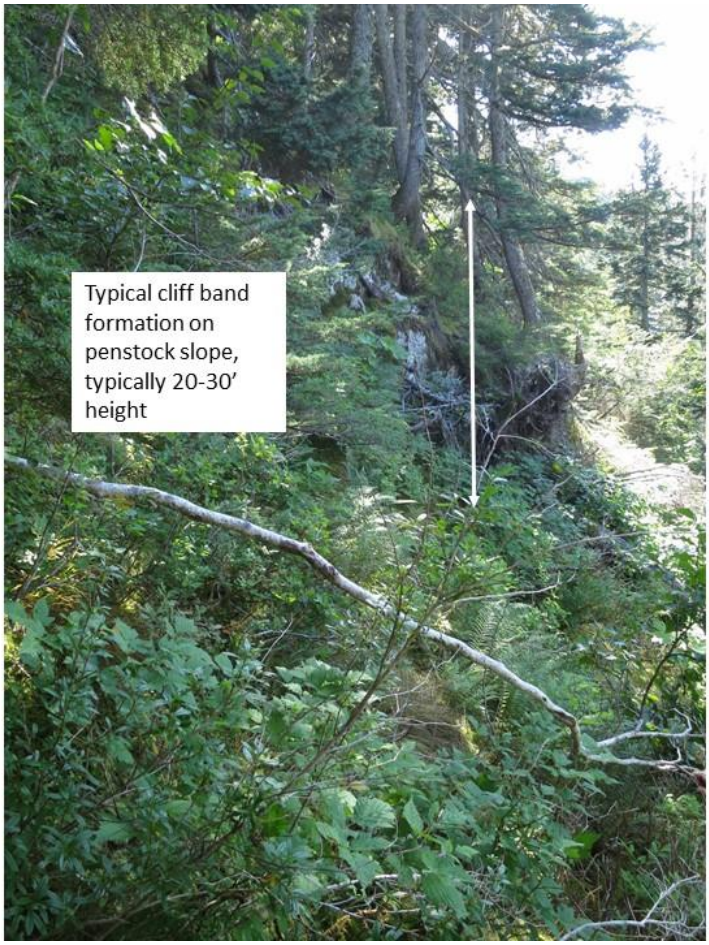


Figure 3-10. Typical Cliff Band Morphology along Penstock Route

The area above elevation 1,400 feet is typically covered with low shrubs and grasses. Below elevation 1,400 feet, the slope vegetation generally consists of mature coniferous forest and brush, interspersed with open, brushy treeless areas. Within tree-covered areas, an organic mat of deadfall and soil has accumulated. Boggy soils are present along the prominent bench at approximate elevation 500 feet.

3.5.2 Geologic and Geohazard Observations

Rock outcrops are prevalent between the lake and approximate elevation 1,400 feet. Outcrops of basalt and metasedimentary rocks are both present. Below elevation 1,400 feet, local rock outcrops were visible

along the surface penstock alignment. Prominent outcrops are summarized in Table 3-2. Outcrops below elevation 1,400 feet consisted of metasedimentary rock. Rock outcrops are also present within the Crater Creek drainage downstream of the COC water supply intake, and along road cuts adjacent to Orca Road.

Table 3-2. Observed Rock Outcrop Locations

Approximate Penstock Station	Approximate Elevation (ft)	Comments
10+00 to 18+00	1,500-1,350	Shallow rock is predominant, very little ground cover – numerous outcrops throughout segment
19+75 to 20+25	1,270-1,230	Exposed cliff band
23+00 to 23+50	1,060-1,080	Exposed 20-foot-tall cliff
23+50 to 26+00	1,060-830	Continuous steep terrain with numerous small cliff bands
39+00	250	200 feet southwest of 39+00, cliff bands exposed in Power Creek channel below COC intake diversion
48+00	60-30	400 feet southwest of 48+00, cliff band exposed in rock cut along existing road (SW PH Site)

Based on slope grades and the locations of surface rock outcrops, bedrock is interpreted to be shallow along the entire slope except at the bench at elevation about 500 feet where boggy ground was observed. In general, thin organic soils are expected with local accumulations of talus below cliff bands. The depth to bedrock is expected to be less than 10 feet below ground surface except at the bench. The soil profile is expected to be deeper here and may exceed 25 feet.

In general, little evidence of significant instability was observed along the penstock alignment. The cliff bands represent zones of potential shallow instability, with near-surface joints showing open relief and the potential for rock topple. These zones would require slot excavation to stable bedrock for penstock routing and anchoring. No landslide scarps, disturbed ground or hummocky topography was observed during the reconnaissance. Locally, pistol-butt trees were observed, indicating that the trees had grown to compensate for ongoing soil movement or creep; however, these were identified in the steepest zones on the alignment, and were interpreted to be caused by surficial soil creep rather than large-scale, deep-seated movements. The mature vegetation on the lower slopes did not exhibit this characteristic. These observations are consistent with the overall grades and shallow rock outcrops present throughout the slope.

West of the preliminary penstock alignment, the slope below the lake forms an approximately 1,500-foot-wide bowl shape (see Figure 1-2). The Crater Creek channel forms the eastern margin of this area. This landform appears to have resulted from a large, historic landslide and should be avoided. The area aligns with cross-cutting, regional shear zones visible to the east which may have bounded the uphill side of the unstable block.

The area east of the alignment without any mature vegetation is interpreted as an avalanche zone. This area is shown on Figure 3-9. Unless the penstock is buried, this area should also be avoided. The avalanche source area may be the high peak to the northeast of this feature. This also may be the site of an historic avalanche which cleared the slope of trees, in turn promoting future snow instability on this slope.

3.6 Penstock Concepts

The surface penstock alignment concept is shown on Figure 1-2. A second concept consisting of a tunnel/shaft arrangement would utilize a drilled rock shaft below ground surface (for a portion of or the entire length) to carry the penstock. A cross-section of the potential drilled shaft alignment is shown on Figure 3-11. Based on the hydraulic evaluation, McMillen Jacobs anticipates that the penstock diameter would be 16 inches outside diameter. The penstock and shaft/tunnel alternatives are discussed in more detail in the following sections.

Three potential surface alignments were preliminarily screened at the desktop level, and the preferred alignment was studied in more detail, as shown on Figure 1-2. The penstock would be installed in a shallow trench on-grade or would be placed above-grade on pipe supports. The alignment has been selected to avoid the potentially unstable terrain west of Crater Creek, and avoid the active avalanche chute to the east.

Either of these alignments could be constructed using conventional means with small earthwork equipment. This may also be constructed without significant road development, and potentially utilize helicopter support to move materials and equipment.

3.6.1 Surface Alignment – Initial Reach

The initial 600 feet of the penstock alignment must either follow the sinuous path of the Crater Creek canyon, go up and over the canyon sidewalls (which are higher than the proposed dam crest), or could be bored through the canyon sidewalls in a relatively straight alignment. The bored option is preferred because it could be easiest to construct and would not be exposed to rockfall and sudden high flows within the upper Crater Creek canyon. Nevertheless, the surface option is also feasible, but may be difficult to anchor on the canyon sidewall, would require complex vertical and horizontal bends and would be exposed to debris and snow loads.

The microtunnel option is shown on Figure 3-11. A straight alignment simplifies the hydraulics of the initial reach of the penstock, but cost should be evaluated objectively to the surface alignment. The creek channel is located within the center of this reach between the intake at the lake and the back side of the ridge that bounds the creek. The creek channel could be used as a jacking station for two 300-foot-long bores; one drilled upstream and one drilled downstream. Bores of this length are feasible using a small boring unit system (SBU) in the range of 24 to 36 inches in diameter. This equipment is relatively small, and could be broken down into components to be mobilized using helicopter support. This option should be included within the geotechnical exploration program.

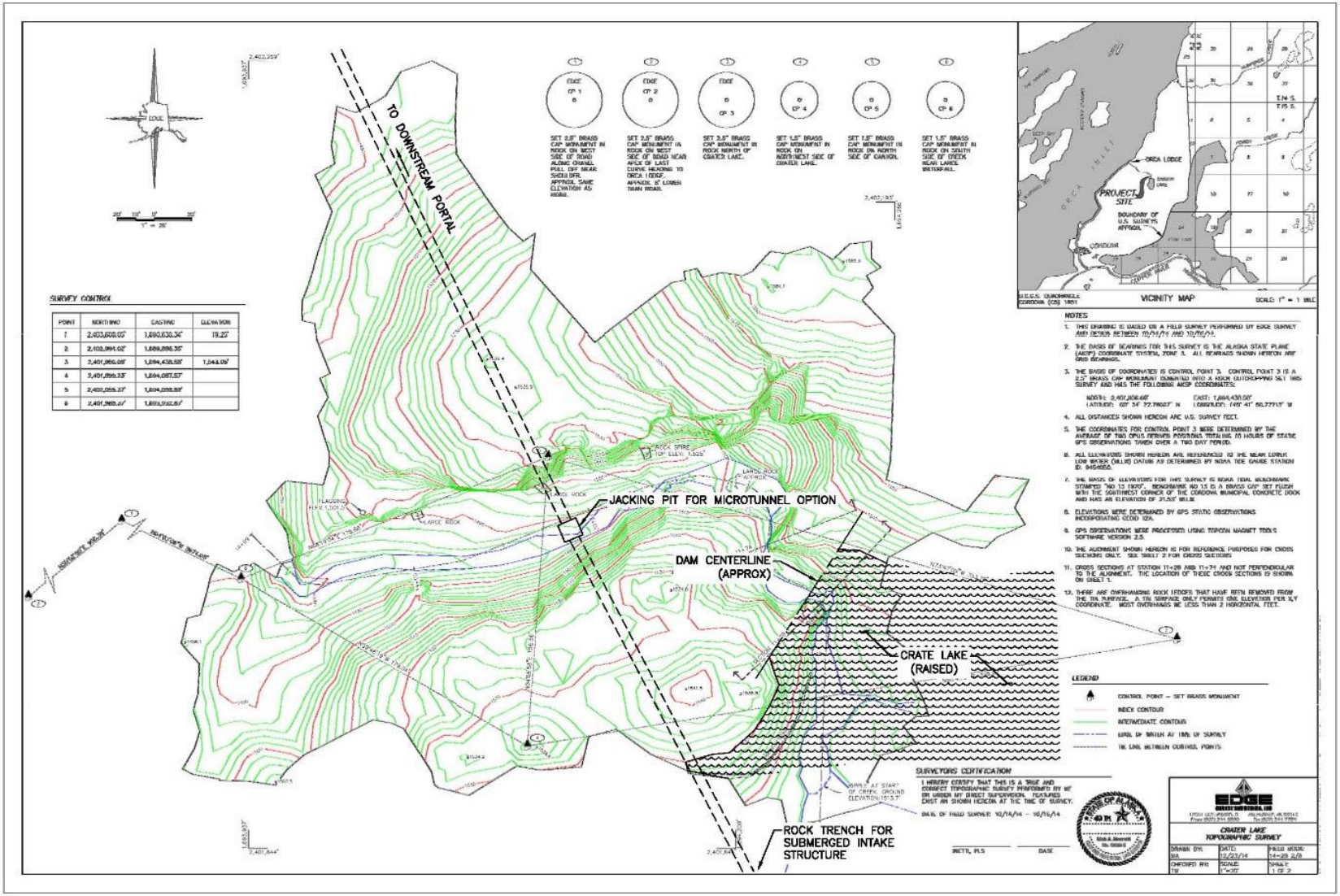


Figure 3-11. Microtunnel Option Showing Jacking Pit Location

3.6.2 Surface Alignment – Downslope of Inner Crater Creek Canyon

The alignment downhill from the canyon initially traverses a steep section of hillside approaching 50% slopes from approximately Stations 33+00 to 27+00. This upper slope consists of a series of rock outcrops with near-vertical foliation that has been deformed by tectonic forces into the current faulted and folded condition. The surface consists of a short series of outcrops and shallow talus benches that are not well-indicated by the current topographic mapping. Below Station 27+00, the alignment traverses relatively uniform hillside averaging 30% slope to the Crater Creek crossing. The ground within this reach consists of a heavy forest duff and intermittent boulders and outcrops.

3.6.3 Rock Shaft Option

The shaft alternative would utilize a drilled rock shaft extending from the lake to an access point on the lower third of the slope. The shaft could be oriented between vertical and about 30 degrees below horizontal. A horizontal adit tunnel would be advanced at the base of the shaft to carry the penstock to a surficial alignment, or directly to the powerhouse if the shaft was bored to about elevation 100 feet or lower. A cross-section through potential shaft alignments is shown on Figure 3-12.

The slope has a number of shear zones that would intersect any shaft alignment. These zones would potentially have high permeability and be prone to water loss in an unlined shaft. Thus, the shaft could require a pipe lining. The bore diameter for this configuration would be between 24 and 36 inches to provide flexibility for pipe installation. The length of the bore would be on the order of 2,000 to 3,000 feet. Depending on the adit elevation, and the orientation of the shaft, the adit would have a minimum length of 300 to 700 feet. The minimum adit size would be approximately 8 feet by 8 feet to optimize construction efficiency and allow for equipment access using drill and blast methods.

The shaft could be drilled using a raised bore system or down-the-hole hammer system. Both systems utilize a drill rig set up at the top of the alignment. Raised bore construction involves drilling between the ground surface and an established lower level (in this case, the adit tunnel) in a sub-vertical orientation. The process is started by drilling a small-diameter pilot bore and establishing a drill string through the bore alignment. After the pilot bore is completed, a reamer is attached to the drill string at the lower level and pulled to the surface. Cuttings are dropped through the bore to the lower level. The reamer is successively upsized to the desired final diameter. A raised bore would require a significantly longer adit tunnel, on the order of 2,000 to 3,000 feet. The down-the-hole hammer system also utilizes a pilot bore drilled from the surface to the target location, which is successively upsized with larger drilling tools. The system has more orientation flexibility and could be drilled subparallel to the slope. Cuttings are typically blown out from the bore to the ground surface using compressed air, or by circulating drilling mud.

Both of these systems are technically challenging, but feasible. The length of the bore is potentially problematic for maintaining precise alignment. This is further compounded by a predominant rock fabric and geologic structure orientation which will tend to make drilling tools, and consequently the finished bore, wander out of alignment. This is shown conceptually on Figure 3-12. Specialized, heavy drilling equipment (typically mounted to large, flatbed trucks) would be required for either type of installation at the proposed lengths and accuracy needed. Both would require road access to the lake outlet suitable for

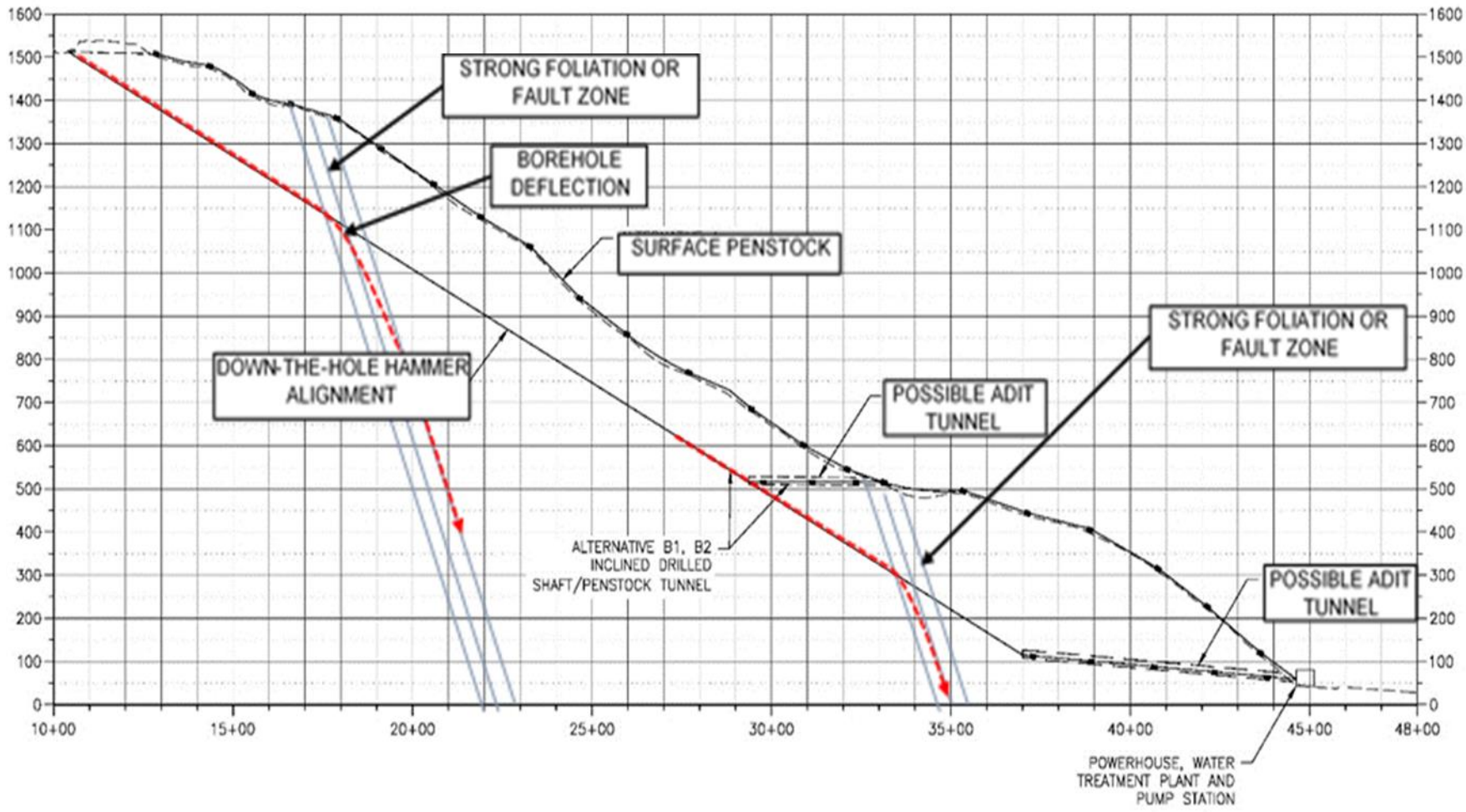


Figure 3-12. Rock Shaft Penstock Alternative Cross-Section

highway vehicles to pass, and construction of a drilling pad. Few contractors have the experience and equipment to install bores of this size, and mobilization costs to Cordova would be significant.

Overall, the costs for this alternative would significantly exceed the cost of a surface penstock alignment. Further, the equipment requirements necessitate construction of an access road which creates a permanent visual site disturbance as well as technical challenges in maintaining road stability across the steep terrain. Based on the anticipated difficulty and expense associated with building this feature, the shaft and tunnel were removed from consideration.

3.6.4 Penstock Support Considerations

Any surface penstock alignment would require anchorage to maintain structural stability in the steep terrain, and resist thrust loads generated at pipe bends. McMillen Jacobs anticipates that the penstock will be supported by concrete pedestals at regular intervals. The pedestals would resist penstock loads by anchorage into rock. It is anticipated that small diameter bar anchors (#8 or less) would be sufficient for the system loads. These anchors could be installed by personnel with hand-operated or limited access drilling equipment that could be transported by helicopter.

McMillen Jacobs recommends that anchors be required to develop their capacity within rock. The depth of soils overlying bedrock along the alignment will be identified during the geotechnical investigation. Anchor lengths would be sized to allow for some variability in ground conditions during construction.

3.7 Powerhouse Geotechnical Observations

3.7.1 Site Description

Three powerhouse sites were considered in the screening phase and the preferred location was selected as shown on Figure 1-2. This elevation delineates the transition from the steep slopes southeast of the lodge to the flats adjacent to Orca Inlet. It should be determined if maximizing generation head takes precedence over potential disturbance, operational access and long-term maintenance for the sites adjacent to Orca Lodge. It is anticipated that non-engineering factors may influence selection of the preferred site.

The selected site has approximate dimensions of 150 feet (perpendicular to slope) by 200 feet (parallel to the slope) and lies at approximately 100 feet elevation. Just beyond the bench, the ground surface drops steeply to the existing roadway, which is immediately adjacent to tidewater. This area currently has no developed access, but bedrock appears to be shallow, indicating that stable foundation conditions are anticipated. The site also appears to overlap with the conceptual plans for Shepard Point road, which is being evaluated by the Eyak Corporation. If this road is constructed, it would need to be rerouted or excavated uphill from the proposed plant to occupy the same general location. Further studies and coordination between CLWPP proponents and the Eyak Corporation may be required to accommodate both features.

3.7.2 Geologic and Geohazard Observations

Rock outcrops were identified in the vicinity of all three powerhouse sites. Shallow soil profiles are anticipated at each site. Soils are expected to consist of colluvium and/or glacial till over bedrock in all of the potential locations.

At the western site, no exposed rock was on the bench; however, the northern limit of the bench is bounded by a 30-foot-tall cliff that is exposed along Orca Road. Bedrock within the bench area is estimated to be shallower than 30 feet.

No rock exposures were observed at the other two sites, which are covered by a deep layer of forest duff; however, the slopes immediately southeast of these locations are 45 degrees (or locally steeper), indicating the presence of rock. The lower flats adjacent to tidewater (where the Orca Lodge and historic cannery are located) are interpreted to be a landslide colluvium/alluvium deposit formed at the outlet of Crater Creek. No recent signs of instability or debris flows were identified within lower reaches of Crater Creek.

No significant geohazards were identified at the powerhouse sites during the reconnaissance.

3.7.3 Preliminary Foundation Assessment

McMillen Jacobs anticipates that the new powerhouse would be founded a minimum of 5-10 feet below grade. Soils are expected to consist of colluvium and/or glacial till over bedrock in all of the potential locations. Suitable bedrock is estimated to lie between 10 and 30 feet deep and no soft or unusual soil conditions are anticipated. The site soils are anticipated to be primarily granular, and would support the loads of the new powerhouse.

3.7.4 Access and Staging Areas

The preferred powerhouse site is located just south of the existing Orca Road. The site could be accessed by pioneering a new road through a draw that leads up to the bench. The bench is approximately 50 to 60 feet above the lower roadway. The access road would need to be 400 to 500 feet in length to maintain suitable grades for hauling equipment to the site. This appears to be feasible with minor cuts and fills based on reconnaissance and survey data. This site appears to have ample area for the proposed structure. The site may also be cleared beyond the plant limits as needed for use as a staging area for construction materials and equipment.

3.8 Proposed Geotechnical Exploration (Future Design)

A future exploration program should be executed to determine the geotechnical characteristics of all Project features to narrow-in on the preferred Project configuration and develop the final design. This exploration program would be developed in a future design phase, but, at a minimum, should include:

- Detailed ground survey of all Project features.

- Additional, detailed geologic mapping once the detailed alignment topography is completed. The mapping should describe and document the dam foundation conditions, traces of mapped and unmapped faults, penstock alignment and powerhouse sites.
- Surface geophysical surveys to estimate the depth to sound rock.
- Foundation exploration drilling and testing is recommended for all Project features. This drilling and testing should include rock coring, rock sampling, strength testing and foundation permeability testing (dam site).

The results of the investigation should be documented in a geotechnical basis report (GBR) and used to support the design of the Project features.

3.8.1 Permitting Requirements / Lead Time

Significant lead time may be required for any potential exploration permits and subcontractor procurement that may be required. The extent of permits will be defined prior to the design phase.

Significant lead time may also be required to procure helicopter-assisted drilling contractor services. We suggest that this subcontractor be procured early in the design process because most qualified remote access drillers book their Projects well in advance.

3.9 Geologic/Geotechnical Summary and Conclusions

A reconnaissance-level geotechnical site investigation was performed for the CLWPP as a part of a larger feasibility study. The results of this investigation are as follows:

- The dam site is underlain by strong basalt. No specific adverse geologic structures were identified but subsurface investigation should be conducted to confirm this observation and provide design criteria. The rock strength and structure appears to be adequate to support a new dam in the size range under consideration.
- The rock mass immediately below the proposed dam foundation is tight and significant seepage is not expected for the range of reservoir pressures expected.
- Faults/shear zones are present both upstream and downstream of the proposed dam site. These zones may be present at depth below the dam foundation. Rock within these zones is expected to be highly sheared and may provide a seepage path. If necessary, the dam foundation may be amended with a grout curtain. The potential for reservoir rim seepage is also a concern. The permeability of these zones will be identified during the design investigation.
- Trenchless methods are feasible to install the penstock in a straight alignment for the initial 600 feet from the lake intake. Two 300-foot-long trenchless bores could be installed from a jacking station in the Crater Creek canyon.
- The presence of shallow rock is anticipated below most of the slope between Crater Lake and tidewater elevation. No signs of large-scale instability were observed along the preliminary alignment.

- A penstock alignment down the slope is feasible; however, the slope is steep, with typical grades of 30 to 45 degrees, and the penstock would need to be anchored into rock to maintain stability.
- The proposed powerhouse/treatment plant site appears to be underlain by rock at shallow depth (less than 30 feet deep). No geotechnical issues were identified based on reconnaissance.

4.0 Hydrologic Evaluation

4.1 Introduction and Purpose

Understanding the potential Project's hydrology is the underlying basis for all other aspects of Project feasibility. Section 4.0 summarizes the hydrologic analysis including data sources, methods, results, and discussion regarding alternative dam heights and potential water supply and management. This section also documents methods used and results obtained in creating a synthetic streamflow record to assess Crater Lake's potential for both water supply and power production. Three dam raise/lake tap scenarios were also evaluated to examine how storage could be used to time both power and water supply for critical time periods. The three scenarios were created to examine different storage opportunities. These scenarios will likely be changed based on the results of this study and other technical information. The synthetic record time period has been contextualized among longer-term climate records to evaluate future climate and management options under various dam height and water supply scenarios.

4.2 Data Sources for Study

Data sources used in the development of the hydrologic and water supply analysis are presented in Table 4-1.

Table 4-1. Data Sources

Data	Purpose	Key Units/Comments
Mt. Eyak SnoTel Data: Gage #1093. Time period 2005-2015; Natural Resources Conservation Service (NRCS).	Climate data to be correlated with Crater Lake streamflow to create a synthetic record	Inches of precipitation and Snow Water Equivalent (SWE). Temperature data in Degrees F.
Crater Lake Outfall streamflow data collected by COC and CEC. Time period: August 2014-2015.	This data represents the raw yield from the lake but there is only 1 year of data.	Streamflow in cubic feet per second (cfs). Gage has natural bedrock control and is not vulnerable to shifts. Note that there is also Crater Creek intake data that does not correlate because it is based on COC intake needs, not natural flow patterns.
Cordova Long-term Climate Data as archived by the Desert Research Institute. Data from 1900-Present.	Long-term climate data to contextualize the SnoTel data in comparison to the longer climate record.	Monthly and Annual Climate data, both temperature and precipitation in degrees and inches. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak2177
Power and Snyder Falls Creek streamflow data. Collected by CEC. Various time periods and Power Creek has a long-term U.S. Geological Survey (USGS) gage that has been discontinued.	Streamflow data with potential to correlate with Crater Lake outfall data; however, relationship with climate was stronger and represented longer record. This data not used at this time.	Streamflow in cfs. Snyder Falls Creek from 2010-2015 and Power Creek 2011-2013. Snyder Falls Creek has issues due to avalanche and debris flow/rockfall changes to gaging stations and flow reference cross-sections. Power Creek only measures a portion of watershed yield at point of measurement and does not overlap with Crater Lake outfall for correlation purposes.

Data	Purpose	Key Units/Comments
Edge Survey detailed dam site topography. Data taken October 2014.	Data to help develop potential dam foundation footprint, lake tap options and downstream penstock configuration.	North American Vertical Datum (NAVD) 88 (feet). Topographic surface and maps in pdf and native data format. Covers the dam site and approximately 300 feet downstream with canyon walls along Crater Creek. Also includes southern saddle location at lake shore and several potential saddle dam locations.
E-Terra satellite-based photogrammetry, entire Project area.	Geographic Information System (GIS) files and topographic surfaces. Data also tied in with bathymetry data and used for bathymetric calculations of current water level.	NAVD 88 (feet). The satellite photogrammetry was tied in with ground-based control provided by Edge Surveying. Control located near lake outlet at several locations and at sea level near Orca Lodge.
Crater Lake Bathymetry provided by CEC.	Elevation data used to determine the stage storage curve and degree of useable storage with different dam height/ lake tap scenarios	NAVD 88 (feet). Tied into survey data using an assumed water surface elevation of 1,514 feet and an 18-inch offset for instrument depth during survey.

4.3 Site Description and Characteristics

This section presents key characteristics of the watershed and reservoir as shown in Table 4-2 below.

Table 4-2. Summary of Key Characteristics

Characteristic	Size or Attribute	Comments	Documentation
Watershed area	183 acres	There is the possibility of increasing watershed by diverting a small adjacent watershed into lake basin.	McMillen Jacobs' delineation of Google Earth data using digital elevation model (DEM) and image.
Lake surface area at current water level	22 acres (approximate)	Will vary with water level.	McMillen Jacobs' delineation of image
Lake storage at given water levels	555 acre-feet (AF) storage at normal lake elevation 1,514 feet. With assumed 25-foot-high high dam, storage increases to 1345 AF at elevation 1539 feet which is near elevation of ridge around lake.	The elevations are for the maximum lake tap elevation, current water elevation and conceptual top of dam elevation.	McMillen Jacobs' GIS analysis of combined bathymetry and GIS DEM data from Edge
Maximum depth of lake	61 feet at current water level		From bathymetry

Characteristic	Size or Attribute	Comments	Documentation
Average Crater Creek streamflow at lake outlet August 2014-August 2015	2.52 cfs (1,824 AF of annual runoff)	2014-2015 only; for longer look see synthetic record in Section 4.4.	Gage data compilation by CEC.
Watershed condition	Rock, tundra, and brush in pristine condition	This watershed has high yield potential if groundwater losses are minimal.	Site visit observations, GIS coverages and photos.

As shown in Table 4-2, the volume of lake storage, given Project assumptions, varies from 215 acre-feet (AF) at 1,494 feet elevation (dead storage) to 555 AF at the current water level (350 AF available storage) to 1,345 AF if water is held to the 1,539-foot elevation (1135 AF with a 25-foot pool raise). The Crater Lake stage storage curve is given in Figure 4-1.

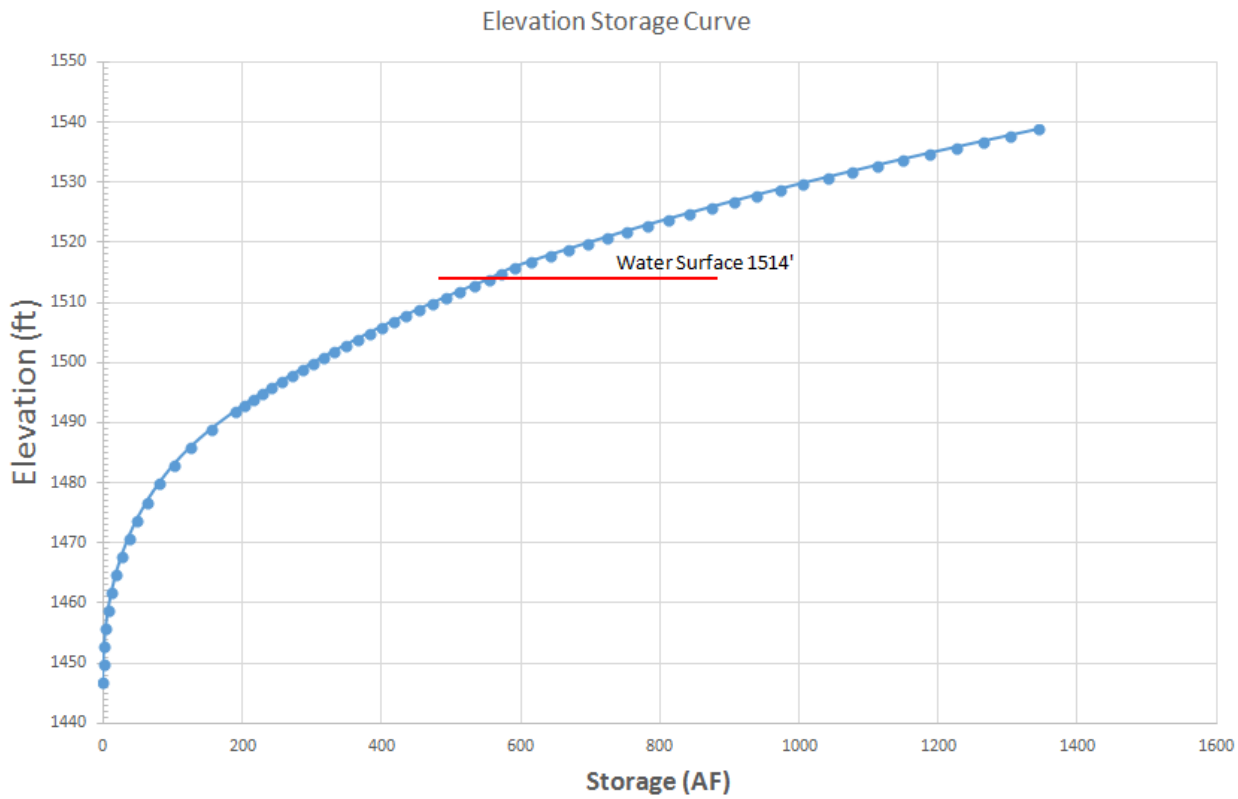


Figure 4-1. Stage Storage Curve for Crater Lake

The Crater Lake watershed area was delineated at approximately 183 acres using Google Earth as shown in Figure 4-2 below. For the date of April 6, 2010, the lake had a surface area of 22.4 acres, which varies naturally with changing lake surface elevation.

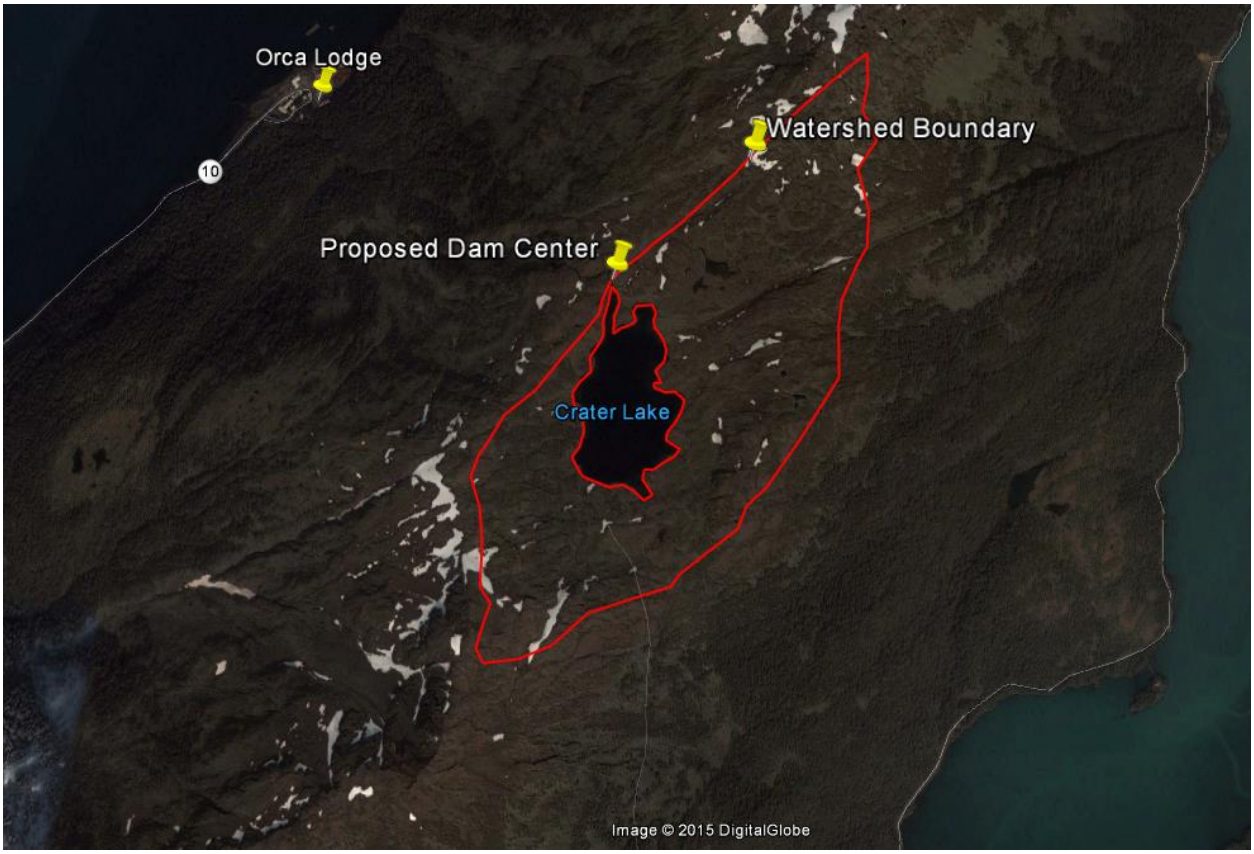


Figure 4-2. Watershed Area Delineation for Crater Lake Watershed

4.4 Synthetic Hydrology Development

The purpose of this section is to present the methodology and results of the site synthetic hydrology development by correlating the 2014-2015 outfall data at Crater Lake with SnoTel data from the Mt. Eyak SnoTel site. This gives data for 9 full water years and one partial year. This data was evaluated by examining the long-term climate data to better understand future water supply based on past history.

4.4.1 Development of Daily Flow Values 2005 – 2015

Crater Creek outlet streamflow data from August 2014 to August 2015, was artificially extended using daily net water input values from the nearby Mount Eyak SnoTel site (NRCS, 2015). The extension of values creates a synthetic record from October 1, 2005 to October 1, 2015.

The Mount Eyak SnoTel site (Figure 4-3) has a 10-year record beginning in September 2005 that extends to the present day. The site is located only 2.2 miles straight-line distance from the centroid of the Crater Lake watershed and is located on the same mountain ridge. The elevation for the SnoTel site is 1,405 feet, which is similar in elevation to the dam site (1,514 feet) and the watershed, which varies from 1,514 feet to approximately 2,200 feet.

Figure 4-3. Photo of Mt. Eyak SNOTEL Site from October 2007 (NRCS, 2015)

The Mount Eyak SnoTel site has sensors that measure Snow Water Equivalent (SWE, using snow pillow method), precipitation accumulation (with a tipping bucket), air temperature, snow depth, barometric pressure, wind speed, and solar radiation. The data is stored in hourly and daily increments. The data of most interest for this analysis is the precipitation accumulation and the gain and loss of SWE. As snow accumulates, SWE builds in the snowpack and water is stored. As the snow melts, SWE is lost from the snowpack and inputs to the watershed as runoff. Therefore, as the snowpack and SWE builds, incremental SWE is a positive number and when it melts it is a negative number. Subtracting incremental SWE from precipitation allows for the calculation of a net incremental water input for runoff (rain + snowmelt). This incremental water input showed correlation and the ability to predict streamflows at the Crater Lake outlet.

The 2014–2015 Crater Lake dataset runs from August 23, 2014 to August 27, 2015. The average streamflow for this dataset is cubic feet per second (2.5 cfs). The range of streamflow over the outlet over this period was 0.2 cfs to 32.1 cfs. At the Mt. Eyak SnoTel site, there was 138.5 inches of precipitation over this same period. The precipitation corresponds to 2,112 AF of runoff if that level of precipitation was delivered to the 183-acre watershed without losses. The runoff at the lake outlet corresponds to 1,824 AF. Therefore, in this comparison, if the gage at Mt. Eyak was accurately portraying precipitation at the watershed, 81% of the precipitation would become runoff, while 19% was accounted for as infiltration,

evaporation and vegetation uptake. This is consistent with a smaller watershed with limited vegetation and groundwater losses as well as a cool and cloudy climate.

In examining runoff patterns from the lake, there appears to be a good correlation between rainfall or snowmelt events from Mt. Eyak and the streamflow pattern at Crater Creek (Figure 4-4); however, in looking at some of the peak events there are offsets, because the 1-day precipitation often does not correspond well with the runoff response in that the routing may be off by a day or it takes several days to decrease while the precipitation has zeroed out. In hydrology this is known as a lag effect. An example of this is expressed in the spring period from May 6 to June 15, 2015 (Figure 4-5). In this period, on May 12th the precipitation zeroes out, but the streamflow takes a few days to recede.

Another example of correlation variability is the occasional incongruity between precipitation and runoff. An example is illustrated in Figure 4-5 where the runoff peaks on June 4 but the precipitation peaks on June 5, and the precipitation increases even though the streamflow is lowering. Even though the SnoTel site is geographically close, isolated rainfall cells can sometimes cause variation like this within larger storms. These types of incongruities are normal in this type of analysis, and will make precise predictions difficult; however, for the purposes of this evaluation, McMillen Jacobs concluded that the precipitation can reasonably simulate general seasonal and even weekly trends with water data.

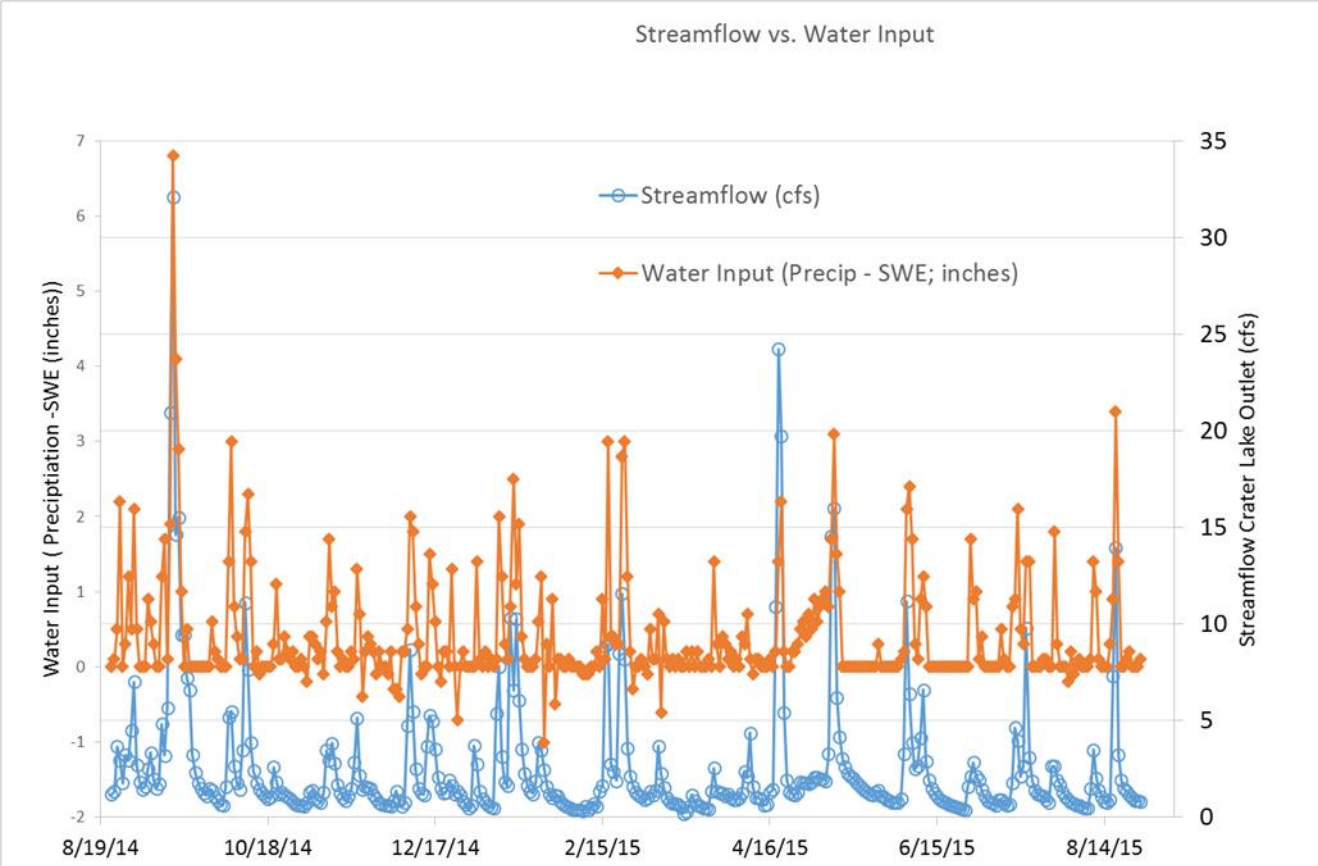


Figure 4-4. Streamflow at Crater Outlet vs. Water Input at Mt. Eyak

The chosen procedure was determined via trial and error. One key observation was that when there was no water input at the SnoTel site over a 2-day period, there was low predicted variation around the mean streamflow value at Crater Creek. Predicted streamflow for 2-day dry periods was 1.1 cfs from the synthetic streamflow, while the observed gage flows ranged from 0.2 cfs minimum to 3.7 cfs maximum. Another key observation was that if the daily input value was compared to the streamflow, a positive correlation and predictive equation was determined as shown in Figure 4-6. The equation demonstrates that the correlation explains over 50% of the variance, but due to issues discussed above, there was still a significant amount of variation.

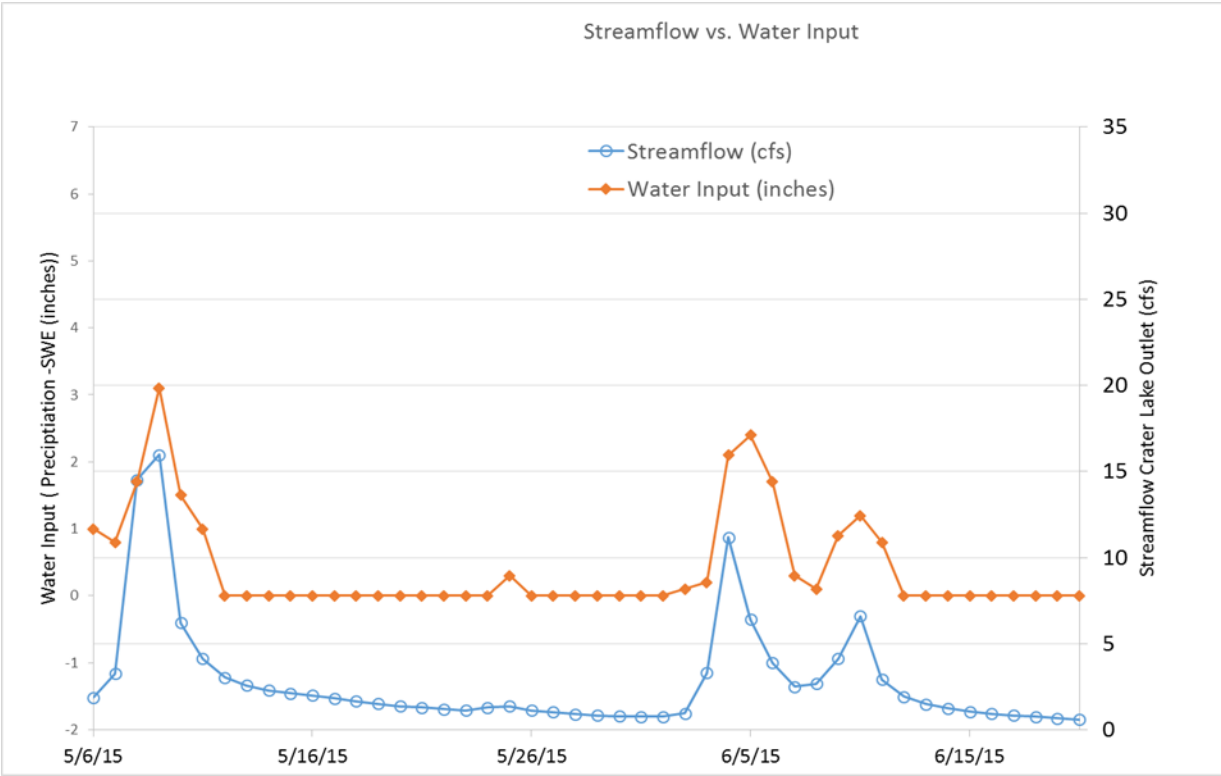


Figure 4-5. Streamflow at Crater Outlet vs. Water Input at Mt. Eyak for Specific Dates

Based on trial and error and these observations, the following procedure was created to convert precipitation values into streamflows:

- Step 1. Determine if the previous 2 days had no net water input (snow or dry condition). If so, assign a streamflow value of 1.095 cfs.
- Step 2. For all other values, use the equation from Figure 4-6 to convert daily precipitation values to streamflows.
- Step 3. Average all streamflow values and compare runoff yield to overall precipitation input. Adjust all streamflows so the yield input will equal 81%.

- This procedure was applied as a spreadsheet formula using "if – then" statements and the equation. Once the raw streamflows were averaged, the overall yield was compared and adjusted to 81%.

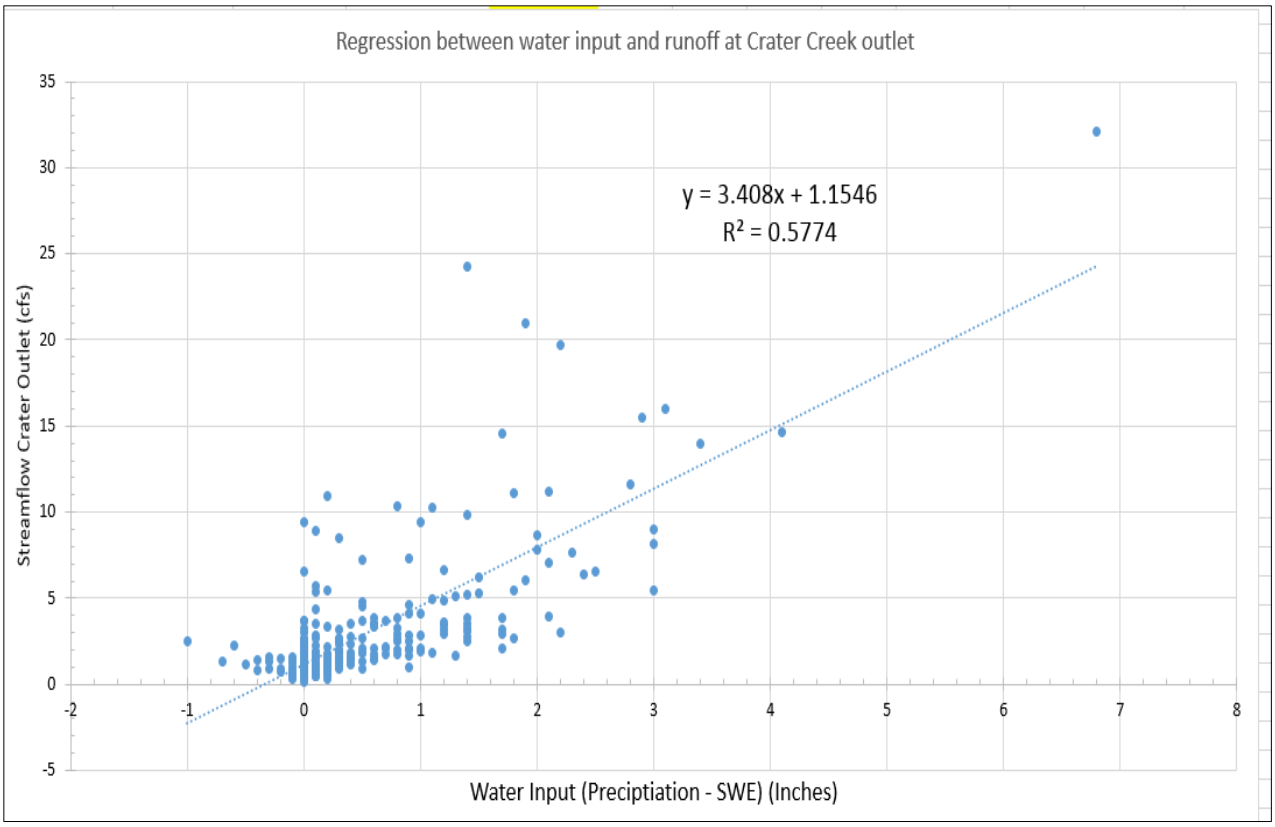


Figure 4-6. Relationship between Daily Precipitation and Daily Outflow from Crater Lake

4.4.2 Use of Snyder Falls Creek and Power Creek Streamflows

Snyder Falls Creek and Power Creek streamflow records were evaluated for use in record extension to create a longer-term synthetic streamflow record, but were not used for the following reasons:

- Upper and Lower Snyder Falls Creek gages: For the 2014–2015 time period where records for both were available, the record did not correlate well, presumably due to the lake effect for the Crater Lake outfall, as well as glacial melt effects in the Snyder Falls Creek drainage that caused the two streams to have somewhat different runoff patterns. Also, the useable length of record for Snyder Falls Creek was less than that of the SnoTel data.
- Power Creek: Concurrent overlapping records were not available to use for correlation and record extension. Also, the Power Creek data does not directly record total streamflow, making a runoff per unit area difficult to calculate. The drainage is also affected by glacial melt.

4.5 Hydrology Model Procedure Results

The results from this procedure created comparisons between observed and predicted values for the 2014–2015 time period for Crater Creek outflows. One comparison is the observed streamflow versus the flow calculated with the procedure (Figure 4-7). There appears to be good general agreement in that flow peaks coincide, but the variability at the ends of the flow spectrum is generally lost between the methods. For instance, the predicted September peak in 2014 is not as high as the observed peak and often the predicted low flows do not go as low as observed because a mean value was used for dry conditions and the constant in the correlation equation does not allow predicted flows to be less than 1.15 cfs. While the median values are similar, the extreme tail ends vary. The loss of variability does not impact the overall annual mean value for a Project with a significant storage component like Crater Lake. The net effect is that there is little impact on storage calculations.

Table 4-3 illustrates the impact on percent exceedance numbers. The major differences occur on the far ends of exceedance. Note that 90% exceedance denotes the streamflow that is exceeded 90% of the time and represents a smaller base flow in which the flow is only lower 10% of the time. In contrast, the 5% exceedance represents an elevated streamflow in response to a flood event that is only exceeded 5% of the time. Using the procedure described above to predict flow yields, there would be very few flows lower than 1.1 cfs. To that end, the 10–30% exceedance is 1.1 cfs; however, the observed record does drop, with the 10% exceedance being lower at 0.6 cfs.

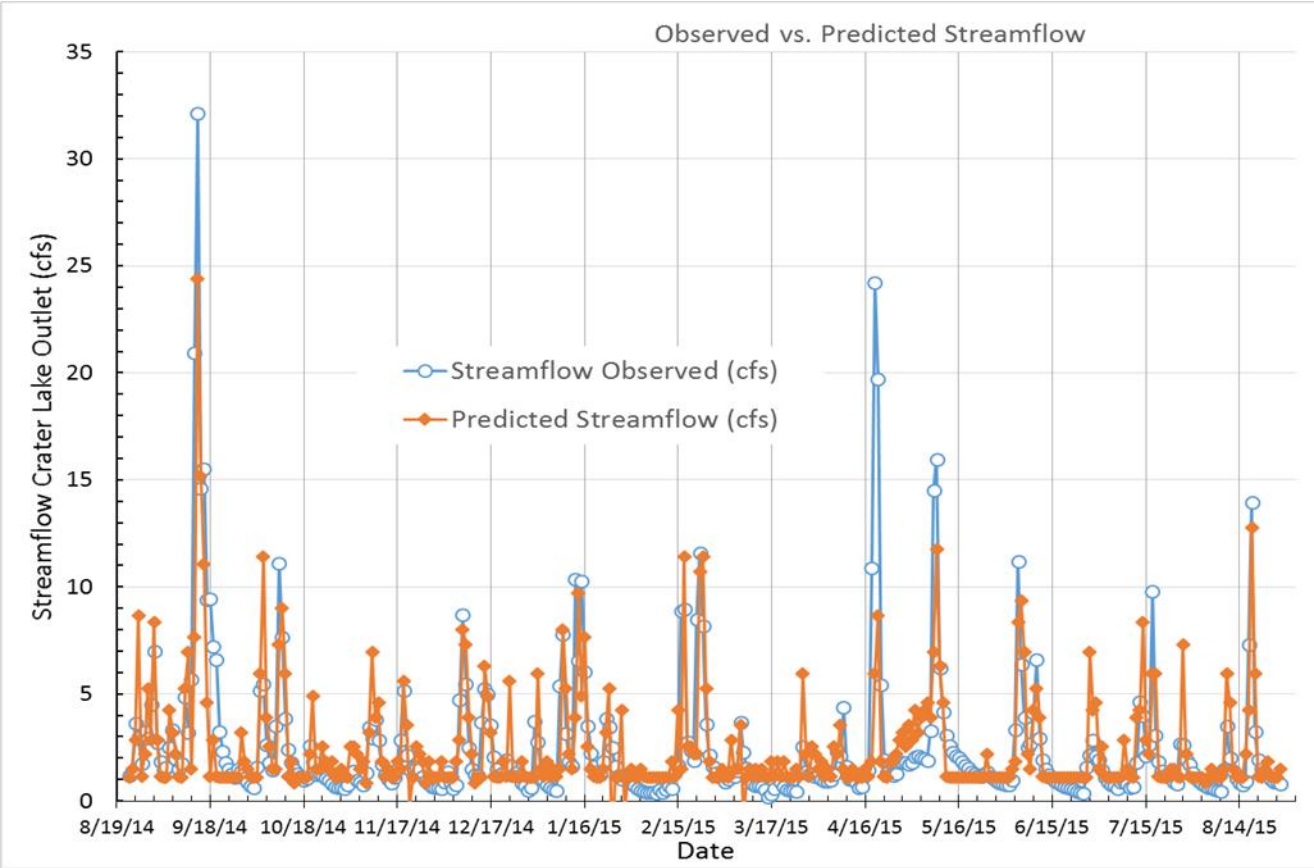


Figure 4-7. Observed vs. Predicted Streamflow Numbers from August 2014–2015 at Crater Lake Outlet

Another observation is that the SWE data comes from snow pillow accumulation and the precipitation data is accumulated via a tipping bucket. During times of snow accumulation, the tipping bucket can under-predict precipitation compared to the snow pillow producing "negative net precipitation input" Negative net precipitation (which cannot occur) led to calculations of negative streamflow. McMillen Jacobs elected to include the few negative values to illustrate the extent of the issue. Fortunately, this only occurred a handful of times during the 2008, 2010, 2012, and 2015 water years. The occurrences are isolated and have little to no effect on storage buildup and release.

Table 4-3. Percent Exceedance Values for Observed vs. Predicted Streamflow for the August 2014-2015 Time Period at Crater Lake Outlet

Percent Exceedance	Observed Flow (cfs)	Predicted Flow (cfs)
90%	0.6	1.1
80%	0.8	1.1
70%	1.0	1.1
60%	1.2	1.2

Percent Exceedance	Observed Flow (cfs)	Predicted Flow (cfs)
50%	1.4	1.5
40%	1.7	1.8
30%	2.1	2.2
20%	3.1	3.6
10%	5.4	5.9
5%	8.9	7.8

Synthetic hydrographs were created for 10 water years. The raw streamflow values were adjusted with a factor to ensure that the yield percentage between the runoff and overall water input was 81%. Table 4-4 reports these adjustment factors.

The adjustment factor mean was 0.95, meaning that streamflows in general had to be adjusted down. The downward adjustment ranged from 0.83 to 1.04 cfs.

One observed limitation of this simple model is that it did not retain the variability of the natural streamflow record. While this will likely not significantly impact storage patterns, it will impact the look and feel of the data and prevent the data from being used as an hourly operational model, which has little significance on a storage Project. Furthermore, the simple procedure does not allow for forecasting, although it could be done with daily precipitation values. During the design phase, it may be desirable to create a continuous hydrologic model that can better account for soil moisture storage and snowmelt and more precisely depict watershed behavior. The data at the SnoTel site is available as hourly data, and if the streamflow was taken hourly this would allow for a very precisely calibrated model.

Table 4-4. Water Years Where Record Was Extended with Overall Precipitation, Yield, and the Adjustment Factor Used to Correct Streamflow Values

Water Year	Annual Precipitation (in)	Annual Yield (AF)	Adj. Factor (Dim)
2006	150.5	1859	1.00
2007	104.5	1291	0.83
2008	137.5	1708	0.96
2009	116.8	1443	0.88
2010	117.6	1453	0.87
2011	145.1	1792	0.98
2012	175.4	2167	1.04
2013	142.9	1765	0.96
2014	156.8	1937	1.02
2015	139.2	1719	0.97

Water Year	Annual Precipitation (in)	Annual Yield (AF)	Adj. Factor (Dim)
Summary			
AVG	138.6	1713	0.95
Max	175.4	2167	1.04
Min	104.5	1291	0.83

4.6 Synthetic Streamflows and Storage

4.6.1 Streamflow Variability and Need for Storage

The Crater Lake system is extremely variable in terms of streamflow, even accounting for the attenuating effect of the lake. There is only one year for which observed streamflow is available, but the degree of variability depicted in Table 4-3 indicates that a full 40% of flows were less than 1.2 cfs and 10% of the flows were 5 cfs or greater. The observed flows are both variable and "flashy", jumping from under 1 cfs to 5 or more cfs between single day periods (Figure 4-7). This is a normal pattern for this type of setting, but without some form of storage, water availability would be hard to predict for energy production and would spike from low supply to over-maximum supply.

4.6.2 Storage Configurations

The developed streamflows were combined with the stage storage curve (Figure 4-1) to examine how different storage configurations could be managed to provide for water storage during the summer and winter higher demand periods. As a sensitivity analysis, two dam heights were chosen based on possibilities with the terrain. As the Project progresses the three configurations are likely to be refined. In practical terms, the Project is likely to have its greatest value at its highest storage scenario. The alternative configurations are as follows:

1. Proposed High Dam (Baseline) and Deep Lake Tap. This is the baseline assumption with a dam crest spillway crest at 1539 feet and lake tap elevation at 1494 feet. This gives a usable storage of 1,129 AF. To make the dam taller would involve numerous saddle dams, so this represents a reasonable assumption at the feasibility level.
2. Baseline Dam Height with Minor Tap Depth. This configuration has the same spillway crest elevation at 1,539 feet with a 5-foot laketap depth at elevation 1509 feet that could be accomplished by trenching a shallower outlet beneath the proposed dam. The usable storage with this configuration is 872 AF. Under this assumption, there would be 473 AF of residual "dead" storage and the lake would be 56 feet deep.
3. Lower Dam Height Option with Minor Tap Depth. This configuration has a spillway crest set to 1,530 feet in elevation with the same tap elevation as Configuration 2 at 1509 feet. This would create 533 AF of usable storage. Residual (dead storage) is the same as Configuration 2.

A more detailed stage storage curve shows the maximum dam height in terms of the storage curve (Figure 4-8)

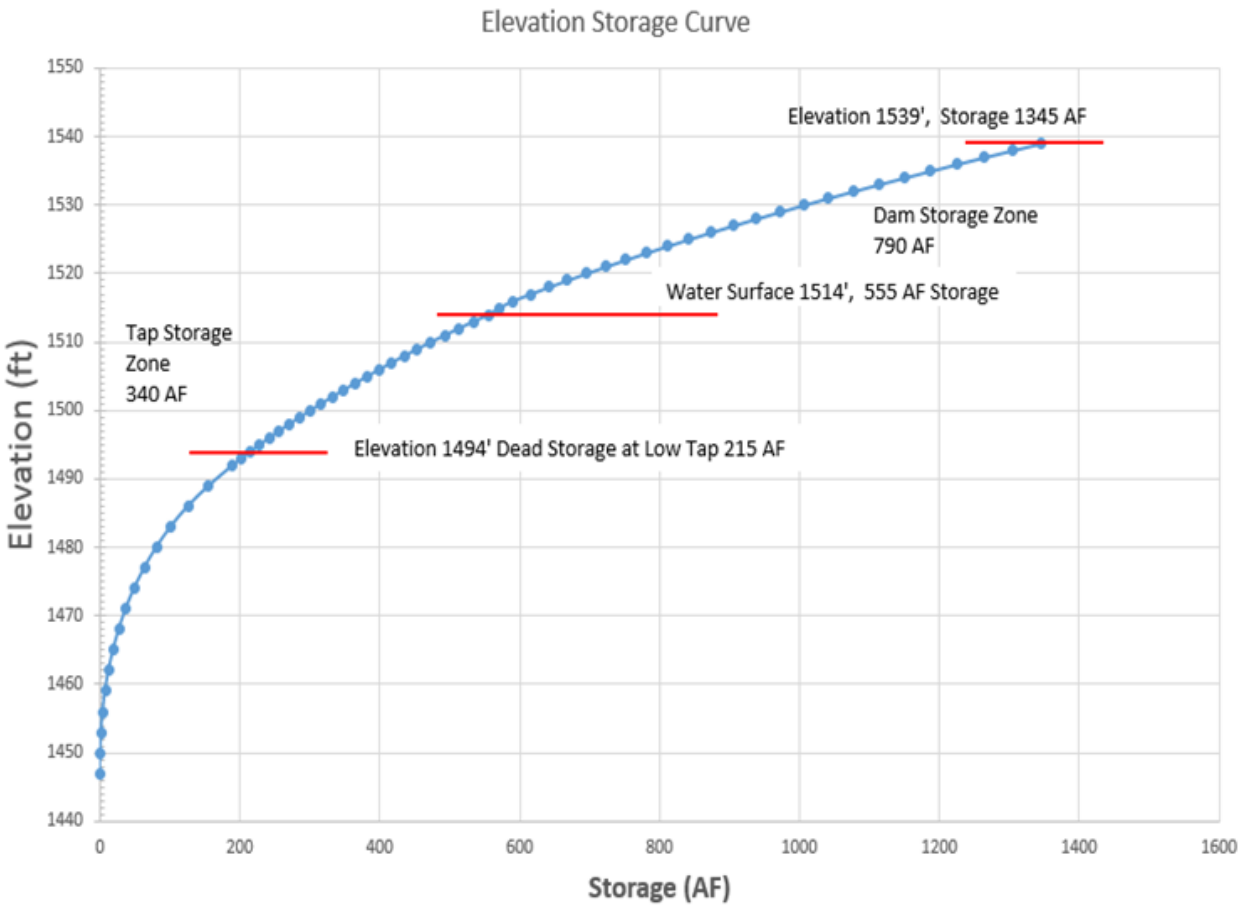


Figure 4-8. Stage Storage Curve with Deep Lake Tap and Baseline Dam Elevation

The generated 10-year streamflow record was used starting each water year (October 1) at the minimal residual storage level (215 AF). Stream flows were converted to acre-feet and accumulated or subtracted based on inflow vs. release rates. Based on discussions with CEC and COC staff, McMillen Jacobs tailored releases to be maximized during fish processing seasons associated with high water demands in the late winter and summer time periods[1]. Water storage is accomplished during other time periods. The releases were executed in 0.5-cfs increments based on water storage levels and the two seasonal needs. Generally speaking, each year and each configuration have the same general pattern:

- The initial fall period October 1 to January 1 is used to accumulate storage. Releases are curtailed or are kept very minimal.
- Releases begin in January and ramp up to 3 cfs to provide winter water for COC demands during a fish processing season and extra power for winter.
- In the spring (late March to June), depending on water levels, releases are minimized to store up both water and power potential for summer demand.

[1] It is important to note that this approach is different than the operational model, which used the same hydrologic input but seeks to offset diesel consumption. Additional analysis will be required during future design phases to refine the balance between water demand and diesel offset.

- In June, water releases are ramped to up to 5 cfs for summer demand and power needs during the fish processing season. The releases are kept at 5 cfs or lower because of pipe size constraint issues within COC's water supply lines.

In some cases, releases had to occur or were increased because storage levels were getting close to maximum values which would initiate flow down the natural channel. In other cases, water releases were decreased because available storage was being depleted.

4.6.3 Effects of Precipitation Patterns and Storage Capacity on Releases

The amount of water that could be stored or released is based on the precipitation input patterns over a given year and the available storage. In a dry year like 2007, there was little difference in what could be stored and then dispersed (Figure 4-9) because there was not enough rainfall/runoff to push the storage volumes to maximum levels in all but Configuration 3. All three configurations were constrained in that the full 5 cfs was not able to be released during the summer months, and during the winter months the release was limited to 2 cfs. As can be seen, because of storage issues, Configuration 3 had to have releases during the storage season for fear it would completely fill and waste water down the natural channel. Because it had releases during the storage season, its release during the summer season was 0.5 cfs lower. Figure 4-10 depicts the storage volumes over the season. Note that the range of total storage (active and dead pool) for Configuration 1 varies from 215 AF to 1,344 AF, while Configuration 2 varies from 473 AF to 1,344 AF and Configuration 3 from 473 AF to 1,006 AF. If storage begins to approach maximum levels, then water releases need to be ramped up. If storage is depleted to the minimum levels, the releases need to be ramped downward. With the larger storage volumes, water can be carried over from year to year, especially with the largest configuration. This happened during several years. This seasonal over-storage allows for greater flexibility in water releases in the subsequent year. As stated above, it was assumed that coming into each year the water was reset to residual storage levels.

During a wet year such as 2012, storage needed to be curtailed for the smaller Configuration 3, as well as Configuration 2, due to concern about completely filling and spilling (Figures 4-11 and 4-12); however, all three configurations were able to meet a full 3-cfs release during the winter period and a 5-cfs release during the summer period. There was also significant carry-over storage, especially with Configurations 1 and 2. The carryover storage allows for considerable flexibility on supplemental release periods to perhaps perform maintenance on other water supply facilities or supplement peaking generation needs.

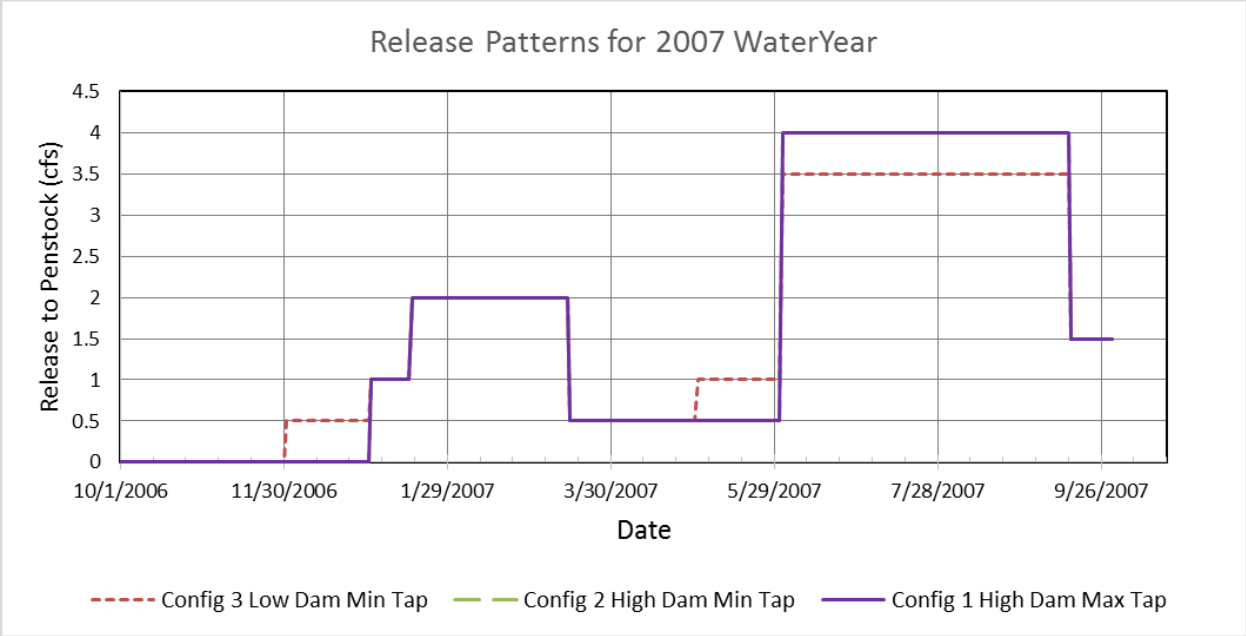


Figure 4-9. Flow Releases, 2007 Water Year (Dry Year)

(Note: Configuration 2 and 3 overlap as purple line)

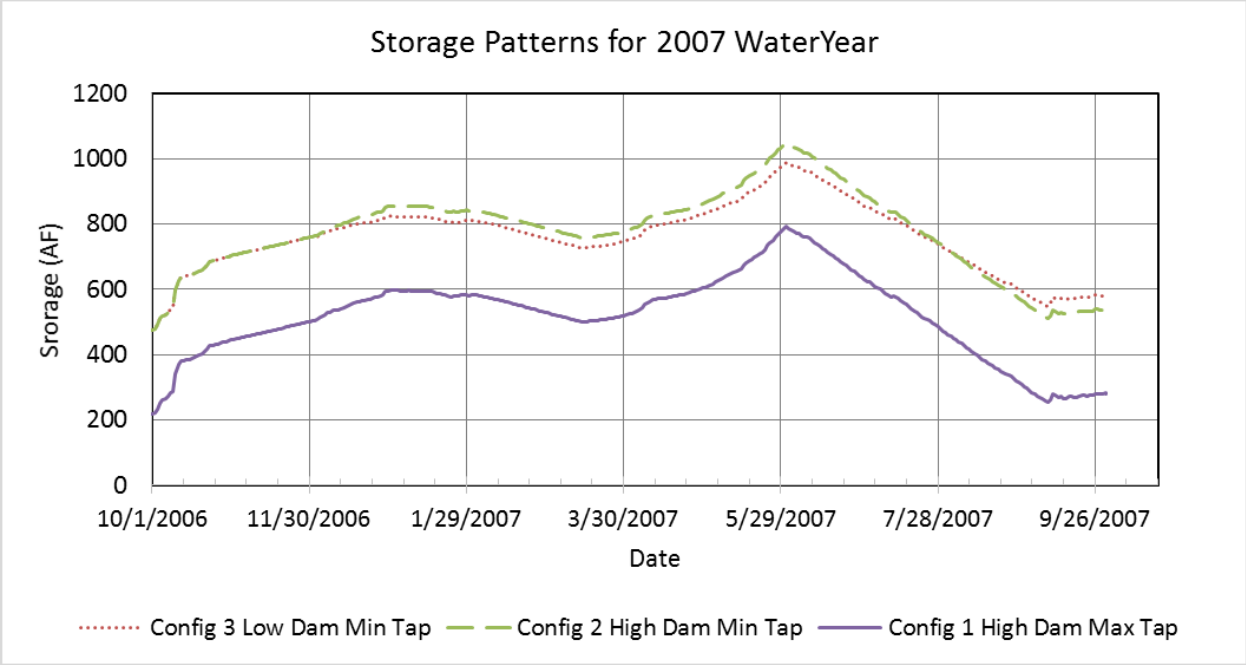


Figure 4-10. Storage Pattern for 2007 Water Year (Dry Year)

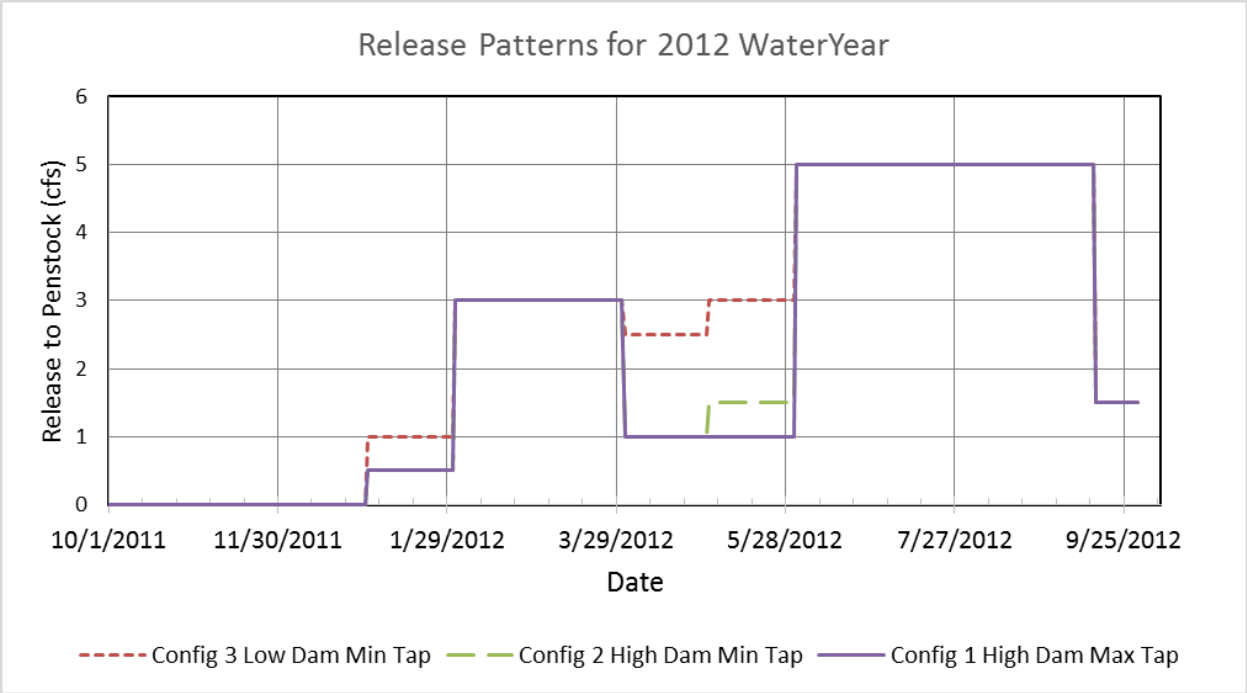


Figure 4-11. Flow Releases, 2012 Water Year (Wet Year)

(Note: Configuration 2 and 3 often overlap as purple line.)

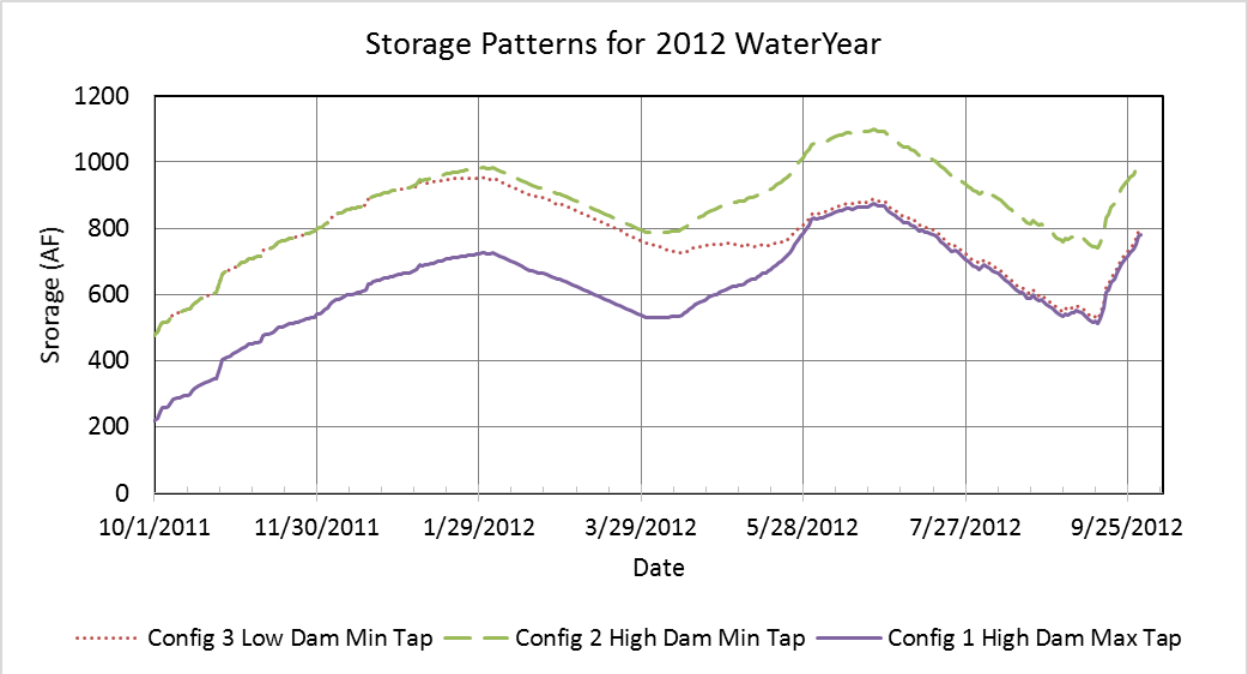


Figure 4-12. Storage Pattern for 2012 Water Year (Wet Year)

During 2008, an "average" year over the 10-year time period, Configurations 1 and 2 had identical release records while Configuration 3 had some supplemental releases in the spring and had to be throttled back, because it was nearing the end of its useable storage capacity (Figures 4-13 and 4-14). It should be noted that there was moderate carryover storage for Configuration 1 (the high dam and maximum tap configuration) and Configuration 2, but less for Configuration 3. Selecting one of the larger dam configurations provides for considerable operational flexibility and the ability to not need to watch the facility as closely. The larger storage configuration can also provide considerable carryover storage in comparison, as noted above.

In understanding the role of precipitation patterns and how different storage configurations compare, some important characteristics during the time period include (1) the ability to release 3 cfs during the winter processing season, (2) the ability to release 5 cfs during the summer high demand and processing season, (3) the ability to provide carryover storage during wet years, and (4)ease of management (i.e. not needing to trigger a curtailment due to lack of storage or trigger releases because of storage becoming full). Table 4-5 summarizes the overall characteristics for precipitation and some of the other key characteristics described above.

From Table 4-5 it is evident that with Configuration 3, there are more adjustments in releases than for the other two storage features. For the two higher storage capacity options, adjustments were only done in 1 out of 10 years for Configuration 2 and no years for Configuration 1. Having said this, during dry years there were times where the releases were set out lower due to lack of storage at the onset of the season. This occurred 5 of 10 years for winter storage and 2 of 10 years for summer processing for Configurations 1 and 2. For Configuration 3, summer processing releases had to be lowered 9 of 10 years.

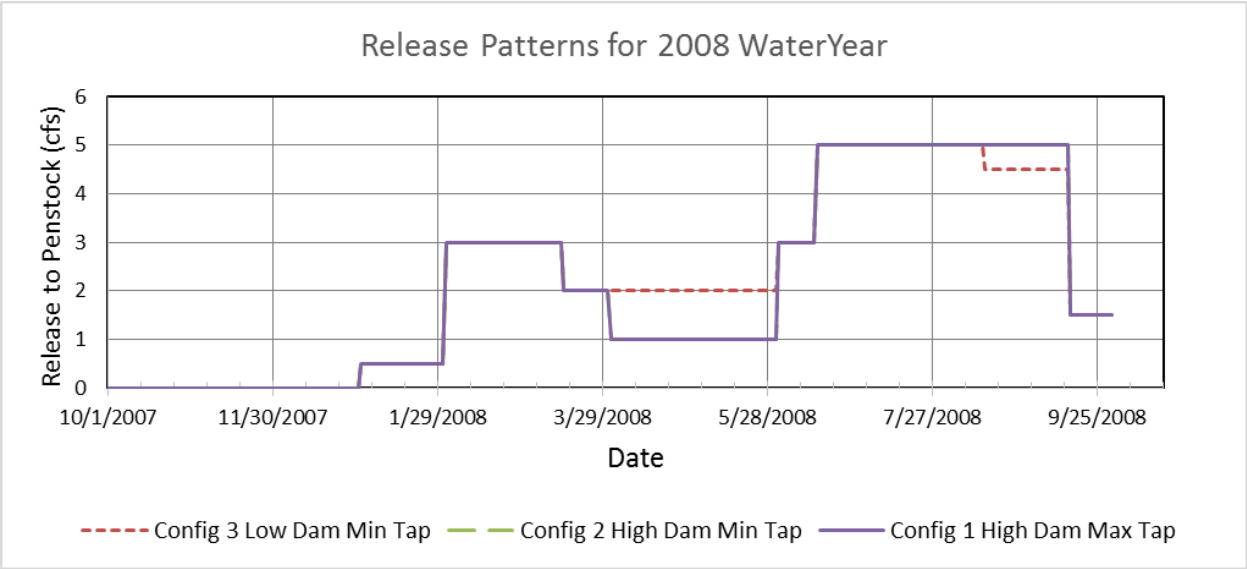


Figure 4-13. Flow Releases, 2008 Water Year (Normal Year)

(Note: Configuration 2 and 3 overlap with purple line)

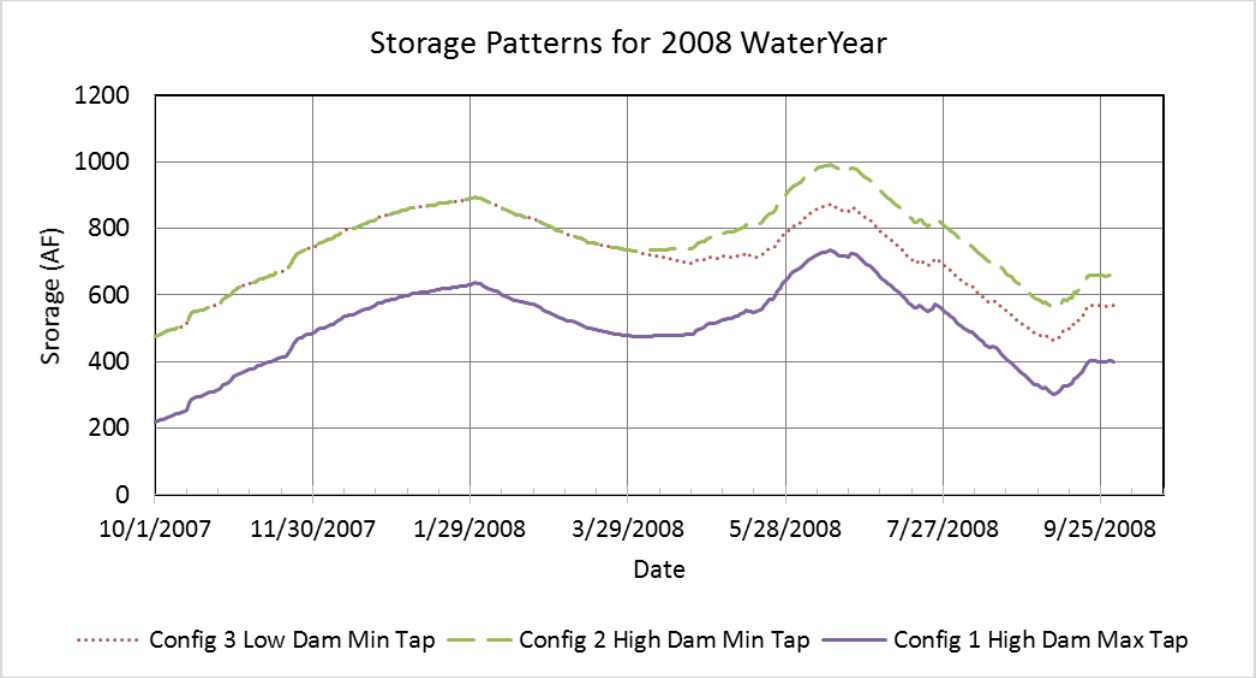


Figure 4-14. Storage Pattern for 2008 Water Year (Normal Year)

Table 4-5. Precipitation and Storage Characteristics by Years and Configuration

Water Year	Annual Precip (in)	Annual Yield (AF)	Max SWE (in)	Winter Process Full 3 cfs release (Y/N) (Config 1,2,3)	Summer Process Full 5 cfs release (Y/N) (Config 1,2,3)	Carry over Storage? Over 200 AF (Y/N) (Config 1,2,3)	In season release changes needed? (Y/N) (Config 1,2,3)
2006	150.5	1859	19	Y,Y,Y	Y,Y,N	N,N,N	N,N,Y
2007	104.5	1291	27.4	N,N,N	N,N,N	N,N,N	N,N,Y
2008	137.5	1706	43.2	Y,Y,Y	Y,Y,N	N,N,N	N,N,Y
2009	116.8	1443	29.1	N,N,N	N,N,N	N,N,N	N,N,Y
2010	117.6	1453	42.2	N,N,N	Y,Y,N	N,N,N	N,N,Y
2011	145.1	1792	27.5	N,N,N	Y,Y,N	Y,Y,N	N,N,Y
2012	175.4	2167	54.3	Y,Y,Y	Y,Y,Y	Y,Y,Y	N,Y,Y
2013	142.9	1765	48.4	N,N,N	Y,Y,N	N,N,N	N,N,Y
2014	156.8	1937	12.3	Y,Y,Y	Y,Y,N	N,N,N	N,Y,Y
2015	139.2	1719	10.4	Y,Y,Y	Y,Y,N	N,N,N	N,N,Y
Total Y/ AVG	138.6	1713	31.4	5,5,5	8,8,1	2,2,1	0,1,10

Carry over storage (values greater than 200 AF) was calculated in only 2 out of the 10 years with the larger storage configurations and in only 1 year with Configuration 3.

Based on ease of use (lack of in-season release changes and the ability to have full summer releases), either of the larger configurations is preferable to the smaller configuration.

4.7 Streamflow Record in Context of Larger Climate Trends

The dataset represents 10 years of climate data correlated to 1 year of streamflow data to create a synthetic streamflow record. In the context of overall climate, 10 years is not much time and could be representative of an unusually wet or dry period or cold or warm period. In order to evaluate the last 10 years of climate in the context of a longer record of climate, a larger dataset was obtained from the Western Regional Climate Center (WRCC, 2015) representing a weather station at the Cordova airport. This record dates back to the early 1900s with 84 complete years of record and records for individual months with 96–102 years of record. Table 4-6 lists precipitation at Cordova Airport for the longer period of record as compared to 2006–2014, which is the bulk of the record period that is being used for this study. In evaluating this record, the average for 2006–2014 is over 20 inches lower than normal (99.8 inches vs. 78.5 inches of precipitation for 2006–2014). There are only 2 out of the 9 years that have precipitation greater than the long-term record average, and both are slightly over the average. The record low precipitation occurred within the 9-year period (2007 calendar year at 43.6 inches), and this represents the bulk of the 2007 water year used as the “dry” year. The “wet” water year (2012; 103.8 inches) represents near average conditions. The year McMillen Jacobs used for “normal” conditions represented an average condition of the 10 years but a drier overall condition (2008; 75.4 inches) from the historical record. Within the 10 years of record at the Cordova gage there was not an abnormally wet year. The wettest year over the 2006–2014 period was 103.8 inches in 2013 at the Cordova airport weather station.

Table 4-6. Long-term Monthly Precipitation Records from Cordova Airport Weather Station

Month	Full Period Years of Record	Full Period Average	Full Period Max	Full Period Min	Average 2006-2014
JAN	96.0	7.3	20.3	0.6	6.3
FEB	97.0	7.4	25.5	0.0	4.6
MAR	98.0	6.4	31.5	0.4	3.0
APR	98.0	6.2	37.0	0.1	3.2
MAY	102.0	6.8	20.9	0.7	4.0
JUN	98.0	5.1	14.6	0.7	3.9
JUL	101.0	6.8	20.1	1.2	5.8
AUG	100.0	10.6	32.5	2.5	9.5
SEP	100.0	15.6	49.6	4.3	14.6
OCT	99.0	15.1	45.1	2.4	11.3
NOV	97.0	9.8	32.3	0.5	6.0
DEC	99.0	9.4	30.9	0.0	6.4
Annual	84.0	99.8	201.1	43.6	78.5

Overall temperatures on a monthly or annual basis over the period were near average. The overall average temperature was 48.6 degrees F. The temperatures over the 2006–2014 period varied from 46.2 degrees F to 50.3 degrees F. The snowfall record was difficult to interpret due to missing values, but it appears that snowfall was much lower over this 2006–2014 period perhaps because precipitation was down during key months when snow accumulation normally occurs, such as November through February.

4.8 Conclusions and Recommendations

From the previous analysis the following conclusions and recommendations are given:

- The correlation between precipitation data at the Mt. Eyak SnoTel site and streamflow at the Crater Lake outlet is an adequate method to develop a synthetic hydrograph, but caution should be used when looking at extreme high and low streamflow predicted values.
- If a better understanding of extreme values is needed, a continuous watershed model is recommended along with continued data collection of streamflow at the outlet.
- The period of record used suggests a drier climate with generally less snow accumulation than the long-term record. This could represent a change due to broader changing climate conditions and a new normal, or could represent a cyclic trend. Based on examining longer-term climate records, there have previously been similar dry trends.

- Storage is highly advantageous due to the variable runoff pattern at the lake outlet. Storage allows managers to better craft releases for both water supply and power production. The two larger storage configurations seemed to allow for proper storage and release management while the smaller configuration had to be adjusted more often and frequently resulted in seasons where the full target release allocation could not be sustained over the entire season.

5.0 Water Supply and Treatment Evaluation

5.1 Water Supply Evaluation Purpose

The main purpose of this section is to document the analysis of COC's current water supply and treatment systems, especially as they relate to the Crater Lake/Crater Creek water supply and the potential new CLWPP power generation and water treatment facility. The results of these findings will be integral to the overall Project feasibility evaluation. Findings and discussion in this report are based upon the data and information collected as discussed below.

This section also provides a concept hydraulic analysis of the new penstock system from Crater Lake to the new Orca Water Treatment Plant (WTP). In addition, a conceptual discussion of penstock pipe system alternatives and preliminary penstock design recommendations are provided.

5.2 Data Collection

Data sources used to prepare this section include the following:

- Discussions with the COC staff on several site visits, including the latest visit conducted on August 27, 2015 (with Fajardo, Greenwood and Stavig) as part of the Project kickoff meeting with COC and CEC staff.
- Annual water production records from the COC's three main sources, beginning in year 2000.
- Copy of design documents from GV Jones from the 2015 Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) Upgrades Project
- Submittal information from Trojan UV on its new UV irradiation systems for COC's three main sources.
- Selected water distribution system maps and drawings provided by COC.

5.3 COC Historical Water Production/Demand

Prior to the recent Project site kickoff meeting, COC provided annual water production records for its three main water sources (Meals Reservoir, Murcheson Reservoir, and Crater Lake/Crater Creek). The Eyak Lake WTP is a lower quality surface water source that is generally held as a backup reserve water source only and is generally used only in times of emergency outage or shortage from the three main unfiltered water sources noted above.

The historical water production data (provided in Excel® spreadsheets) was organized by COC in terms of monthly total volume use from each source for each given year. The monthly data was averaged over the historical time periods as follows:

- 15 years of data from 2000 through 2014
- 5 years of recent data from 2010 through 2014

To assess the relative contributions of each source, the historical data was tabulated, with an emphasis on the Crater Creek contribution. Table 5-1 below provides a summary of that data for both the Crater Lake supply alone and for the total of all unfiltered sources (Crater Creek, Meals, and Murcheson). Figure 5-1 presents a graph of the monthly average flow (in cfs) for 2010-2014 at Crater Creek and the COC system as a whole.

Table 5-1. City of Cordova Historical Avg Water Usage from Crater Creek and Total from all Sources

Month	Crater Creek Hist. Avg Water Use* (2000-2014) (MG)	Crater Creek Hist. Avg Water Use* (2000-2014) (cfs)	Crater Creek Hist. Avg Water Use* (2010-2014) (cfs)	Total (All Sources). Hist. Avg Water Use (2000-2014) (MG)	Total (All Sources). Hist. Avg Water Use 2000-2014) (cfs)	Total (All Sources). Hist. Avg Water Use (2010-2014) (cfs)
January	11.4	0.57	0.66	29.5	1.47	1.99
February	10.9	0.60	0.70	29.2	1.61	2.15
March	9.18	0.46	0.38	35.1	1.75	2.25
April	12.2	0.63	0.74	37.7	1.94	2.71
May	18.0	0.90	1.02	42.6	2.12	2.74
June	20.8	1.07	1.14	51.3	2.56	3.30
July	24.6	1.23	1.66	77.6	3.87	6.06
August	22.3	1.11	1.55	78.9	3.93	4.79
September	12.6	0.65	0.71	43.5	2.24	2.52
October	12.3	0.61	0.58	31.3	1.56	1.78
November	11.5	0.59	0.58	28.8	1.48	1.73
December	11.7	0.58	0.62	30.7	1.53	1.90

Avg. Annual Production			**204 MG** (625 acre-ft)			**612 MG** (1880 acre-ft)
Max. Annual Production			**245 MG** (2014)			**636 MG** (2014)

* Based upon ~15 years of historical water usage collected by COC data from 2000 through 2015. Yr. 2006 data not used due to incomplete records and issues with flow totalizers, and use of Eyak Lake source.

MG = million gallons

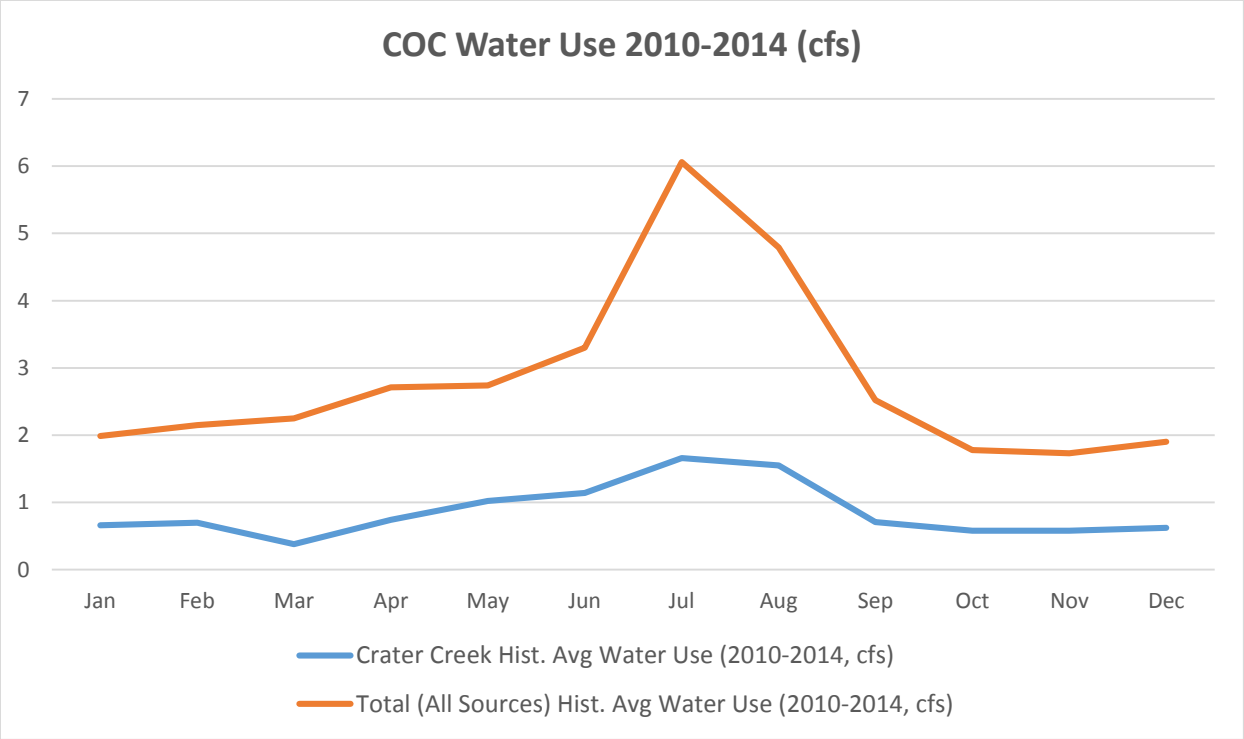


Figure 5-1. Monthly Crater Creek and Total COC System Water Flows 2010-2014

5.3.1 Water Production History since 2000

The following provides a basic summary of these water production records starting in year 2000, as well as observations provided by COC staff during discussions on water supply sources:

- Total COC annual water production has increased from about 400 million gallons (MG) from year 2000 to about 640 MG in 2014. (No data was provided that would indicate whether the water demand increase was primarily residential or commercial [cannery expansion], although discussions with COC staff would seem to indicate more commercial use requirements.)
- The Crater Lake / Crater Creek annual water production has historically ranged from about 120 MG up to 200 MG, with a high level of 244 MG in 2013. (Eyak Lake WTP was run for the first 4 months of 2014, due to maintenance issues in other water supplies of the COC system. Thus – water production numbers from Crater Creek / Orca WTP were quite low for 2014.)
- Total water demand for the entire COC system has grown steadily over the last 5 years from about 570 MG in 2010 to about 640 MG in 2014 and 2015 (anticipated).
- Since 2000, Crater Lake has historically accounted for ~28 to 38% of annual water production for COC, with an average of about 35% of total annual water production.
- The highest quality water sources for COC are the Crater Creek and Murcheson sources. (The Crater Creek source would be expected to improve even further with construction of the CLWPP, by preventing further entrainment of suspended solids and organic carbon as the water travels down Crater Creek.)

- During late August and September, Crater Creek often produces around 2 cfs (900 gallons per minute [gpm] of water) with perhaps 100 to 200 gpm of excess water that currently seeps through the gabion basket rock dam on Crater Creek.
- During late March through May, flows in Crater Creek are generally the highest (see hydrology section above).
- The low demand period on the COC water system is the months of October through January.

5.3.2 High Demand Water Seasons for COC

COC experiences one small late winter / spring water demand peak and one distinct high-demand water peak (summer) each year as follows:

- A small water demand peak occurs from February through April due to commercial long-line fisheries season (cod, halibut, and others) and associated ramp-up on local cannery operations and water use.
- The largest water demand peak each year occurs in June through August due to the commercial salmon fishing season and ramp-up on local cannery operations and water use. To a much smaller extent, summer tourism also places an increase on water demand during this same period. This increase in total water demand can be easily seen in the last column of Table 5-1 and in Figure 5-1.

Cannery high water demand should also correspond similarly to cannery high electricity demands during the same periods. Thus, COC would benefit from an increase in Crater Lake water supply and CEC may benefit from increased hydropower generation during this time period.

5.3.3 Problems with Freezing Water Sources

Both Murcheson Falls and Crater Creek currently run the risk of freezing and losing water production in the middle of winter. This is generally true and/or possible from mid-January through mid-March. The outlet of Crater Lake can freeze nearly solid at its current shallow depth of less than 1 foot deep. During such cold weather times, only Meals and lower quality surface water from Eyak Lake WTP are available for water supply to COC. ***This represents a critical time period for COC, as it must substitute lower quality Eyak Lake water for higher quality Crater Lake water***. As noted above, the COC typically experiences a slight increase in water demand when the canneries demand water to support the commercial “long-line” fisheries season (February through April). A reliable, unfrozen source from Crater Lake could provide additional benefit during this period.

5.3.4 Future Demand Growth Estimates for COC

Future water demand growth on the COC system is largely tied to the existing commercial canneries in Cordova and their desire to increase fish processing capabilities on-shore. Recent letters and discussion with COC staff have indicated the possibility of a desire to expand existing facilities by as much as 25%. This represents both a water supply challenge and a potential opportunity to meet these needs with an expanded CLWPP.

5.4 Existing Water Transmission out Of Orca WTP

5.4.1 Existing 16" Diameter Treated Water Pipeline from Orca WTP to Morpac Reservoir

The existing treated water that leaves from the Crater Creek / Orca WTP currently flows by 16-inch diameter gravity pipeline to the Morpac treated water reservoir, located some 2.6 miles in pipeline distance to the southwest. The Morpac Reservoir has a storage capacity of 480,000 gallons and is located just uphill from COC's ferry dock. The reservoir has a floor elevation at 178 ft mean sea level (msl), above Orca Bay. The tank has a total sidewall reservoir height of about 30 ft with an overflow elevation at ~207.3 feet.

The transmission pipeline that conveys water to Morpac Reservoir is a mostly 16-inch nominal diameter ductile iron (DI) pipe. This transmission pipeline along New England Cannery Road was installed in the early 1980's and is estimated to have an overall length of about 13,800 feet (2.6 miles). The entire pipeline was purposely oversized (mostly 16-inch diameter), because its main design purpose was to serve as chlorine contact retention volume to provide detention time for the inactivation of Giardia with the current chlorine system.

The transmission pipeline is made up of the following segments:

- The first ~600 ft leaves the existing Orca WTP as a 12-inch diameter DI pipe until it crosses the Crater Creek culvert just south of the Orca Lodge where it changes to a 16-inch diameter pipe.
- Approximately 12,600 ft of 16-inch diameter DI pipe until the pipe reaches the dedicated access driveway leading up to Morpac Reservoir.
- The last ~600 ft of pipeline prior to reaching the Morpac Reservoir inlet is a 10-inch diameter DI pipe.

Table 4-2 below shows that flow velocities in this mostly 16-inch diameter transmission pipeline are very low for the current water flows typically between 1.1 and 2.2 cfs (500 to 1,000 gpm). These low velocities are consistent with the pipelines original design intent to serve as a chlorine contact chamber specifically for Giardia inactivation.

Significance of New LT2 Upgrade Project on Existing Transmission Pipeline. It should be noted that when UV radiation is installed as part of the COC's current LT2 Upgrades Project, all Giardia inactivation will be accomplished by the new UV irradiation system. Once the UV treatment is installed, the oversized transmission pipeline to Morpac will no longer be constrained by its need to disinfect for Giardia, meaning that treated water flow rates through this existing 16-inch diameter line can easily be increased from the current 2.2 cfs (1,000 gpm) maximum levels up to levels near 5 cfs (2,300 gpm).

5.5 Hydraulic Analysis of Existing Transmission Pipeline to Morpac Reservoir

If a new CLWPP is constructed, it is very likely that the first ~600 ft of 12-inch diameter pipeline that leaves the current Orca WTP would be eliminated, and replaced with new penstock pipeline from the

Crater Lake supply. Also, the last ~600 ft of the existing 10-inch pipeline that feeds the Morpac Reservoir would likely have to be either upgraded to a new 16-inch pipeline, or another parallel 10-inch diameter pipeline would need to be installed alongside the existing 10-inch pipeline, to increase transmission capacity in this short line. As a result, the hydraulic analysis provided in Table 5-2 effectively assumes that all of the pipeline between the new CLWPP and the existing Morpac Reservoir would be 16-inch-diameter DI pipe.

Table 5-2. Flow and Head Loss Estimates in the COC's Existing 16 Inch Dia Treated Water Transmission Pipe along NE Cannery Rd to Morpac Tank Reservoir

Water Flow Rate (cfs)	Velocity in 16" DIP Pipeline (ft/sec)	Pipeline Frictional Head Loss* (ft / 100 ft)	Total Head Loss over 13,200 ft (ft)	Added Pump Power Req'd** to overcome Friction loss (kW)	Daily Energy Loss due to Pipe Friction (kW-hr/day)
1	0.72	0.015	2.0	0.20	4.7
2	1.4	0.055	7.3	1.47	35
3	2.2	0.12	15.8	4.78	115
4	2.9	0.19	25	10.1	243
5	3.6	0.30	40	19.7	474
6	4.3	0.42	55	33.6	806
7	5.0	0.55	73	51.6	1,240
8	5.8	0.70	93	74.7	1,790

* Assumes Hazen Williams coefficient of 130 in DI pipeline.

** Assumes overall motor and vertical turbine pump efficiency of 84%

Results. Table 5-2 provides an indication of how friction losses (i.e. headloss in the pipeline) will increase with increase in flow rates, if CLWPP (new hydropower / UV facility and booster pump station) is constructed. The table shows that at current pipeline flow rates in the 1 to 2 cfs range, there is virtually no head loss in this long pipeline. In order to maximum the COC's use of high quality Crater Lake water, maximum flow rates out of the new CLWPP are anticipated to increase from current levels up to potentially the 5 to 6 cfs range.

In general, small-diameter water transmission lines should be designed to limit friction loss in those pipes to less than about 4-ft of friction loss per 1,000 ft of pipeline (or 0.4-ft per 100 ft of pipeline). ***For the existing 16-inch-diameter transmission water line along NE Cannery Road, this criteria means that the pipeline could efficiently carry future flows up to about 5.5 cfs (2,500 gpm) maximum***. In McMillen Jacobs' opinion, Table 5-2 shows that flows above that 5.5 cfs level maximum for this existing pipeline will result in excessive head loss (i.e. daily energy loss) and extra pumping requirements.

5.6 UV and Booster Pump Station Design for Crater Creek Source

5.6.1 COC's 2015 / 2016 UV System Upgrade Project for Compliance with EPA's LT2 Regulations

All three of the main surface water sources for COC (i.e. Meals, Murcheson, and Crater Lake / Orca) are presently unfiltered water supplies. The US Environmental Protection Agency (EPA) regulations generally require that unfiltered surface water supplies receive some form of treatment to inactive *Cryptosporidium* and other chlorine-resistant microorganisms. Starting in 2014, COC began the planning and design process with GV Jones and Associates, to implement new UV irradiation technologies at each of these three sites, to ultimately comply with the EPA's LT2 Rule. Construction of that Project is expected to be completed in 2016.

The UV reactors that will be used at each of the three COC water treatment sites, will all be the same model low pressure, high output (LPHO) reactors as manufactured by Trojan UV. ***All reactors are the same Trojan UV Swift SC Model D12, with each reactor containing 12 LPHO lamps and reactor vessels with a 12-inch ANSI flange inlet and outlet***. COC wisely decided to make all reactors of the same model number and componentry in order to simplify operations and maintenance (O&M) requirements and to allow for future interchangeability of the reactors amongst the treatment sites.

The water flow rate treatment capability of each UV reactor is dependent upon the measured UV transmittance (UVT) of the raw water. The lower the UVT of the water, the more difficult it is for UV radiation to penetrate the water column and disinfect against microorganisms. The design UVT plays a very significant role in sizing UV reactors, and low UVT values can often be the limiting factor for the design treatment capacity of a given unit. As a gross rule-of-thumb for LPHO systems, a difference in UVT of 8% (from 80 to 88%) can often result in a doubling of the treatment capacity of a given unit.

COC along with its design engineers has designed for the following UVT values at each water source along with the number of the *Trojan UV Swift SC* Model D12 reactors as indicated below:

Crater Creek Source UVT design value = **80%**

(Orca WTP) UV dose = 12 millijoules per square centimeter ($mJ/cm^{2)}$ for a 3-log *Cryptosporidium* Inactivation

Total No. of Reactors = 2 (1 Standby)

No. of Duty Reactors = 1

Treatment capacity per Model D12 reactor = 1,900 gpm (4.2 cfs) at 80% UVT

Total treatment capacity = 1,900 gpm

Murcheson Source UVT design value = **80%**

UV dose = 12 mJ/cm^2 for a 3-log *Cryptosporidium* Inactivation

Total No. of Reactors = 2 (1 Standby)

No. of Duty Reactors = 1

Treatment capacity per Model D12 reactor = 1,600 gpm at 80% UVT

Total treatment capacity = 1,600 gpm

Meals Source UVT design value = **70%**

UV dose = 12 mJ/cm^2 for a 3-log *Cryptosporidium* Inactivation

Total No. of Reactors = 3 (1 Standby)

No. of Duty Reactors = 2

Treatment capacity per Model D12 reactor = 900 gpm at 70% UVT

Total treatment capacity = 1,800 gpm

The above data shows the treatment significance of the UVT design value. The 80% UVT values at Crater Creek and Murcheson can treat more than twice the flow rate of water than that of the same reactor with a 70% UVT design value at the Meals site. One of the Model D12 reactors at the Orca WTP site is pre-validated to treat up to 1,900 gpm of flow (4.2 cfs), assuming the UVT is at or above the 80% level, at least 95% of the time.

The *Trojan UV Swift SC* Model D12 reactors being supplied to all three of the water supply facilities mentioned above are designed to run on 240 / 120 VAC, single-phase, 60-Hertz (hz) power as input to their main control panel. Each unit has a connected power load of ~ 3.3 kW. At the maximum flow above of 1900 gpm through one reactor, the expected head loss through the reactor is only about 1.1 feet.

5.6.2 Future UV Treatment at new CLWPP Site

Given that the new Crater Lake CLWPP will have higher quality / less turbid water due to the new small dam impoundment, it is expected that the UVT of the water should improve by 2% to 5%, meaning that one of the Model D12 reactors should be able to treat 2,250 gpm or more (i.e up to 5 cfs). Trojan UV could easily verify the treatment capacity of one of these units at slightly higher UVT values, up to 85%. ***This means that it is highly likely that the one duty UV reactor planned for the current Orca site will be able to be relocated to the new power plant / treatment building, and properly treat up to about 2,500 gpm (5.5 cfs) of water flow meeting the dose for 3-log Cryptosporidium inactivation***. Under this case, no new UV units would need to be purchased for the new CLWPP facility.

The worst case scenario for providing UV treatment at the new CLWPP site would be one of the following:

- One additional Model D12 (or smaller) reactor would need to be purchased from Trojan UV, or
- Assuming that the water demand requirements might drop off at the Meals source, possibly one of the three UV reactors at Meals could be relocated to the new CLWPP site, to provide added treatment capacity, if needed.

The configuration of the relocated UV system at the new CLWPP powerhouse would be one where the new Pelton turbine discharges into an open tailrace wet well, which feeds the Trojan Model D12 UV reactors under gravity flow. This is a very practical hydraulic solution, because these UV units would be expected to have a flange to flange head loss of less than 1.5 ft at maximum flow of 5 cfs. The UV reactors would then discharge their treated water into another wet well that would feed the booster pumps necessary to convey water to Morpac Reservoir. (Plan and section drawings of this layout configuration will be provided in the preliminary design report.)

5.6.3 Booster Pump Station at the New CLWPP Site

Depending upon the site selected for the new CLWPP facility, it is highly likely that this site will be below the possible high water surface elevation of the existing Morpac Reservoir (~ elevation 206 feet msl). For treated water to flow by gravity from the new CLWWP site to the existing Morpac Reservoir, the new CLWPP facility would need to have a powerhouse finish floor elevation (FFE), assuming a maximum treatment flow of 5 cfs, at or above the following:

- FFE = High water surface elevation (WSEL) at Morpac + headloss through transmission piping + ~10-feet (for turbine discharge pit and headloss through UV system)
- FFE = 206 feet + 40 feet + 10 feet = 256 ft msl

Given the height of this FFE and the lack of easily accessible land at this elevation around the Orca Lodge area, it is reasonable to assume that the new CLWPP facility would include a booster pump station to move treated water to the Morpac Reservoir site.

Configuration of Booster Pump Station. The most efficient and reliable pumps that a booster pump station can have for this type of configuration are multi-stage, short-set column vertical turbine pumps. These pumps can typically be designed for overall wire-to-water efficiencies of up to 86%, maximum. To maintain simplicity of design and O&M needs on this new pump station, the first concept design should investigate providing a simple one duty pump plus one standby pump configuration, with each pump being driven by a variable frequency drive (VFD). Due to the small electrical grid size of the CEC system, the booster pumps would need to be equipped with a VFD to limit the in-rush / high amperage currents upon pump startup. (Even for standard larger utilities, it should be noted that for most pumps larger than about 25 horsepower (HP) in size, use of a VFD to start the pump [and limit in-rush currents], is a current standard practice with the great improvements and reduced costs in VFD technology over the past 15 years.)

The duty pump configuration could be as follows:

- **Maximum pump output** = Up to ~5 cfs (2,250 gpm) at full motor speed of 1760 revolutions per minute (rpm), corresponding to 60-Hz output from the VFD.
- **Minimum pump output** = About 50% of maximum output or ~2.5 cfs (1,120 gpm) at half motor speed of 880 rpms, corresponding to 30-Hz output from VFD.

The standby pump would be of identical make and model to that of the duty pump. Note that VFDs operating on vertical turbine pumps can typically run effectively from about 30 Hz to 60 Hz. Output frequencies of less than 30 Hz (i.e. half speed of the motor), often result in instabilities and hydraulic performance issues for the pumps. The pumping scenario described above would mean that the minimum future water flows from the Crater Lake supply could be as high as 2.5 cfs +/-.

Table 5-3 provides a calculation of the motor size and pump power required of the duty pump, depending upon the working water surface elevation of the booster pump station wet well. Note that the powerhouse turbine generator finish floor would likely be about 8 to 10 ft above the pump station wet well water surface elevation (WSEL).

Table 5-3. Duty Pump Requirements for new Booster Pump Station at new CLWPP Facility

Pump Sta. Wet Well WSEL. (ft msl)	Duty Pump Max. Flow (cfs)	Static Lift * (ft)	Estimated TDH** (ft)	Duty Pump Power Required (hp)	Duty Pump Motor Size Required*** (hp)
50	5.0	161	207	138	150
75	5.0	136	182	121	125
100	5.0	111	157	105	125
125	5.0	86	132	88	100
150	5.0	61	107	72	75
175	5.0	36	82	55	60
200	5.0	11	57	38	40

Note: (Assumes maximum pump flow output of 5 cfs or 2,250 gpm)

*Assumes Morpac Reservoir operation water surface elevation of 206-ft msl.

** Total Dynamic Head - see Table 4-2 for added friction loss through existing transmission piping system at designated flow rate (~40-ft headloss for 5.0 cfs) and add 6-ft headloss for pump column and discharge valving, etc.

*** Note that any motor sizes over 15 HP are almost always 3-phase motors and most typical and efficient in a 480-VAC service, 3-phase power supply.

From a pump efficiency perspective and due to the fact that VFDs work better when the frictional head loss is a larger percentage of the overall Total Dynamic Head (TDH) value, ***the optimal pump station wet well WSEL would be for the range of about 100 ft to 200 ft msl.*** Higher values of the wet well WSEL closer to 200 ft msl may provide higher overall net energy production for CEC, assuming that all the water flows through the turbine system are treated and pumped to the COC storage facilities. This assumption about COC water use of Crater Lake water may be true for only certain seasons of the year, and the monthly and annual power operations modeling currently being performed as part of the Project work will help define and clarify these assumptions about water use and net energy production by CEC on a monthly basis, from the new Project.

Sizing of Booster Pump Station Wet Well for Chlorine Contact Needs. The new chlorine contact chamber for the CLWPP would be small enough that it could serve also as the wet well supplying water to the new booster pumps. In brief summary, the new chlorine contact system would only need to be designed to provide a 4-log virus inactivation of the unfiltered water,

The retention time for 4-log virus inactivation is only about 5% of that current retention time required of the current system for 3-log Giardia inactivation. The new water treatment UV system would provide for both 3-log Giardia and 4-log Cryptosporidium inactivation to meet the EPA's Surface Water Treatment Rule (SWTR) and the LT2ESWTR. (UV disinfection systems are given little credit in the LT2ESWTR regarding their ability to inactive a wide range of viruses.) This means that chlorine would no longer need to serve as the disinfectant to provide Giardia inactivation, as it currently does down the 2.5-mile-long, 16-inch-diameter transmission line along New England Cannery Road.

The following provides a brief overview of the disinfection requirements for unfiltered surface water supply systems per the old SWTR and the new LT2ESWTR regulations by the EPA. Total disinfection needs for the new CLWPP facility will be as follows, at worst case (i.e. cold) water temperatures of presumably 1 degree celcius (C):

- 3-log inactivation of *Cryptosporidium*
- 3-log inactivation of *Giardia*
- 4-log inactivation of virus

The current chlorine system provides for disinfection of the last two categories (Giardia and virus) only. Chlorine is completely ineffective in the inactivation of against *Cryptosporidium*. The new LT2ESWTR rule mandates that all unfiltered surface water supply systems will need to provide some log inactivation of *Cryptosporidium* to protect the health of the general public against this and other chlorine-resistant micro-organisms. The new treatment plant, after UV is installed, will have UV radiation providing the following full disinfection services at 0.5 degrees C:

- 3-log inactivation of Cryptosporidium
- 3-log inactivation of Giardia
- 0-log inactivation of virus

Note that UV is basically ineffective against virus inactivation. The overall system must provide 4-log inactivation of virus. Therefore, the new plant will still need to provide for 4-log inactivation of virus – <u>but zero-log inactivation against Giardia</u>. The significance of this is that virus inactivation takes a much lower CT value (i.e. residual concentration "C" times contact time "T") than Giardia inactivation currently requires of the system. The values of CT for worst case cold water (0.5 degrees C) and assuming a free chlorine concentration of 1.0 milligram per liter (mg/l) are as follows:

- CT for 3-log inactivation of Giardia by free chlorine = **210 mg-min/L** at pH=7.0; or **253 mg-min/L** at pH=7.5
- CT for 4-log inactivation of virus by free chlorine = **12 mg-min/L** at pH in range of 6.0 to 9.0

Notice the difference in the CT values of those two above conditions between disinfecting for Giardia and virus. Disinfecting for virus will take only about 1/20 or approximately 5% of the contact time than the current Giardia CT system requires for chlorine from Orca WTP facility. **This means the new treatment facility will be able to achieve full disinfection against 4-log virus with free chlorine in just 6 minutes (for a chlorine residual of 2.0 mg/l) or 12 minutes (for a chlorine residual of 1.0 mg/l) hydraulic detention time.** This low detention time requirement of between 6 to 12 minutes to achieve full disinfection can be obtained in a simple design of the new wet well that feeds the CLWPP booster pumps which pump fully treated water to Morpac Reservoir. A 6-minute hydraulic detention time at a flow rate of 5 cfs, with a smart hydraulic design, represents a wet well volume of about 2,250 cubic feet or 17,000 gallons. That volume of wet well can be achieved with a hydraulically efficient and simple concrete wet well design that occupies a floor space of only about 12-feet by 30-feet which is reasonable. Additionally, the same water leaving the booster water pumps will also be totally potable, and can be fed directly to Orca Lodge without further treatment.

Water Conveyance to Morpac Reservoir and the COC Distribution System. During the fall and winter months of October through March when total system demands are currently less than 2.5 cfs (and assumed to be less than about 3.5 cfs in the future), it is possible that this new booster pump station could supply all the water for the entire COC system. This statement assumes that water could be efficiently moved from the Morpac Reservoir system toward the center of Cordova to the southwest. Further consultation with City staff and the current distribution system network would need to be checked to confirm the current hydraulic conveyance capacity from Morpac Reservoir to the southwestern part of the distribution system. Such should be a straight forward hydraulic analysis to determine if any main trunk distribution pipelines would need to be upsized.

5.7 Water Supply Evaluation Summary and Conclusions

Preliminary design steps completed to date indicate that, when considering the COC water demands and characteristics of the current water treatment and delivery systems, the CLWPP should be designed for operational flows in the 5-cfs range considering current and future COC water needs. The Crater Lake raw water source represents the highest quality water source for the COC system, meaning that it requires basically the least amount of overall treatment, including energy used for UV irradiation, as any of COC's sources. This high quality water will also provide finished water with the best taste and odor characteristics of any of the current COC water sources.

Essentially, this high quality Crater Creek source means that for most time periods, it would be in COC's best interest to utilize as much of the diverted water for power generation as possible. Water flows up to 5.5 to 6 cfs could effectively be conveyed from the new CLWPP to Morpac Reservoir through the existing 16-inch-diameter transmission piping. For the distribution piping leaving Morpac Reservoir heading back southwest back towards the city center, some additional analysis would need to be conducted to confirm the flow capacity of that portion of the system. Preliminary information would seem to imply that the distribution system can convey at least 4 cfs back to city center.

The main exception to this idea that COC would use all water that flows through the new CLWPP would be during the months of October through January, when total COC water demands are relatively low at about 2.5 cfs. During this time period, CEC's need for hydropower generation in COC's energy market

may be higher to help offset current diesel consumption for electrical generation. During these months, it may be practical to send high water flow rates for power generation purposes, with excess water discharged to Crater Creek and Orca Bay, rather than pumping to the COC water distribution system. More information on the energy modelling needs during this time period will be provided by the energy operations model being conducted as part of this concept study.

Based on the discussion provided in this section and from the perspective of trying to utilize as much Crater Lake water as possible for the COC potable water delivery system, a new turbine generator unit with a design flow of no more than 5 cfs would be ideal for all of the following facilities:

- **Penstock**. It appears that a nominal 16 inch-diameter penstock may be the most economical choice, given the current design constraints, and water demand needs. A 16-inch penstock could efficiently deliver up to 8 cfs of water flow to the new CLWPP efficiently and hold energy loss to under 2% of total energy production. This is a lower percentage considering that most penstock / powerhouse Projects design for the penstock to consume from 2 to 4% of the total potential energy available. Final determination of the most cost effective penstock size can be better estimated once the hydro-power operations and modelling work is complete.
- **UV System**. The current planned UV system for Orca WTP would be able to support a maximum flow rate of about 4.3 cfs for the conservative 80% UVT value currently chosen for Crater Creek. The UV treatment capacity could increase up to 5 to 5.5 cfs, assuming the UV transmittance of the raw water increases from the current design value of 80% (Crater Creek) to 82 to 84% (for new Crater Lake reservoir).
- **Booster Pump Station**. New VFD-driven vertical turbine pump operations would be ideal for flow rates in either the 2.0 to 4.0-cfs or the 2.5 cfs to 5.0-cfs range, corresponding to the maximum typical 2:1 turndown on these pumps. A booster pump station designed with one duty pump plus one standby pump would be most efficient from both a capital cost and from an O&M perspective. Adding more pumps to the pump station configuration, for a relatively small system such as for this new Orca WTP facility, simply adds unwarranted capital cost as well as O&M cost to the system.
- **Existing 16-inch Distribution Pipeline**. The existing 16-inch-diameter transmission pipeline to Morpac Reservoir also constrains effective hydraulic conveyance of treated water to between 5 and 5.5 cfs maximum.

6.0 Generation and Operations Model

6.1 Introduction and Purpose

This section provides and discusses the high-level results of a water and power operational model and serves as a summary only. The main purpose of this section is to document the findings of the preliminary generation model developed for the proposed Project. The results of these findings will be integral to the overall Project feasibility evaluation. Findings and discussion are based upon the data and information collected as discussed below. The model output spreadsheets are charts for the various cases are presented in Appendix A and the electronic file of the model was provided to the clients directly.

6.2 Data Collection

Data sources used to prepare this study include the following:

- Discussions with COC staff on several site visits, including the latest visit conducted on August 27, 2015 (with Fajardo, Greenwood and Stavig) as part of the Project kickoff meeting with COC and CEC staff.
- Hydrology data developed for the feasibility evaluation by McMillen Jacobs.
- Power and generation data provided by CEC staff for diesel generation and generation at the existing hydroelectric Projects.
- COC water supply demand requirements. This data was also used to determine the amount of pumping that would be required.

6.3 Evaluated Project Configurations

The following sections present each of the Project configurations evaluated as part of the preliminary generation model. The Project configurations incorporate the results of the hydrology analysis, but vary slightly based on aesthetic concerns, as described below. Additional analysis could consider a wider range of Project configurations. Each of the models was evaluated for the year 2012 because it was determined that this year was most representative of an average water year. The models utilized daily parameters, including inflow, reservoir level requirements, and diesel generation values, when determining annual power generation and diesel generation offset.

The primary focus of the model was to maximize the amount of diesel generation offset. Many other iterations on the model basis are possible and should be performed in future design phases. This includes analysis with more granular hourly data to modify the estimate of diesel generation offset, assessing the Project with a focus on water supply and expanding the model to include both wet and dry years.

6.3.1 High Dam, Low Tap Configuration

The baseline configuration assumed the highest dam possible without perimeter saddle dams. This corresponds to a lake maximum water surface elevation of 1539.0 feet. The low tap assumes a deep water tap within the lake at elevation 1494 feet (approximately 19 feet below natural pool elevation). This configuration achieves the maximum usable storage of approximately 920 acre-feet and thus maximum

Project flexibility to retain excess water during wet years, as well as maximum generation during high diesel generation periods.

6.3.2 High Dam, Channel Release Configuration

The next configuration utilized the same high dam as the first configuration, but with an outlet at approximately the same 1513 foot elevation as the existing Crater Lake outlet. The existing outlet elevation was chosen to minimize the overall recreational impact associated with lowering the lake beyond current levels. While this reduces aesthetic visual impacts to the existing lake shoreline, it lowers the amount of usable storage within the lake to approximately 662 acre-feet. This reduces the overall Project flexibility and could impact the ability to maximize diesel generation and storage carryover from wet years.

6.3.3 Low Dam, Low Tap Configuration

The third configuration consisted of a low dam that results in a maximum water surface elevation of 1530.0 feet. This configuration also utilized the low tap as previously described, allowing the water surface to be drawn down to elevation 1494 feet. This arrangement results in usable storage of approximately 790 acre-feet. It should be noted that, with this arrangement, a large portion of the usable storage is located below historic water surface elevations.

6.3.4 Low Dam, Channel Release Configuration

The final configuration modeled was that of a low dam with the channel release. This configuration has the lowest amount of usable storage of approximately 533 acre-feet, almost half of the high dam, low tap configuration. Due to the smaller amount of usable storage, this configuration has the least amount of flexibility in Project operations and carryover storage capacity.

6.4 Analysis

The model output spreadsheets are presented in Appendix A and the model Excel electronic file was transmitted previously to CEC and COC. The approach and key assumptions for each configuration were similar. Each configuration was modeled to maximize diesel offset and with no net increase or decrease in available storage at the start and end of the water year. Essentially, generation flows were released in order to minimize diesel consumption while maintaining a minimum release for water supply. During the months of November through April, the Project was assumed to be running continuously because diesel appears to be constantly online during this period. During summer months when diesel is used only intermittently, the Project is assumed to only generate when diesel is required.

All of the configurations used the 5-cfs maximum flow assumption in accordance with the COC water system capacity limit. This dictates a 500-kW Pelton style turbine/generator system. However, if more flexibility and peak capacity are desired, the flow capacity could be increased to roughly 8 cfs with minimal change to the selected turbine and a slight increase in generator size. This could increase Project flexibility to offset diesel generation but would result in conditions where water is spilled rather than being made available to COC. The impacts on total water supply have not been assessed in detail, but the larger storage scenarios provide more flexibility to accommodate both water and power demand. Additional discussions on the value of water versus power will support future design scenarios.

Unit efficiencies for the turbine generator package were based on vendor curves for the proposed equipment. The corresponding generation from flows less than 5 cfs were also derived from these curves. The total generation was a sum of these various flow assumptions.

To create an equal starting point for all the configurations, the lake was modeled with the same starting water surface elevation of 1525.0 feet. This resulted in varying amounts of available storage between the high and low dam configurations to start the water year. Net head available from generation was determined using the lake water surface elevation minus penstock friction losses.

It was assumed that all of the configuration models must return to the same starting water surface elevation at the end of the water year. This ensured that the model represented a water year that allowed for sustainable and consistent operation from year to year. It should be noted that the 2012 year represents an average year and this assumption would differ for wet or dry years.

It should also be noted that the diesel generation levels presented within the model are the daily average values. The diesel generators may only operate for a portion of the day if a large load comes on, or one of the other hydroelectric plants goes offline. This may overestimate the amount of diesel offset obtained by the Project in all of the configurations. For example, if a diesel generator were to operate at high load for only 3 hours, this would show in the daily values as a smaller load over 24 hours. The overall Project generation is unchanged, but there would be 21 hours in which no diesel offset was actually obtained.

It was also assumed that all water delivered to the powerhouse was pumped to COC for use within the water supply system. This pumping power was subtracted from the generation to develop net generation for the Project. This net generation would increase if not all the water delivered to the Project was pumped into the water supply system. Pumping power was determined assuming a 16-inch water supply pipeline from the Project to the COC holding reservoir. An overall pumping system efficiency of 80% was used to accommodate for pumping and transformer losses.

The model does not account for emergency or maintenance outages or power losses from distribution of the generated power. Based on the model results, it appears that annual maintenance outages could be performed in late May or June with minimal impact to generation or diesel offset.

6.5 Operations Modeling Results

Table 6-1 presents the total generation as well as the estimated diesel offset for each of the four Project configurations. As previously stated, the diesel generation offset values are consistent in calculation among the configurations, but may slightly overestimate the diesel offset amount due to actual daily diesel generation routines. A more in-depth analysis of diesel generator run times and load efficiencies should be performed during subsequent design phases.

Table 6-1. Operations Modeling Hydro Generation and Diesel Offset Summary

Parameter	Project Configuration			
	High Dam, Low Tap	High Dam, Channel Release	Low Dam, Low Tap	Low Dam, Channel Release
Net Generation (kWh)	2,255,500	2,268,400	2,255,500	2,268,400
Diesel Offset (kWh)	2,008,100	1,745,000	2,008,100	1,745,000

While the channel release configurations may generate slightly more power over the course of the year, the reduced flexibility of when that power is generated can be seen in the diesel offset values. This is due to the fact that during the high demand period of the winter months, when diesel is consistently running, the reduction in available storage does not allow the channel release alternatives to generate as much power. Then in the summer and early fall months when Crater Creek flow is prioritized as recovered storage, diesel or other hydropower must generate to accommodate the target water year-end water surface elevation.

A potentially significant observation not included in these model assumptions is that the true benefits of the high dam are not observed because the modeled year is an average precipitation year. During a wet year the high dam could store significantly more water and allow for increased operational flexibility, diesel generation offset, or carryover of storage to the next water year. Any remaining storage at water year-end could also be used to supplement flow for any later dry year. These aspects should also be evaluated in future design phases.

6.6 Operations Modeling Conclusions

Based on the preliminary results from the operations model, there a number of important observations and recommendations related to future design efforts if the Project is determined to be feasible. These include:

- It is clear that the low tap configurations allow for the most flexibility of Project operations and therefore maximize the potential for diesel generation offset.
- The current analysis prioritizes diesel generation offset. Water values should be incorporated and additional analyses conducted to account for the value of providing supplemental water during periods when the Eyak pumping plant is forced into service. This analysis should account for operating expenses and deferred or avoided maintenance expenses for the pumping plant.
- The true value of diesel offset should be modeled using hourly rather than daily data. The use of daily data does not account for the daily diesel generation protocols that may spike for short periods well in excess of the Crater Lake hydropower generation capacity. This leads to an overestimation of diesel offset value for the Project. Additional analysis is recommended in future design phases.
- The true benefit of the high dam cannot be visualized in modeling a single average year. A multiple-year model would provide a measure of the benefit of the high dam on varying hydrologic cycles. The wet year could show significant improvements to diesel offset or Project flexibility that are not captured in a single average year model. The high dam could also provide carryover storage for subsequent dry years. Multi-year scenarios should be modeled where assumed inflows vary from dry through wet years.

In summary, the current analyses provide a reasonable baseline for Project feasibility. There are many other combinations of potential Project configurations that can be modeled in future design phases.

7.0 Conceptual Civil Design Criteria and Drawings

The conceptual design is derived from the sum of engineering studies to date. The design is conceptual in nature as defined by the scope of work and lacking site-specific detailed geotechnical information. The concept incorporates the results of the data review, geotechnical reconnaissance, hydrologic analysis, water supply analysis and operations modeling. The conceptual design drawings are presented in Appendix B. Specifications were not included at this stage of Project development.

The Project is described in terms of general design criteria at this stage. Individual Project component criteria are summarized in the following discussions.

7.1 Preliminary Dam Design Criteria

Two separate gravity dam sections were preliminarily developed for this feasibility study. Both were designed for the height required to accommodate the design water surface elevation for each respective study and along the centerline of the dam at approximately Station 2+30. Both sections were designed to minimize the amount of mass concrete needed to satisfy stress and stability (overturning and sliding) analyses per US Army Corps of Engineers guidelines (USACE, 1995). Only the “usual” load case, Load Condition No. 2 (defined in Chapter 4 of the above-mentioned document) was investigated for this level of study. Discussions with the Project geotechnical engineer regarding the available strength of the rock foundation warranted using high-strength rock anchors in combination with the mass concrete weight of the section to resist the potentially significant seismic forces in the Project area. The anchors could possibly have a hold-down capacity of at least 100 kips per anchor, and these were used to assist with the structural stress and stability.

The tallest gravity concept considered is 28-feet tall from the top of the dam at elevation 1542.0 to the bottom of the dam at elevation 1514.0 with a cross-section area of 286 square feet (sf) and a spillway crest at elevation 1537.0. The smaller concept crest elevation at 1533.0 ft is 19-feet tall with a maximum cross-sectional area of 156 sf and a spillway elevation of 1530.0 ft. The stress and stability of the gravity sections were investigated for the “usual load case” of normal pool water surface elevation at the top of the spillway crest, no tailwater, and full uplift along the base of the section and ice load. Both gravity sections meet the stress and stability criteria shown in Table 7-1 per the USACE document discussed above.

Table 7-1. Dam Design Criteria

Dam Type	Design Guidance	Other design factors
Concrete Gravity	USACE EM 1110-2-2200	Static Water and Ice Load, Seismic

7.2 Penstock Design

The discussion below presents the initial design concepts for the penstock between Crater Lake and the new CLWPP powerhouse.

7.2.1 General Discussion

The new Crater Lake to powerhouse penstock is characterized by very steep slopes with most slopes generally ranging from 30% to 35% and several steep short cliff band sections approaching 100% (45-degree) slope as discussed in the geotechnical section. The penstock falls nearly 1400 feet over about a 4,200-foot length, indicating an average slope on the order of 30%. The design flow rates for the new penstock would be relatively low (anticipated to be in the 4 to 8 cfs range) indicating that the penstock would be of small diameter (on the order of 14 to 18 inch nominal diameter).

One design approach for the small steel penstock would be to attempt to design a light-weight, low environmental impact, "nimble" steel penstock pipe system that can be installed above-grade for most of its length. Given the small diameter of the penstock, significant lengths (probably up to 50 ft in length) with flanged end connections could be flown into place on the mountainside (or moved by high-line cable system), with each section of pipe (including flanged ends) weighing as follows:

- Worst case 18-inch nominal diameter pipe of 5/16-inch- thick steel wall, polyurethane lined and coated, would weigh ~3,000 lbs per 40-foot-long stick.
- Likely case 16-inch-diameter steel pipe constructed of 1/4-inch thick steel wall, polyurethane lined and coated, would weigh ~2,300 lbs per 40-foot-long stick.

7.2.2 Penstock Design

Hydraulics. Preliminary hydrology and power operations studies conducted to date seem to indicate that the new penstock should be designed for the following flow rates:

- 3.6 cfs corresponding to 20% exceedance level (value to be confirmed with power operations modeling)

As a general rule in hydropower design, the primary design criteria for the penstock is the first flow value given above for the 20% exceedance level (i.e powerhouse / water supply flows will be greater than this value ~20% of the year or 10 weeks per year), which in this case is 3.6 cfs. The powerhouse is estimated to operate at or under this flowrate 80% of the year. Further evaluations during design and as the operations model may change this value, depending on the integration of both water supply and power production priorities. The fundamental aspect at this design stage is to develop a Project configuration that maintains as much flexibility as possible. This effectively translates to a water power Project that can efficiently operate in the approximate 2- to 8-cfs range.

For the relatively low flow rates that are estimated for the CLWPP, the penstock outside diameter size is in the range of 12-inch to 18-inches. Table 7-2 presents a summary of the estimated frictional head losses and associated power generation loss (and daily energy loss) for three pipeline sizes for a range of different anticipated flow rates. Typically, for larger flow hydropower Projects, penstock sizing is optimized to balance the cost of the penstock production and installation with the cost of the lost revenue resulting from energy loss due to pipe-wall hydraulic friction in the penstock. A normal rule-of-practice for larger diameter penstocks is that friction loss should be held to about 4% of total energy production or less. For a smaller flow rate Project such as the CLWPP, the small diameter pipelines required typically allow for this rule to be tightened-up even further, allowing for friction head loss not to exceed 2% of total energy production.

Generally, it is recommended that pipeline velocities in the new CLWPP penstock be designed for under 8 feet per second (fps) and to limit the total power generation loss to a maximum of 2.0% of the total power being generated. This criterion is lower than what is normally used on high-head penstock systems, but it is justified given the very small diameters of the considered penstock. Another way to state this, is that the maximum velocity criterion is lower for small diameter penstocks (down around 6 fps) as compared to typical velocity criteria for much larger penstocks (>30 inch) where pipeline velocities of 7 to 10 fps are often more economical. This design phenomena occurs because the larger penstock systems have less wall-drag effect overall in comparison to their cross-sectional area. Table 7-2 shows that for the anticipated design flow rate of 3.6 cfs (corresponding to the 20% exceedance level), that a 16-inch-diameter penstock should be selected for design.

Table 7-2

Hydraulic Calculations for Optimal Penstock Sizing

Owner: **CEC / COC**

Project: **Crater Lake Water and Hydropower Project - Feasibility Study**

Date: 9/30/2015

Speadsheet Input Parameters (Bold): **(Manual Inputs are in Bold)**

f	Darcy-Weisb. Friction Factor	**0.01**	
	plant factor	**input above**	decimal part of yr syst in generating mode
m	Composite Value of Power	**input above**	$/kWh)
E	Overall Turbine / Gen Efficiency	**0.83**	
Q	Design Flow Rate	0.0	
W	Specific Weight of Steel	**490**	lb/in^3
C	Installation Cost	**4.0**	$/lb (used 2.0 on BC Lucky Creek Project)
t	Shell Thickness	**D/288**	inch (minimum for handling)
	Stl Yield Stress	**42,000**	psi
S	Stl Allowable Stress	21,000	psi
H_M	Design Max. Head	0.0	ft
H	Average Weighted Head*	0.0	ft

*H is the average head over the length of the pipeline that would result in about an average thickness of the penstock -
- based upon hoop-stress design approach. Use a value that is about 60 to 70% of the max head to be conservative
Economic Diameter 1: Minimum thickness for shipping & handling
Economic Diameter 2: Internal Pressure Governs

Penstock Velocity and Headloss Calculation Reference Table **(Manual Inputs are in Bold)**

*Hazen Williams Coef for Polyurethane lined (non-mortar) Stl Pipe: 140 (for flexible liner, 145 new &smooth, 135 old and rough)

** Includes ~weight of ANSI B16.5, Class 300 Flanges on both ends, PU lined and coated pipe)

Pipeline Diameters & Wall Thick OD (inches)	Wall thickness (inches)	ID (inches)	40-ft Stick Weight** (lbs/stick)	Design Flow Rate (cfs)	Avg Pipe Velocity (fps)	Headloss Calculations* ft / 100 ft	for Penstock L of 4000 ft	Power Generation Loss (kW)	Fraction of Ttl Power Lost (%)	Daily Energy Loss (kW-hr/day
14.0	**0.25**	13.5	1896	**4.0**	4.0	0.37	14.70	**4.1**	**1.04**	**99**
14.0	**0.25**	13.5	1896	**5.0**	5.0	0.56	22.22	**7.8**	**1.56**	**187**
14.0	**0.25**	13.5	1896	**5.5**	5.5	0.66	26.51	**10.2**	**1.87**	**246**
16.0	**0.25**	15.5	2210	**5.0**	3.8	0.28	11.34	**4.0**	**0.80**	**96**
16.0	**0.25**	15.5	2210	**5.5**	4.2	0.34	13.53	**5.2**	**0.95**	**125**
16.0	**0.25**	15.5	2210	**6.0**	4.6	0.40	15.89	**6.7**	**1.12**	**161**
16.0	**0.25**	15.5	2210	**7.0**	5.3	0.53	21.14	**10.4**	**1.49**	**250**
18.0	**0.25**	17.5	2524	**7.0**	4.2	0.29	11.71	**5.8**	**0.82**	**138**
18.0	**0.25**	17.5	2524	**8.0**	4.8	0.37	14.99	**8.4**	**1.06**	**202**
18.0	**0.25**	17.5	2524	**10.0**	6.0	0.57	22.67	**15.9**	**1.60**	**382**
18.0	**0.25**	17.5	2524	**11.3**	6.8	0.71	28.42	**22.6**	**2.00**	**542**

System Input Data

Lake WS elev =	**1540**	ft	(includes 25-ft dam over current WS elevation 1515 ft)
Powerhouse elev=	**120**	ft	(assumed - may be higher or lower)
Gross (Static) head =	1420	ft	
100% Discharge =	**5.00**	cfs	
Nominal Power=	499	kW	Based on 100% Discharge @ gross head, E factor for Turbine / Gen Package

Wall thickness Calculations - High Pressure Section (under Static & Surge Conditions)

Static Surge multiplier:	**1.0**	unitless	(1.0 for static pressure condition)
Allowable stress in stl:	21,000	psi	allows for upto 50% of yield stress under static conditions
Static pres only: p =	615	psi	static pressure only
t =	0.234	inch	wall thickness for surge condition at powerhouse (use 1/4" wall)
Dynamic surge multiplier:	**1.3**	unitless	(typically ranges from 1.1 to 1.4 for Pelton Units)
Allowable stress in stl:	27,720	psi	allows for upto 66% of yield stress (short term surge)
Static + Surge pres: p =	799	psi	Static +Surge Pressure - Worst Case
t =	0.231	inch	wall thickness for surge condition at powerhouse (use 1/4" wall)

Minimum Penstock Wall thickness (Handling)

Approximate Diam =	**16.0**	in	(for handling calc only)
Min wall thick =	0.056	in	For pipe < 54" Dia. by D/288 calc
Min wall thick =	0.188	in	For pipe < 24" Dia - default to 3/16" min wall thickness

Pipe Material. Given the relatively small diameters and very high hydrostatic pressures (over 600 pounds per square inch gage [psig]) for this new penstock, it is very hard to beat the economics of lined and coated steel pipe. Steel provides for a high strength, yet relatively light weight pipe material that can be designed to hold up well to most external loads. Plastic pipe materials (high density polyethylene [HDPE] and polyvinyl chloride [PVC]) do not have the hoop strength characteristics required for this penstock's internal hydrostatic pressures, nor are they desirable from the perspective of the external loads that can be placed on the penstock (snow, small tree and limb fallings, etc). Fiberglass pipe materials and their locking-ring coupling joint system can be investigated further during the design phase, but McMillen Jacobs does not believe that this material will prove a more economical alternative to the option of steel pipe with polyurethane lining and coating.

Pipe Joint Design. The penstock pipe joint design would also need to follow the same "nimble" and simple joint connection design for the penstock pipe. Pipeline joint connections would be designed as flange connections on the lower half of the penstock (ANSI B16.5 – Class 300 flanges with an operating working pressure over 600 psig) that were pre-welded onto each stick of pipe at the factory (i.e. the pipe joints arrive to the Project site as already constructed flange by flange sticks). The upper half of the penstock (where hydrostatic pressures are lower) would be either a similar factory-welded flanged system, or a heavy restrained coupling system (Victaulic Style 232 with welded restraint rings, or equal). Use of these joint designs would effectively eliminate all welding on the mountainside installation and virtually eliminate the need for repairs of lining and coatings after installation. Again, the design approach is to make field installation work as easily as possible given the steep terrain and lack of heavy construction equipment access.

Pipe Design and Wall Thickness. Given the small diameter needs of the penstock (14 to 18 inches), McMillen Jacobs recommends that readily available ASTM A312 / A358 steel pipe, in either Schedule 10 (generally 0.25" thick in the size range of 12- to 18 inches) and/or Schedule 20 (generally 0.312" thick in size range of 12 inches to 18 inches), be allowed as a viable and inexpensive pipe choice for the penstock. Most steel pipe manufacturers on the west coast (Northwest Pipe, Ameron, and others) generally start their pipe fabrication work around 18 to 20 inches in diameter size as the minimum, and move up in size / diameter from there for pipe fabrication. It would be wise to allow these pipe fabrication companies to buy premade ASTM schedule pipe from other manufacturers and then take responsibility for welding on required flanged ends (or welding on restraint rings as the design requires) at the factory. The factory would also be responsible for providing hydrostatic testing of all pipe segments, and applying the lining and coating systems as specified.

Pipe Support Design. In keeping with the "light and nimble" approach for construction of the new penstock, McMillen Jacobs' conceptual design analysis will focus on developing an adjustable steel pipe support system that is easy to install, and would require little to no welding of pipe support structures in the field. The proposed concept design is included on Sheet S-101 in Appendix B. The concept is that given that ground conditions will be so variable and hard to accurately survey, the penstock support ears or collars will be provided in greater quantity than that which is actually required to hold the penstock in place. This means that some of the factory support ear / collar assemblies on the penstock will not be used in field installation.

The concept pipe support system is envisioned to have the following features:

- The pipeline segments (30 to 45 feet long) would have some type of steel "ear or pipe support collar assembly" that are factory welded onto both sides of the pipe – perhaps every 10 to 13 feet of pipe length on every pipe segment. These ears could serve as easy anchoring points, via bolting, to connect the pipe support systems to the penstock.
- The steel pipe supports would be easily adjustable in the field, to provide up to several feet of vertical adjustment, and some horizontal adjustment during installation.
- Pipe supports would be primarily constructed of steel – to maintain relatively light weight (as compared to large concrete support block design), allowing for easier helicopter transport / or all-terrain-vehicle (ATV) transport of materials into the penstock support locations
- A simple gas or generator-powered hand-held drilling protocol would be needed for digging through top-soil / duff and drilling perhaps 4- to 6-inch-diameter anchor holes into underlying rock strata.

Spare Pipe Sections for Future Repairs. Given that the penstock would be above grade and exposed to tree-fall damage and possible local snow-slide events, McMillen Jacobs assumes that CEC would have at least three or four spare straight pipe segments (flange by flange) in its equipment storage yard as readily available pipe segment replacements. McMillen Jacobs also assumes that designing the penstock with perhaps no more than four or five different angle / bends on the alignment – so that at least one spare of each type of bend could also be held in storage for emergency repairs of the penstock. These segments could be flown by helicopter into the damaged sections of the penstock to make repairs more efficient and timely.

7.3 Powerhouse/Water Treatment Plant Design

This Project feature is conceptualized as a single on-grade pre-engineered metal building housing both the hydroelectric and water treatment components. The hydroelectric features consist of a design flow 8 cfs Pelton turbine package with associated controls and electrical hardware. This type of turbine is capable of running between 2 and 8 cfs at high efficiencies to accommodate the full range of potential flows. The building layout, turbine/generator, water treatment components and electrical transmission features are shown in the conceptual design drawings in Appendix B. The Project electrical one-line diagram is included in these drawings.

The water treatment plant and booster systems were designed to accommodate the existing water distribution infrastructure in Cordova at its 5-cfs upper flow limit, while the turbine was specified for up to 8-cfs flow. This is to accommodate the peak flow capable within the Cordova system, while also accommodating higher flows to provide diesel offset peak generation if deemed advantageous in the future. The plant is designed with both overflow return to Crater Creek when flows exceed the existing distribution pipeline capacity and turbine bypass capability to continue providing water during turbine/generator outages.

The components are arranged in series, such that generation flow is delivered to a stilling basin at the upstream point of the water treatment system. The water flows by gravity through a settling tank, through the UV treatment into a chlorine contact basin, then finally out to a pair of booster pumps that deliver the

water at the correct pressure through a discharge pipeline to the existing water pipeline within New England Cannery Road.

The electrical system is designed with a lead off the generator to switchgear cutout and a step-up transformer to raise the generator voltage to transmission voltage for the Humpback Creek transmission line. Station service is also provided and the system is configured to backfeed from the Humpback Creek line to provide service during turbine/generator outage periods. The summary of the hydroelectric/water treatment plant is presented in Table 7-3 below.

Table 7-3. Powerhouse/Treatment Plant General Design Criteria

Project Element	Criteria
Building	Pre-engineering metal, approximately 36-x45-foot primary building, excluding chlorine contact basin.
Chlorine contact	Include pellet/injection equipment and contact basin. If existing pipeline is sufficient, can eliminate contact basin at treatment
Water treatment flow	5 cfs
Turbine type	Single Nozzle Pelton
Operating head/flow (assumed)	Net 1450 feet, 8 cfs flow design, 1-8 cfs anticipated
Generator rating	900 kW-480V synchronous
Expected output	825 kW
Turbine Inlet valve	Ball-type

7.4 Powerhouse/Treatment Plant Access Road

The proposed access road would exit the private road at the Orca Adventure Lodge and climb approximately 60 feet vertically to the proposed plant location. The road is design as a balanced cut-and-fill and would include conventional excavation and likely some short reach of drill-and-blast rock excavation. The road is concept only at this stage, with preliminary centerline and assume configuration and dimensions to be adjusted based on future design investigation and survey.

8.0 Constructability, Cost Estimate and Schedule

8.1 Constructability, Cost Estimate and Schedule Introduction

The section explains the methodology and summarizes the results of McMillen Jacobs' constructability, cost estimate and schedule development for the CLWPP. The physical challenges of working on steep, roadless areas of Alaska and other logistical aspects (transportation logistics, weather, accessibility of construction resources) have been incorporated to develop a balanced approach to the construction based on McMillen Jacobs' Alaska-specific hydroelectric Project construction experience. This section is organized into specific constructability, cost estimate and schedule sections as described below.

8.2 Constructability Review Results

8.2.1 Constructability Review Parameters

This constructability review was compiled by a McMillen Jacobs senior construction manager with significant, recent Alaska experience. While there are numerous considerations when developing conceptual means and methods for constructing a Project like CLWPP, the Project's most significant construction challenges include the following:

- Lack of road access to Crater Lake and the penstock route for both material deliveries and construction.
- Steep mountainside terrain, which comprises the majority of the penstock route.
- Cost, capacity and availability of helicopter resources large enough to support construction.
- The uncertainty associated with how weather may affect construction progress.

A number of approach logic iterations were considered during this review, with a conclusion that two basic approaches should be considered:

1. Assume maximum helicopter support for equipment and materials delivery; and
2. Assume a balance between helicopter time and innovative construction methods that would be more economical and would have more schedule certainty.

The helicopter-heavy alternative assumed that all construction equipment and materials would be delivered via helicopter to the dam site and penstock alignment. This approach resulted in over $1.5 million in estimated helicopter rental costs for concrete delivery only, and an unacceptable level of schedule uncertainty associated with potential weather delays. As a result, the next step in the review incorporated the underlying principle that helicopter reliance would be kept to a minimum. This "agile" approach entails a combination of assumed construction methods, most of which combine conventional remote construction techniques with alternative methods from the logging and pipeline industries. The key was to envision a combination of methods that would reduce reliance on helicopter transport and associated variable weather-induced delays. This means that the helicopter use should be concentrated as short bursts of Project activity that maximize productivity during available weather windows. Ultimately, the construction of this Project must be self-sustaining and not dependent on factors that are out of the Project's control.

Establishing heavy all-terrain vehicle access to the dam site would be especially beneficial to the Project. This would allow serious consideration of alternative construction approaches and minimize the use of helicopters. This type of access could consist of improving the existing trail to Crater Lake or establishing logging-type skid road access, as discussed in the penstock section below.

8.2.2 Dam Site Construction Assumptions

All scenarios envision helicopter delivery of all formwork, supports and small form-handling equipment to the dam site. The options considered for concrete procurement included the following:

1. Ready-mix supplier delivery of wet concrete to a staging point along New England Cannery Road, delivery of the concrete by helicopter to the dam site and placement via a helicopter-suspended concrete bucket into waiting formwork. This is the method selected for the current cost estimate.
2. Batch plant set up at the dam site, with associated lightweight crane and delivery boom assembly, onsite batch plant and support equipment. Initially, this would entail significantly more equipment delivery to Crater Lake (concrete bins, pumps, aggregate mining equipment, batch plant and material loaders), but could significantly reduce dam production concrete from helicopter constraints. This approach should be evaluated further in detailed design, especially with respect to availability of acceptable aggregate in the Crater Lake vicinity.

Other issues not addressed in this review include quality control requirements for remote batching and testing, whether the batch water would need to be heated before use, any impacts to concrete production and placement, and handling/disposal of excess or waste materials from the concrete process. These issues should be addressed in future design and construction planning phases if an onsite batch plant appears to be viable and more cost effective.

8.2.3 Penstock Construction Assumptions

The penstock construction will be challenging, primarily due to the steep slope and need to anchor all supports into suitable foundation materials. The future geotechnical investigation will focus its efforts on foundation conditions as input to design. McMillen Jacobs has developed a conceptual design for an adjustable penstock support that can accommodate the need to adjust the fixed base support on a variable hillside (see design drawings) as a concept to address these conditions.

The assumptions for the penstock include using logging operation equipment to construct all-terrain equipment access to the lower portion of the penstock where slopes allow. During the site walk, several apparent logging skid roads were observed along the alignment, and the viability of this method should be evaluated more thoroughly during future design. The concept includes retrofitting either rubber-tired skidders or track-mounted excavators that would allow lift and maneuvering of individual penstock segments into place. Most of the penstock support pedestals and frames would be installed by hand methods with hand tools, staging the tool and equipment packages along the route with a helicopter. Our construction estimates include two 6-man crews working simultaneously along the penstock route; one crew would excavate and construct the support structures and one crew would set the pipes in place. The crews would then move up or down the alignment as appropriate as each support was completed. McMillen Jacobs anticipates that crew travel would be on foot or via ATVs on newly-constructed skid

roads adjacent to the alignment. The penstock pipe would be delivered along the alignment by sections with the helicopter, then lifted and fixed to the supports by labor crews using the excavator or skidder. For the steepest sections of penstock, alternative heavy equipment could be employed including Spyder-like excavators or cranes that are capable of climbing on slopes as steep as 100%.

8.2.4 Powerhouse/Treatment Plant and Access Road Assumptions

It is anticipated that the powerhouse/treatment plant (plant) and plant access road would be constructed by conventional construction methods. The powerhouse/treatment plant is conceptually located on a natural topographic bench at approximately elevation 100 feet (as shown on the design drawings). This bench is accessible off the Orca Lodge Road near its intersection with New England Cannery Road via an approximately 400-foot-long access road. The access road and plant pad are conceptually envisioned as balanced cut-and-fill features. There would be some drill-and-blast excavation along the access road and minimal rock excavation for the plant footprint. Once the access and rough grading was accomplished, it is anticipated that the remaining plant construction would be less constrained by weather conditions.

8.3 Cost Estimate

8.3.1 Crater Lake Estimate Approach

The cost estimate was developed by McMillen Jacobs' senior construction estimators and construction managers using the conceptual design drawings developed by the engineering group. The conceptual design drawings are included in Appendix B. Details from similar Projects and historical unit cost data that took into consideration the location and site-specific conditions of this Project were also utilized when developing the cost estimate. Preliminary estimates of quantities, crews, and equipment were developed to support the estimate preparation using prevailing wage rates. These unit costs were then adjusted for the CLWPP location, site logistical challenges, and other factors specific to the work on this Project. More specifically, the access challenges of constructing the dam and penstock were incorporated into the estimate. With the remote location of the dam and penstock, a large helicopter was factored into the costs to provide staging of materials and concrete delivery to the dam site.

Furthermore, given the Project's location, it is anticipated that weather delays could represent additional downtime for crews and equipment working on the Project, resulting in elevated Project costs. A significant amount of materials would require barge transport to Cordova, and these costs have been incorporated. Material costs for much of the work were obtained through Alaska Project experience of similar size and complexity. With an unknown amount of dewatering required by the Project, an allowance was given for dewatering efforts in the cost estimate.

At this stage of the design development, adequate detail was not available to obtain advanced quantity takeoffs of specific design elements. Similarly, insufficient data was available to obtain detailed estimates from material and equipment vendors for Project components such as the water treatment plant, vertical pumps, penstock pipe, instrument power requirements and related equipment. For these features, estimates developed for similar Projects that were in the advanced stages of design or construction were used to support the cost estimate preparation. A preferred vendor's budgetary estimate for the turbine/generator package was also part of the current estimate and is included as Appendix C.

The construction cost data presented is not intended to represent the lowest cost for completing the work. Instead, the costs represent the range of costs that would result from responsible bids received from qualified contractors. A conceptual engineering level estimate has an expected accuracy of -30/+50 percent in accordance with the Association for Advancement of Cost Engineering (AACE) Level 4 classification. This range allows for unknowns to be accounted for at this stage of the design development. As the design is advanced and more details are developed, the estimating precision would be expected to increase with a corresponding decrease in estimating contingency applied to the estimate. The description of the Class 4 estimate from the AACE guidance is presented in Table 8-1 below.

Table 8-1. AACE Class 4 Estimate Description

CLASS 4 ESTIMATE	
Description: Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for Project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists. **Level of Project Definition Required:** 1% to 15% of full Project definition. **End Usage:** Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, Project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	**Estimating Methods Used:** Class 4 estimates virtually always use stochastic estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques. **Expected Accuracy Range:** Typical accuracy ranges for Class 4 estimates are -15% to-30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the Project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. **Effort to Prepare (for US$20MM Project):** Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the Project and the estimating methodology used. **ANSI Standard Reference Z94.2-1989 Name:** Budget estimate (typically -15% to + 30%). **Alternate Estimate Names, Terms, Expressions, Synonyms:** Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.

The estimate includes future planning, design and permitting support costs, but does not include Project financing, cost of money during construction or owner's administration costs.

8.3.2 Cost Estimate Results

The CLWPP cost estimate is structured with a base Project and two optional approaches. The base Project includes the following features:

- A concrete gravity dam with a crest elevation at 1,542 feet and spillway elevation of 1,539 feet.
- A shallow cut-and-cover trench approach to a lake tap at approximately elevation 1,490 feet.
- A surface penstock from the downstream side of the dam to the powerhouse/water treatment plant at approximately elevation 100 feet.
- A combined hydroelectric and water treatment plant consisting of an engineered building, subgrade structural concrete foundation and associated interconnections with existing water and power infrastructure along New England Cannery Road.
- A 400-foot-long powerhouse access road connecting near the Orca Adventure Lodge.

The two optional configurations relate to the lake tap/upstream conveyance and the dam height. Based on early discussions and constructability concerns associated with the narrow slot canyon directly downstream of the dam, a dual-heading microtunnel approximately 600 feet in total length was considered as an alternative to a cut-and-cover penstock lake tap and dam penetration. Based on preliminary hydrology studies, an alternative lower dam was also considered with a crest elevation of 1,533 feet and spillway sill elevation at 1,530 feet. These options were termed the microtunnel option and the low dam option for the estimate. Table 8-2 presents the conceptual construction cost estimate for the CLWPP.

Table 8-2. Conceptual Cost Estimate

Project:	Crater Lake Hydroelectric Project					
Location:	Cordova, AK					
Nameplate Capacity (kW):	825					
Date:	2-Dec-15					
				Base Project	**Option 1 - Micro Tunnel**	**Option 2 - Lower Dam**
Direct Construction Cost						
Item #	**Description**			**Amount**	**Amount (Delta from Base Project)**	**Amount (Delta from Base Project)**
1	General Requirements (15%)			$1,543,000	$228,000	-$347,000
2	Mobilization (5%)			$515,000	$76,000	-$116,000
3	Powerhouse Access Road			$82,000	$0	$0
4	Dam			$3,595,250	$0	-$2,309,975
5	Micro Tunnel			$0	$2,295,100	$0
6	Penstock			$3,069,400	-$777,996	$0
7	Intake - Lake Tap Inlet and Trash Rack			$70,000	$0	$0
8	Powerhouse/Treatment Plant			$3,014,600	$0	$0
11	Switch Yard			$250,000	$0	$0
12	Return Water to Crater Creek - Tail Race			$50,000	$0	$0
13	Intertie - Electrical Transmission Line			$75,000	$0	$0
14	Intertie - Treated Water Transmission Line			$80,000	$0	$0
	Subtotal			**$12,344,250**	**$1,821,104**	**-$2,772,975**
	Total Direct Construction Price			**$12,344,250**	**$14,165,354**	**$9,571,275**
Markups & Overhead						
	Taxes	0.00%		$0	$0	$0
	Equipment Markup	0.00%		$0	$0	$0
	GC Overhead and Profit	15.00%		$1,851,638	$2,124,803	$1,435,691
	Construction Bonds	1.00%		$141,959	$141,654	$95,713
	Total - Overhead (all included in unit prices on first page)			**$1,993,596**	**$2,266,457**	**$1,531,404**
Direct Cost Contingency						
	*Overall Project Contingency (Excludes Turbine/Gen. Costs):		0.00%	$0	$0	$0
	Total - Contingency			**$0**	**$0**	**$0**
	Median Direct Construction Cost			**$14,337,846**	**$16,431,811**	**$11,102,679**
	Total Direct Construction Cost Range (-30% to +50%)			**$10,036,492 to $21,506,770**	**$11,502,267 to $24,647,716**	**$7,771,875 to $16,654,019**
Planning, Permitting, & Engineering						
	Planning		5.00%	$617,212.50	$708,267.70	$478,563.75
	Permitting & Environmental		5.00%	$617,212.50	$708,267.70	$478,563.75
	Geotechnical			$500,000.00	$500,000.00	$500,000.00
	Engineering		10.00%	$1,234,425.00	$1,416,535.40	$957,127.50
	Total Planning, Permitting, & Engineering Cost			**$2,968,850.00**	**$3,333,070.80**	**$2,414,255.00**
	Median CAP EXP Cost			**$17,306,696**	**$19,764,881**	**$13,516,934**
	Opinion of Probable CAP EP Cost Range (-30%/+50%)			**$12,114,687 to $25,960,045**	**$13,835,417 to $29,647,322**	**$9,461,854 to $20,275,401**

Notes:
All costs based on 2015 Construction Dollars
Does not include: interest during construction, legal, financing, bonds, or admnistration costs.
* Overall Project Contingency set to 0% due to confidence range of -30% to +50% being provided below

8.4 Conceptual Project Schedule

The conceptual Project schedule is based on the specific work breakdown structure (WBS) developed during the cost estimate effort. A McMillen Jacobs senior construction manager developed the activities list from the WBS and compiled the Project schedule in Primavera P6 scheduling software. The logic and means and methods determined during the constructability review were incorporated into the construction approach and cost estimate, providing a seamless integration between the planning, estimating and scheduling.

The schedule attempts to account for construction aspects that are generally unique to coastal Alaska, which lacks any form of interconnected roadway system. These aspects include the cost and general availability of helicopter construction support, barge transport of major components from Seattle, weather delay potential associated with fog, rain and snow in the Cordova area, and the assumption of a limited local material and personnel resource pool.

The schedule assumes that final design, permitting and Project financing arrangements will take place during the latter half of 2016 and that early procurement of long lead items could be started in mid-2016 by the owner. The assumed duration of the construction phase from contractor mobilization through Project completion is planned as a 2-year effort in 2017 and 2018. The schedule is based on calendar days and a 6-day work week once onsite activity begins. The detailed schedule assumptions include the following:

- Final design contract in place by April 2016
- Design Notice to Proceed in May 2016
- Early owner procurement for long lead items such as turbine/generator, overhead crane and penstock pipe by scheduled start in October 2016
- Final design and all agency permitting/negotiation complete by February 2017
- Final agency approvals by early March 2017
- Construction Notice to Proceed by end of March 2017
- Construction mobilization starts May 1, 2017
- Construction broken into two seasons, with early progress on all Project elements leading to a logical seasonal shutdown in November 2017
- Completion of plant commissioning in October 2018
- Contractor demobilization end of November 2018
- Project complete December 2018

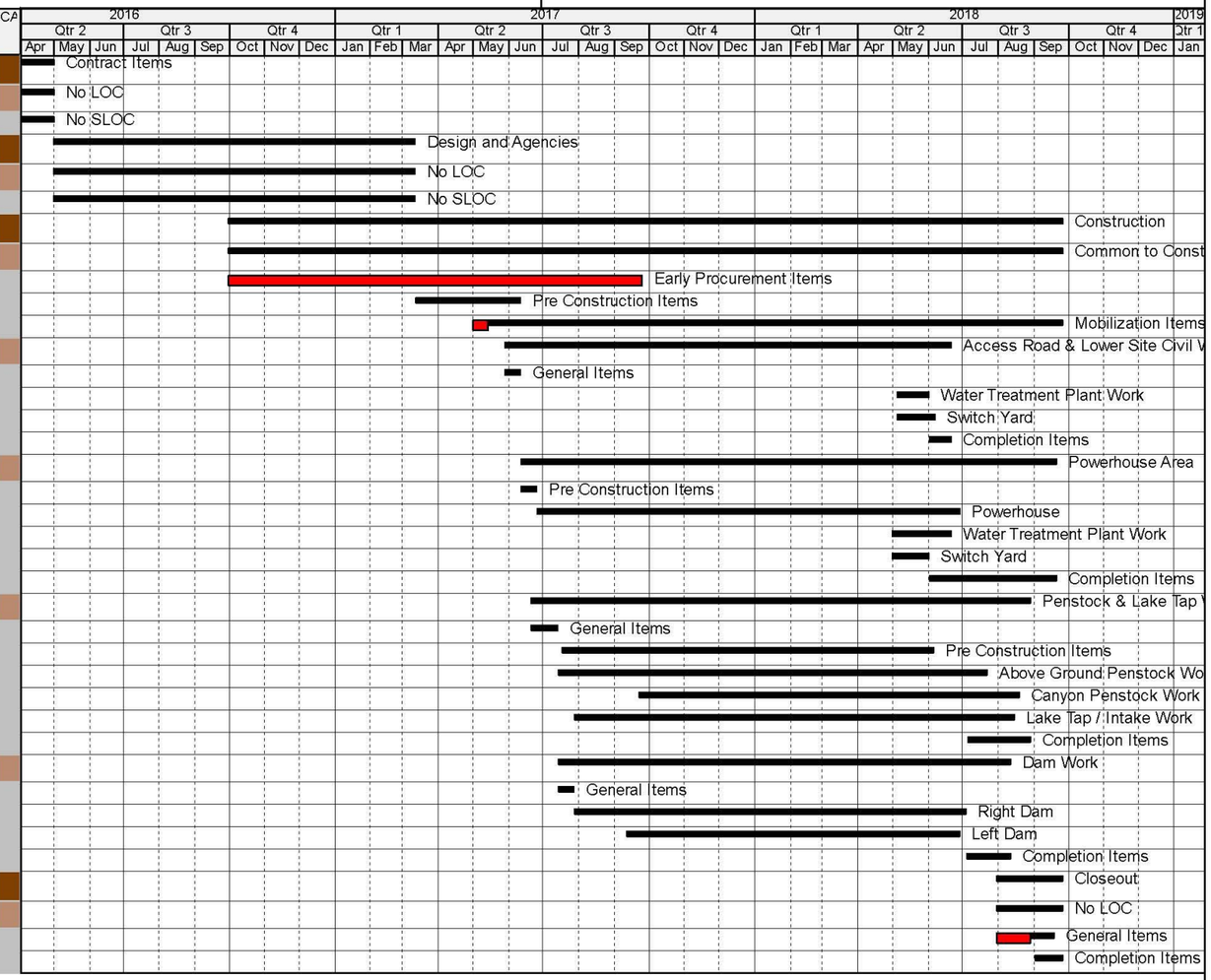
The conceptual Project roll-up schedule in P6 format is presented as Figure 8-1.

McMillen Jacobs Associates

Cordova Electric Cooperative and City of Cordova
Crater Lake Water and Power Project

November 2015

Activity ID	Activity Name	Orig Dur	Start	Finish	Calendar
Contract Items		30.0	01-Apr-16	01-May-16	7day
No LOC		30.0	01-Apr-16	01-May-16	7day
No SLOC		30.0	01-Apr-16	01-May-16	7day
Design and Agencies		315.0	01-May-16	11-Mar-17	7day
No LOC		315.0	01-May-16	11-Mar-17	7day
No SLOC		315.0	01-May-16	11-Mar-17	7day
Construction		497.9	30-Sep-16	25-Sep-18	
Common to Construction		497.9	30-Sep-16	25-Sep-18	
Early Procurement Items		360.0	30-Sep-16	24-Sep-17	7day
Pre Construction Items		91.0	12-Mar-17	10-Jun-17	7day
Mobilization Items		356.1	01-May-17	25-Sep-18	Lower
Access Road & Lower Site Civil Work		222.5	29-May-17	20-Jun-18	Lower
General Items		15.0	29-May-17	10-Jun-17	Lower
Water Treatment Plant Work		30.0	05-May-18	01-Jun-18	Lower
Switch Yard		35.0	05-May-18	06-Jun-18	Lower
Completion Items		20.0	02-Jun-18	20-Jun-18	Lower
Powerhouse Area		322.0	12-Jun-17	20-Sep-18	
Pre Construction Items		15.0	12-Jun-17	24-Jun-17	Lower
Powerhouse		253.4	26-Jun-17	28-Jun-18	
Water Treatment Plant Work		55.0	01-May-18	20-Jun-18	Lower
Switch Yard		35.0	01-May-18	01-Jun-18	Lower
Completion Items		118.8	02-Jun-18	20-Sep-18	Lower
Penstock & Lake Tap Work		299.0	21-Jun-17	28-Aug-18	
General Items		25.0	21-Jun-17	13-Jul-17	Lower
Pre Construction Items		222.1	17-Jul-17	05-Jun-18	
Above Ground Penstock Work		206.3	14-Jul-17	21-Jul-18	Lower
Canyon Penstock Work		110.0	22-Sep-17	18-Aug-18	Upper
Lake Tap / Intake Work		165.0	28-Jul-17	14-Aug-18	Upper
Completion Items		57.6	05-Jul-18	28-Aug-18	Upper
Dam Work		177.0	14-Jul-17	11-Aug-18	Upper
General Items		15.0	14-Jul-17	27-Jul-17	Upper
Right Dam		120.0	28-Jul-17	03-Jul-18	Upper
Left Dam		66.0	11-Sep-17	28-Jun-18	Upper
Completion Items		42.0	04-Jul-18	11-Aug-18	Upper
Closeout		57.9	30-Jul-18	25-Sep-18	7day
No LOC		57.9	30-Jul-18	25-Sep-18	7day
General Items		50.0	30-Jul-18	18-Sep-18	7day
Completion Items		24.0	02-Sep-18	25-Sep-18	7day



Feasibility Study and Conceptual Design
Preliminary Design and Construction Schedule

1 of 1

Figure 8-1. Project Schedule

8.5 Constructability, Cost and Schedule Conclusions and Recommendations

A summary of the overall conclusions from the constructability, cost estimate and schedule development indicates that the Project can be constructed and suggests some ways to reduce cost and schedule uncertainty. Relevant observations and recommendations include the following:

- The constructability review indicates that the Project can be constructed with a combination of conventional techniques and innovative application of logging techniques adapted for this Project.
- The use of helicopter assistance on the Project should be minimized to reduce overall construction cost and schedule uncertainty related to weather and helicopter availability.
- The potential for use of an onsite batch plant should be evaluated further. This option should be considered in detail if heavy ATV access could be established to the dam site for equipment and material deliveries.
- The dam was configured with the maximum height that would not require perimeter wing dikes within the Crater Lake basin. An alternative dam height is also presented for cost comparison. Additional studies during design could include alternatives to reduce total concrete volume, such as variable height crest gates (e.g. Obermeyer gates).
- Two methods for constructing the laketap and initial conveyance facility are included in this review. The base approach applied in the cost estimate consists of an excavated cut-and-cover pipeline approach that passes beneath the dam, transitioning to a surface penstock downstream. The option includes a microtunnel from the lake to a point approximately 600 feet downstream. This option appears to be significantly more expensive than the conventional pipeline/penstock configuration.
- The cost estimate identifies the range of expected construction costs and shows the additional planning, permitting, geotechnical investigation and final design efforts as separate line items.
- The conceptual schedule indicates that the anticipated timeline for final design and permitting would be complete by March 2017. The construction is planned over a 2-year period, through fall 2018, with a shutdown period during winter 2017–2018. The Project commissioning and Project completion are planned for November 2018.

9.0 Permitting Scope and Planning

The purpose of this section is to summarize the permitting considerations, required approvals, and expected responsibilities of the proponents if the CLWPP moves forward. Potential permitting impacts to cost or schedule are also described.

9.1 Permitting Considerations

Clay Koplin, CEC's CEO, has been the primary lead and point of contact for external permitting discussions and Project regulatory approvals to date, with McMillen Jacobs' ongoing support. The following is a planning-level summary of the key points related to permitting the CLWPP.

Federal Energy Regulatory Commission (FERC). FERC will have no involvement because the Project has been determined to be non-jurisdictional (Order on 1/22/2015). The requirements of the Federal Power Act do not apply to this Project and neither a license nor an exemption would be required.

U.S. Army Corps of Engineers (USACE). Once FERC determined the Project to be non-jurisdictional, the USACE became the lead federal agency for purposes of environmental review. However, as a result of consultation with the USACE Alaska Division, it has been suggested that a Nationwide Permit (NWP) #17 (Hydropower) may apply to this Project. The primary benefit is that no new environmental document would be required, eliminating the need for a comprehensive field study program. This has both cost and schedule benefits. The permit application would be able to rely on existing information, e.g. the Shepard Point Road Environmental Impact Statement (EIS) and other sources. If USACE determines that NWP #17 is not applicable to the Project, environmental baseline studies would be required and, although not anticipated to be extensive, would require a baseline year and probable second monitoring year before the Project could move forward.

State of Alaska (as landowner). COC has indicated that it administers State-owned lands that may be occupied by the proposed powerhouse. COC has also discussed the concept of acquiring those lands (potentially via exchange). In any case, it appears that COC would be responsible for permitting use of these State-owned proposed Project lands.

Permits Coordination. The State of Alaska's Office of Project Management & Permitting's (OPMP) role as permitting coordinator is to ensure that complex Projects move forward in a coordinated manner with minimum permitting effort duplication. The CLWPP, with its dual purpose of hydropower and water supply, can benefit from this additional support coordination. CEC has initiated discussions with the OPMP and has received an initial quote for its services. Because the Section 404 permit process requires coordination with other agencies, USACE is also interested in working with the OPMP process.

The permitting focus areas are summarized in Table 9-1 below. The table is based on current understanding of proposed Project lands and recent agency planning-level discussions.

Table 9-1. Summary of Permitting Requirements

Project Phase	Agency/Org	Permit/Approval
Investigation Permits	Alaska Department of Natural Resources (ADNR)	Permit for wetlands assessment on state lands
	ADNR	Permit for geotechnical assessment on state lands
	ADNR	Permit(s) for equipment installation (e.g. stream gage, thermistor, fish weir, etc)
	ADNR State Historic Preservation Office (SHPO)	Approval of Area of Project Effects (also The Eyak Corporation [TEC] or Native Village of Eyak [NVE] consultation)
	Landowners (COC, Eyak, State, Orca Lodge)	Access approval (for studies and equipment installation)
Project Development Approvals	USACE	Section 404 – Nationwide Permit #17 (Hydropower)
	Alaska Department of Environmental Conservation (ADEC)	Section 401 Certificate of reasonable assurance or Waiver
	ADEC	Approval to Construct, followed by Approval to Operate (Drinking Water System)
	ADNR	Water Right
	ADNR	Dam Safety Certificate of approval
	SHPO	Cultural Resources Inventory and concurrence
	Alaska Department of Transportation and Public Facilities (DOT&PF)	Right-of-Way Permit (for Access Road Approach)
	Landowners	Lease/easement approvals (City administers State lands in the proposed powerhouse vicinity)
	Alaska State Fire Marshall's Office	Fire, Life and Safety Permit
Construction-Specific Permits	ADEC	Construction General Permit (NOI and SWPPP)
	ADNR	Temporary Water Use Permit
	US Forest Service (USFS)	Special Use Authorization (if USFS lands will be accessed for construction)
	City of Cordova	Approvals and building permits: Conditional use Grading, clearing, excavation & fill Building permit

9.2 Permitting Conclusions and Recommendations

The overall conclusion of the permit planning effort is that no constraints were identified to advancing the Project, should it prove feasible. Indeed, the single-most challenging hurdle from a cost and schedule perspective, i.e. the requirement to obtain a FERC license, was eliminated prior to McMillen Jacobs'

involvement. Furthermore, indications that USACE Section 404 permitting may be accomplished under a Nationwide Permit would further reduce schedule impacts and may remove the need to conduct natural resource studies.

Additional relevant permitting insights and recommendations include the following:

- The Project has the potential to provide mitigation beyond diesel offset and reliable drinking water supply by way of preventing ice damming in Crater Lake and significant periodic flooding at the Orca Adventure Lodge.
- Only wetlands that are proposed to be filled, not the entire Project, are jurisdictional to USACE. Therefore, for permitting purposes, the footprint of the Project would be limited to the dam, powerhouse, penstock supports and access road if wetlands are mapped within those features' footprints.
- It is expected that fish considerations will be relatively minor for several reasons: 1) Crater Creek is not recognized as anadromous in the State's Anadromous Waters Catalog (AWC), 2) Rainbow Trout in Crater Lake are a non-native population stocked by the Alaska Department of Fish and Game (ADF&G), and 3) it is understood the USACE authority does not extend to the inundation area.
- Given the anticipated schedule for Project development, McMillen Jacobs recommend that proponents initiate permitting efforts and information gathering (e.g. wetlands mapping) in spring, 2016 to be complete by January 2017.
- As recommended by the USACE, submit an application for Nationwide Permit #17 (Hydropower) prior to the expiration and renewal of this permit in 2017, to avoid future additional provisions that may be placed on this permit. Additionally, the current standard conditions for NWP #17 should be reviewed.
- Final recommendation to be made by COC on the need for and a schedule to transfer State-owned lands to COC in the vicinity of the proposed powerhouse.
- Apply for any permits required for geotechnical investigations and other design activities upon Notice to Proceed, assuming these permits would be needed for field work in summer, 2016.
- Confirmation is needed from The Eyak Corporation (TEC) that a Lands Permit would be required. This permit application and TEC's processing should be straightforward.
- Review Shepherd Point Road EIS for applicability to the lower Project (powerhouse and access road) area, particularly the SHPO approved historical/cultural review.

10.0 Feasibility-Level Cost/Benefit Analysis

10.1 Introduction

The proposed Project potentially responds to strategic objectives of both COC and CEC. COC seeks to increase the availability and continuity of water supply from Crater Creek (a more desirable source and providing for expanded economic activity), while CEC identifies an opportunity for displacement of diesel generation with additional hydroelectric resources. The Project conceptual design includes features that directly address the joint objectives, which is reflected in the capital cost estimates. The effective accomplishment of the joint objectives is described through the operational modeling of the proposed reservoir alternatives and the powerhouse/pumping system. The cost/benefit analysis considers the design features incorporated in Project capital cost estimates and compares that cost over time with the benefits to be gained through the installation and operation of the system.

10.1.1 Power Supply Considerations

Additional renewable energy supply to offset summertime peaking and wintertime continuous diesel load was the primary design consideration for CEC. Currently, existing hydroelectric resources provide over 70% of the system annual generation requirements, and nearly all required energy during the summer months except July and August fish processing peak demands. The investigation into Crater Lake considered the opportunity to further reduce the amount of off-peak diesel generation based on the availability of water and the addition of storage capacity. The available hydraulic head and turbine generator were sized to provide the most advantageous use of the hydrological conditions. Diesel generation, now between 20% and 30% of the power supply, amounts to around 8 million kilowatt hours per year (kWh/yr) and any renewable opportunities are sought to reduce the reliance on fossil fuels.

The operational model for the Crater Lake system included four configuration options for the reservoir based on dam height and tap location to determine the amount of energy to be produced. All of the configurations were modeled in similar fashion to obtain the greatest amount of diesel offset while maintaining a minimum release for water supply. With the maximum water flow constraint of 5 cfs for the COC system, the maximum annual energy for diesel offset after accounting for pumping load and transformer losses was between 1.7 and 2 million kWh per year, or about 25% of the annual diesel requirement. The potential 8-cfs flow generation was not considered at this time.

The savings over time from a reduction in consumption of fossil fuel for generation are, of course, the primary benefit of an additional renewable resource, and a benefit that is shared by all residents and commercial enterprises of the CEC.

10.1.2 Water Supply Considerations

The design of the Crater Lake reservoir, penstock, powerhouse and pumping system considered current and anticipated additional water consumption rates, as well as current water system configuration and limitations. With no anticipated volumetric upgrades for the system, the design characteristics for the Project were based upon currently planned upgrades for water treatment and the potential to limit more expensive existing system operation at the Eyak filtration plant. From discussions with COC, and the perspective of trying to utilize as much Crater Lake water as possible for the COC potable water delivery

system, a new turbine generator that comfortably accommodates 5 cfs would be best suited for the facilities. The water treatment components of the conceptual design include a 16-inch-diameter penstock, the current planned UV system, the booster pump station with 2 VFD pumps (duty and standby) and the existing 16-inch-diameter transmission pipeline to Morpac Reservoir.

The operational model evaluated the system design for water supply purposes under the assumption that all water delivered to the powerhouse was treated and pumped to COC for use within the water supply system. Pumping requirements were determined assuming a 16-inch water supply pipeline from the Project to the COC's Morpac holding reservoir.

The economic benefits to be gained from the new facilities under the current operational model would primarily be the opportunity to increase water supply for commercial purposes (seafood processing), enhancing revenues for COC through greater shared fish tax collections and some modest, but additional, revenues from water sales. A potential benefit would be the displacement of $26,000 per year in operational expenses associated with the Eyak Lake water pumping and filtration supplemental supply, as well as a potential future deferral of a replacement filtration plant.

10.2 Modeling Approach

To date, the design and operational analysis of the Project has provided initial evidence of accomplishing the primary objectives of COC and CEC – added water for COC and additional renewable energy for CEC. Using the information provided on the preliminary cost estimates and the energy production operations model, an evaluation may be made of the initial screening-level feasibility by comparing the Project costs and the expected identified benefits. Annual costs of owning and operating the facility, shared between CEC and COC, are compared with the annual savings associated with the reduced reliance on diesel generation for CEC, and improved quality and availability of COC-provided water for the citizens and commercial enterprises in Cordova. The stream of costs and stream of benefits are compared on a net present value basis, which recognizes the significance of the time value of money expended and monetary savings.

An early expectation for the feasibility study was preparation of the cost/benefit results in such a format as to support an application to the State of Alaska for economic support through the Renewable Energy Fund (REF) administered by the Alaska Energy Authority (AEA). Upon review of the development of the Project characteristics, design and operational modeling, it appeared that a viable screening model for the initial feasibility assessment could be based upon the model suggested by AEA for the fund application. The cost/benefit assessment was therefore prepared using considerations of the REV9 model (for applications under Round 9 of the funding opportunity) and the fuel price Projections supplied and supported for a screening evaluation by AEA. The primary difference in the cost/benefit analysis approach herein, though, is that CEC and COC are modeled together and the results reflect the allocation of costs and benefits to each. The AEA REF evaluation includes only the expected net community benefits that are ancillary to the benefits gained by the electric utility. Since the Project is uniquely designed to provide joint operations and joint benefits, the costs and benefits are jointly determined.

In addition, the high level reconnaissance model evaluates the economics of the Project for each of the proposed design options. It has been noted in the operations model section that the preliminary expectation of the primary benefit of the Project will be the diesel generation offset. The cost/benefit model, however, considers diesel generation offset as well as the effects of the additional water supply

source to meet the expectation of additional land-based seafood processing, to the extent of as much as 20% over current water use levels. Also, based on information provided by COC, the potential exists for additional shared tax revenue from the seafood processers. Such tax revenue increases would be proportional to the growth in seafood processing.

10.3 Primary Assumptions of the Crater Lake Cost/Benefit Evaluation Model

10.3.1 Crater Lake Capital Cost Assumptions

The construction cost of the base Project as reported in Section 8 is allocated between CEC and COC in Table 10-1, as follows:

Table 10-1. CLWPP Cost Allocation Summary

Crater Lake Cost Components	$ 2015	CEC Share	%	COC Share	%
Direct Construction Costs:					
Powerhouse/Treatment Plant					
Turbine and Generators		500,000			
Overhead Crane		150,000			
Water Treatment Plant				400,000	
Vertical Turbine Booster Pumps				100,000	
Buildings, Electrical, I&C, etc.		932,300		932,300	
Subtotal Powerhouse	3,014,600	1,582,300	52	1,432,300	48
Switchyard	250,000	250,000			
Intertie – Electrical	75,000	75,000			
Intertie - Water	80,000			80,000	
Other Direct Costs	8,924,650	4,462,325		4,462,325	
Subtotal Direct Costs:	12,344,250	6,369,625		5,974,625	
Markup, Plng., Permits, Engineering:	4,962,446	2,580,472		2,381,974	
Grand Total:	**17,306,696***	**8,950,097**	52	**8,356,599**	48

* Median Project cost estimate including future engineering design, permitting and coordination.

The changes associated with Option 1 (microtunnel laketap), increasing the total cost to $19.3 million, and for Option 2 (lower dam height), decreasing the cost to $13.1 million, are directly associated with the Other Direct Costs, and therefore present no change to the allocation of capital costs between CEC and COC. The evaluation model does, however, include provision for revised cost allocations for sensitivity analysis or changed construction requirements that may be determined from further investigations.

The Project is assumed for the preliminary analysis to be on-line in November, 2018. The installed cost at the start of 2018 is the "overnight" construction cost – i.e., no interest during construction, owner's costs or other administrative expenses, as these have not yet been defined.

10.3.2 Crater Lake Energy Production Assumptions

The preliminary evaluation assumes that the energy produced in 2018 and in subsequent years is based on the 2010-2011 "average" water year, as defined and estimated by the hydrologic evaluation and incorporated within the generation operations model. The amount of annual energy, estimated on the assumption of maximum diesel displacement and the COC water system maximum capacity of 5 cfs, is 2,008,696 kWh. The energy delivered to the electric system is net of pumping load for delivery to the COC distribution system. Because the operation model was limited to the average water year, each year of the analysis assumes a similar level of diesel displacement. Further analysis will be required to estimate the impact of alternative annual water conditions, and the effect of hourly dispatch, as described in the operations modeling section. The evaluation model will accommodate a variety of annual or hourly dispatch results and varying energy production.

Crater Lake is estimated for evaluation purposes to operate for at least 50 years, and provides energy annually in the amount Projected. No estimate has been provided of expected forced outage or maintenance periods of reduced generation, nor of periodic equipment replacements. By the same token, no estimate is made of possible deferral of diesel generation overhauls, deferrals, or retirements. It can be expected that some portion of the generation facilities, both hydro and diesel, will be subject to such costs or savings. The contribution of Crater Lake is estimated to offset 25% of CEC's total diesel requirements, so diesel requirements will continue in the absence of other energy sources. Diesel requirements could also be reduced by significant loss of load or additional useable water inflows at existing hydroelectric facilities.

An important consideration for this stage of the Crater Lake evaluation is that load growth of the CEC electric system is not taken into account in the determination of energy production. A more robust dispatch model, however, may reflect the capability to provide more energy over time through enhanced hydroelectric/thermal optimization, particularly if the COC increases the distribution system capacity to accommodate flows in excess of 5 cfs.

10.3.3 Crater Lake Operations and Maintenance Cost Assumptions

Detailed assessments of the operations and maintenance costs of the new facility (civil structures and mechanical equipment) have not yet been prepared. In the absence of more specific information, the Alaska Energy Authority, Renewable Energy Fund application standard O&M expectation for renewable energy plants is 1% of the capital costs. This expectation was used consistently throughout the economic evaluation. Plant O&M costs are shared on a basis equivalent to the allocated capital costs because a large component of the Crater Lake costs are allocated to COC for water availability, treatment and delivery. Plant O&M costs are expected for analysis purposes to increase at the rate of general inflation, absent any information to the contrary.

10.3.4 CEC Diesel Production Efficiency Assumptions

The impact of diesel displacement by Crater Lake is the reduction in fuel requirements, and therefore potential savings in fuel costs. Historical data from CEC was analyzed for estimates of the production

efficiency of the CEC diesel generation facilities, as was the most recent Power Cost Equalization (PCE) data from the State of Alaska. The 2014 PCE data indicates an average efficiency for the CEC diesel equipment for fiscal year 2014 of 13.3 kWh/gallon. But, the most recent calculated data provided by CEC indicated 13.48 kWh/gallon over the 2011-2012 average water year of October through September. For analysis purposes, with the expectation that additional hydroelectric resources will provide greater operating flexibility and resultant greater efficiency, it is assumed that 13.48 kWh/gallon will prevail. AEA, however, estimates efficiency for renewable energy funding analysis on the basis of size of machine for an expected level of 14.5 kWh/gallon. The Crater Lake Evaluation Model accommodates alternative estimates of the production efficiency, allowing for testing of the impact of improvements. Future work with a more detailed dispatch model, such as hourly dispatch and diesel/hydro optimization may reveal further potential gains in efficiency that can be examined for additional cost savings.

10.3.5 Cost of Diesel Fuel Assumptions

AEA annually publishes the expected fuel costs for use in evaluating renewable energy Projects. The fuel prices are developed from a number of sources and carefully researched and prepared models for regional deliveries, timing of lifts, and an assortment of factors. The published prices are used by AEA in the renewable energy fund evaluation models and have become the in-state standard for analysis of renewable energy Projects. The fuel costs are estimated in “real” 2015 dollars. That is, no general inflation is assumed, and the rate of change in the fuel prices is a result of supply and availability conditions. The AEA evaluation system estimates the impact of renewables in equivalent fashion, assuming no general inflation.

The AEA range of fuel costs over the operating period proposed for Crater Lake begins at $3.26 per gallon, specific to the Cordova region, rising to $5.41 by 2040, the 23rd operating year of the Project, after which it is held constant in real terms. For sensitivity purposes, an inflation adjustment is included in the Crater Lake Evaluation Model to take into account the impact of general inflation on various cost components, including fuel. For estimates of cost/benefit under conditions of general inflation, the fuel prices are increased at an equivalent percentage as other variable costs. In that case, fuel prices would range from $3.36 to $5.57. It was not assumed for this model that the fuel prices would be subject to the compounding effects of inflation, but the model can accommodate a range of expectations in fuel prices. As fuel prices increase, of course, the benefits of a renewable energy resource increase, and by a rather dramatic amount. A modest expectation of fuel price increase is, therefore, a conservative estimate of benefits.

10.3.6 Seafood Processing – Additional Growth Scenario

A goal of Cordova and of other municipalities in the Prince William Sound region is to improve regional economics through, among other things, expanded harvesting and processing of seafood, including expanded production into the shoulder periods around the summertime peak. The COC Public Works enterprise representatives (and CEC staff) have reported that landed seafood processing in Cordova has been constrained by the availability of water, which supported COC investigation of the Crater Lake development opportunity. While processing could increase by about 1-2% per year under current conditions, the Project provides an additional volume of spring and summertime water supply that could be available to processors. This added source would provide support for even further processing activity, in addition to obtaining an improvement in water quality compared to other current water supply sources

The estimates provided have suggested that water requirements for the existing seafood processors could increase seafood production by as much as 20% over a multiple-year expansion period. For evaluation purposes, the Project is assumed to provide for such an expansion of processing without additional investment in the water supply distribution system of Cordova. The growth in processing for purposes of evaluation is expected to develop over time, at the rate of about 5% per year beginning at the start of Project operation in 2018. The incremental impact is an increase in water system revenues.

Data provided by COC indicated that the most recent 3-year usage of water by the five major seafood processors averaged 187,705,809 gallons per calendar year. A 20% increase would be 225,246,970 gallons, and at the current fee for water use ($1.60/1000 gal.), water sales revenues would increase by $60,066 per year. Because the growth in processing would take time, it is assumed that incremental water revenues grow at 5% per year. Thus, in year 1, incremental revenues would be $15,016, and in year 2 would be $30,033. By year 4 (2021) the entire revenue increment would be achieved. That increment would be subject to increases with inflation, if COC were to adjust water rates on a continuing basis.

10.3.7 Shared Seafood Taxes – Additional Revenue Potential

Seafood taxes are assessed by the State of Alaska on seafood gathering and processing. A portion of those seafood processing taxes collected by the State are distributed to the municipalities (or other organized locations) in which the activity occurs. COC has reported that shared seafood taxes have grown by an average of 9% over the last several years, and by 2014, the taxes distributed to COC had reached a level of $1,661,223.

A growth in seafood processing would potentially increase the share of seafood processing taxes distributed to the Municipality of Cordova in proportion to the growth in processing. The increase would be expected to grow at the same rate as the processing activity, or about 5% per year upon initiation of Crater Lake water availability. In 2018, the incremental increase in fish tax distribution would be about $66,876, and by 2021, the amount would be $267,506. The fish tax would be subject to inflationary adjustments over time, but since the tax includes product valuation as well as volume of activity, it is assumed for analysis purposes that changes over time would be slightly less than the rate of general inflation.

10.3.8 Reduced Requirement for Eyak Pumping and Filtration Costs

An additional consideration of COC public works is the potential for displacement of the supplemental pumping and filtration processes at the Eyak Lake facility. It was reported that COC annually requires about 10 days of pumping at a cost of $26,000 per year for 10 million gallons, particularly required during the early spring period when there are critical limitations from other sources. The additional water supply and the operational flexibility of the Project is expected to allow the Eyak facility to be effectively placed in standby mode, reducing that operating cost. The cost/benefit evaluation of the Project thus includes a potential savings of $26,000 per year (2015$), beginning at the time the Project goes into operation in 2018. Those savings would be expected to increase with inflation, as a result of the age of the equipment and the characteristics of the system. A potential deferred, or avoided, replacement of the Eyak pumping and treatment plant (at a cost of $15 million, 20 years from now) could be considered as a benefit of the Project, but is deemed speculative for evaluation purposes.

10.4 Results of the Crater Lake Feasibility Cost/Benefit Analysis

Two cases were evaluated for Crater Lake to gain an understanding of the feasibility of the Project and identify the potential benefits of continued investigation of construction options and operations. The Crater Lake Evaluation Model was developed to provide a structured approach to the cost/benefit analysis. Two cases were evaluated for the initial feasibility analysis. Additional cases may be examined upon request for alternative economic assumptions or additional savings opportunities from availability of energy or water from the Project. The detailed cost/benefit model results are provided in Appendix D and software files for the model were provided to CEC and COC as part of the report deliverable.

10.4.1 Case 1 – Modified AEA

The first case evaluated uses an approach similar to Alaska Energy Authority Renewable Energy Program application method (Table 10-2), but with a couple of modifications. AEA assumes that capital expenditures in the years prior to operation produce negative benefits – that is, the capital expenditures reduce the stream of future benefits of the Project. In practice, however, for electric utilities the costs of a Project are not included in rates and charges until complete and placed in operation. Thus, in the Crater Lake Evaluation Model, the annual costs of the Project are based on capital recovery over the term of financing. The Crater Lake Evaluation Model assumes capital cost recovery and cost savings begin in the same year. Also, the AEA method treats community benefits as a separate category of cost savings, and because Crater Lake is conceptually a joint product resource, the evaluation model identifies the benefits and costs on the basis of each beneficial service provided by the Project.

The Case 1 assumptions (Figure 10-1) treat all other conditions in a manner similar to the AEA evaluation approach.

CASE NAME:	Modified AEA
Assumptions:	
General Inflation	0.0%
Discount Rate	3.0%
Fish Tax Escalator	0.0%
CEC Project Share	52%
CEC Fuel Efficiency, kWh/gal.	14.5
CEC Load Growth	0.0%
Both CEC & COC:	
% Financed	100%
Interest Rate	3.0%
Term of Note, Yrs.	30

Figure 10-1. Case 1 Assumptions

Table 10-2. Modified AEA Cost/Benefit Summary

Crater Lake Preliminary Economic Feasibility - CEC and COC ($000)

Modified AEA

Crater Lake	CEC NPV Benefit $	CEC NPV Cost $	CEC B/C Ratio	COC NPV Benefit $	COC NPV Cost $	COC B/C Ratio
Base Project	15,353	11,315	**1.36**	8,629	10,445	**0.83**
Option 1	15,353	12,910	**1.19**	8,629	11,917	**0.72**
Option 2	15,353	8,837	**1.74**	8,629	8,158	**1.06**

10.4.2 Case 2 – Inflation Adjusted Method

An alternative evaluation of the base Project and Options 1 & 2 (Table 10-3) adds inflation on certain components – fuel, O&M, water and tax revenue, etc., and assumes the CEC historical diesel generation efficiency. Case 2 assumptions are shown in Figure 10-2 and include:

CASE NAME:	Inflation Adjusted
Assumptions:	
General Inflation	3.0%
Discount Rate	3.0%
Fish Tax Escalator	2.0%
CEC Project Share	52%
CEC Fuel Efficiency, kWh/gal.	13.48
CEC Load Growth	0.0%
Both CEC & COC:	
% Financed	100%
Interest Rate	3.0%
Term of Note, Yrs.	30

Figure 10-2. Case 2 Assumptions

Table 10-3. Inflation Adjusted Cost/Benefit Summary

Crater Lake Preliminary Economic Feasibility - CEC and COC ($000)

Inflation Adjusted

Crater Lake	CEC NPV Benefit $	CEC NPV Cost $	CEC B/C Ratio	COC NPV Benefit $	COC NPV Cost $	COC B/C Ratio
Base Project	17,010	13,368	**1.27**	13,498	12,340	**1.09**
Option 1	17,010	15,253	**1.12**	13,498	14,080	**0.96**
Option 2	17,010	10,441	**1.63**	13,498	9,638	**1.40**

10.5 Conclusions and Recommendations

A preliminary cost-benefit model was developed for the CLWPP based on technical engineering studies provided as part of the overall feasibility evaluation. The model was developed to compare the expected joint cost of ownership and operation of the facility by CEC and COC with the benefits likely to be gained from installation and operation of the Project over a 50-year period. The Crater Lake Evaluation Model provides the following preliminary economic feasibility conclusions:

- The CLWPP has the potential to provide potentially significant benefits to both the electric and water supply infrastructure within Cordova
- These potential benefits were assessed through a cost-benefit model that considers the major factors associated with ownership and operation of the facility, using information gained from the engineering studies, historical system operations, and reasonable expectations for the future.
- The cost-benefit model provides for analysis of economic feasibility with consideration of the approach and assumption guidelines of AEA in support of renewable energy funding opportunities in the State of Alaska. The Crater Lake Evaluation Model assessed the costs and benefits of the base Project and Options 1 and 2 under two sets of assumptions. The first set, Case 1, estimates costs and benefits using an approach essentially equivalent to that of AEA. The second, Case 2, estimates costs and benefits under the condition of assumed inflation in certain cost and benefit components.
- The results of the preliminary feasibility analysis indicate the following:
  - CLWWP appears to be economically feasible for CEC under the design considerations and operational characteristics of the base Project, and design Options 1 and 2.
  - CLWWP appears to be marginally economically feasible for COC in the absence of inflationary impacts on revenues and taxes, but will be economically feasible if revenues and tax receipts increase nominally (at the rate of inflation) over time.

- For both CEC and COC, Option 2, the low dam configuration, provides the most benefit during the average precipitation year and is economically feasible with and without inflation impacts on certain economic factors.

- Additional considerations in reviewing and considering the preliminary feasibility results include:
  - The allocation of ownership and operating costs between CEC and COC significantly affects the economic feasibility for COC. Alterations in the design stage of the Project may shift Project costs to CEC, increasing the viability of the Project for water service.
  - The economics of CLWPP for COC are driven by the assumptions of additional water revenues and economic activity in seafood processing. Assignment of other values to the Project by COC – e.g., improved water quality, continuity of supply or other demonstrable gains to the community as a whole – will reduce the feasibility dependence of the seafood processing assumptions for the benefits to COC of the Project.

11.0 Summary and Conclusions

This report presents the result of a feasibility level analysis and conceptual design for the CLWPPP. The analyses include:

- Existing data review and compilation
- Geologic and geotechnical reconnaissance
- Hydrologic evaluation
- Water supply and treatment evaluation
- Generation and operations model
- Conceptual civil design criteria and drawings
- Permitting scope and planning
- Feasibility-level cost/benefit analysis

The results of these efforts represent a feasibility-level assessment only to support whether or not to continue Project evaluations, evaluate further or move forward with the Project. These preliminary analyses indicate that:

- The Project appears to be constructible from a geotechnical perspective.
- The hydrologic resource at Crater Lake/Crater Creek is underutilized and appears to support the concept of a storage Project.
- The potential hydroelectric benefit may offset up to 25% of CEC diesel consumption.
- Crater Lake would provide high quality water supply and a more firm and reliable water supply resource for COC.
- The COC could incorporate planned UV treatment upgrades within a new CLWPP.
- The civil design for CLWPP is relatively straightforward and conventional.
- The Project appears to be constructible from a construction perspective, but will face the challenges of Alaska construction including steep, roadless access and reliance on helicopter material deliveries.
- The Project cost estimate provides a range of estimated costs from $9.1 million to $28.9 million, depending on configuration and level of estimate sophistication at the conceptual stage. The median cost for the preferred alternative is $17.1 million.
- The Project is envisioned as a 3-year development effort, with the first year dedicated to design and permitting and the remaining 2 years for construction.
- It is anticipated that the permitting effort would be simplified through FERC non-jurisdiction, land ownership and administrative control and the assumption of interpretation by USACE as a Nationwide Permit #17 eligible Project.
- The Project cost/benefit analysis shows the Project as having a net benefit to CEC in all assumed Project configurations, while within the range of slightly negative to slightly positive net benefit

to COC, assuming a 52% to 48% equity sharing agreement, respectively. Future discussions toward an agreement between CEC and COC may alter this shared cost/benefit.

The overall results of the feasibility assessment appear to be favorable.

12.0 References

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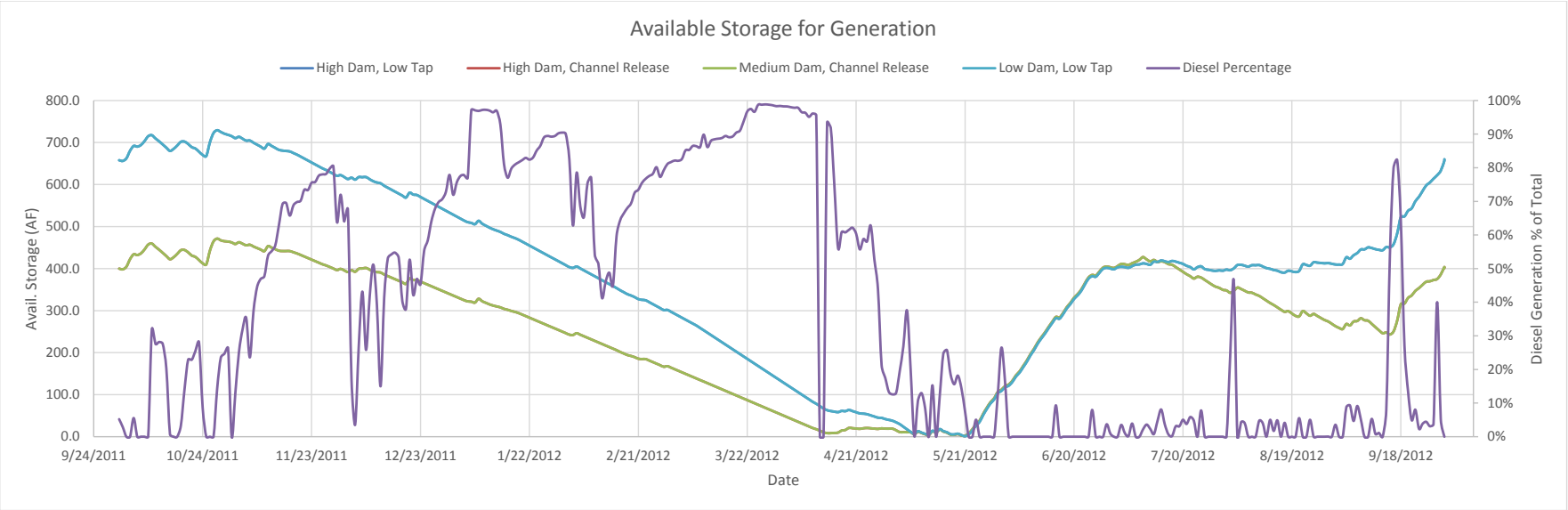
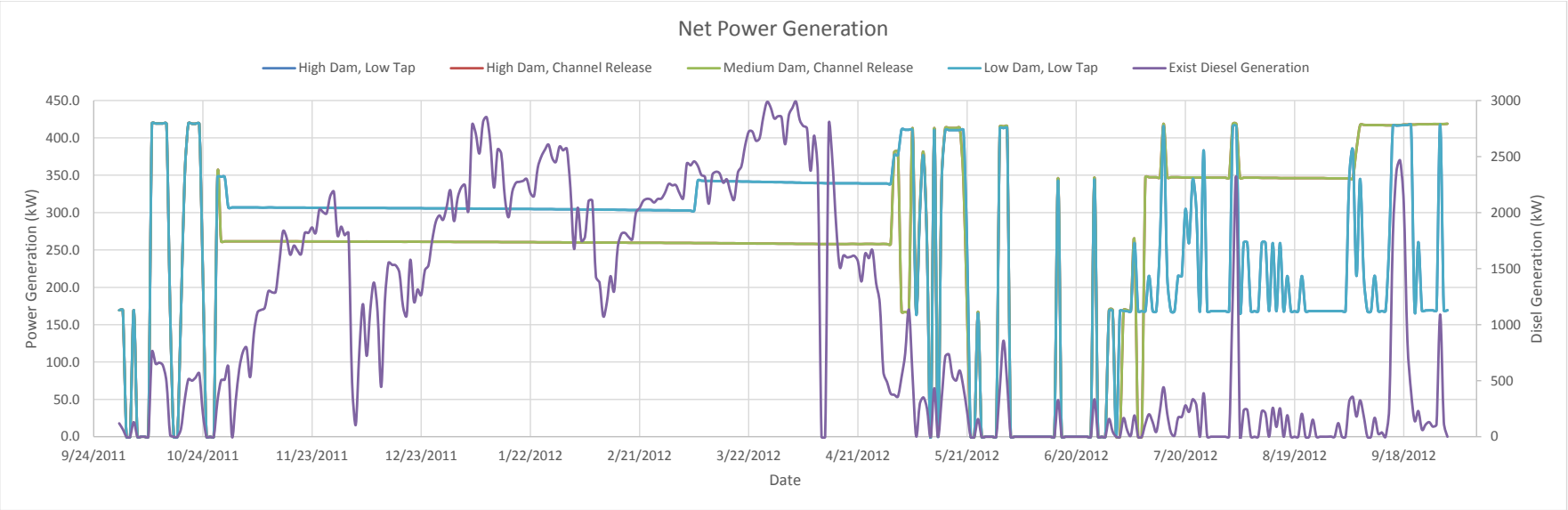
Appendix A

Operations Modeling Charts
(electronic model file delivered to client)



Avail Storage Chart


Net Power Generation
High Dam, Low Tap
High Dam, Channel Release
Medium Dam, Channel Release
Low Dam, Low Tap
Exist Diesel Generation
Power Generation (kW)
Disel Generation (kW)
Date
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
3000
2500
2000
1500
1000
500
0
9/24/2011
10/24/2011
11/23/2011
12/23/2011
1/22/2012
2/21/2012
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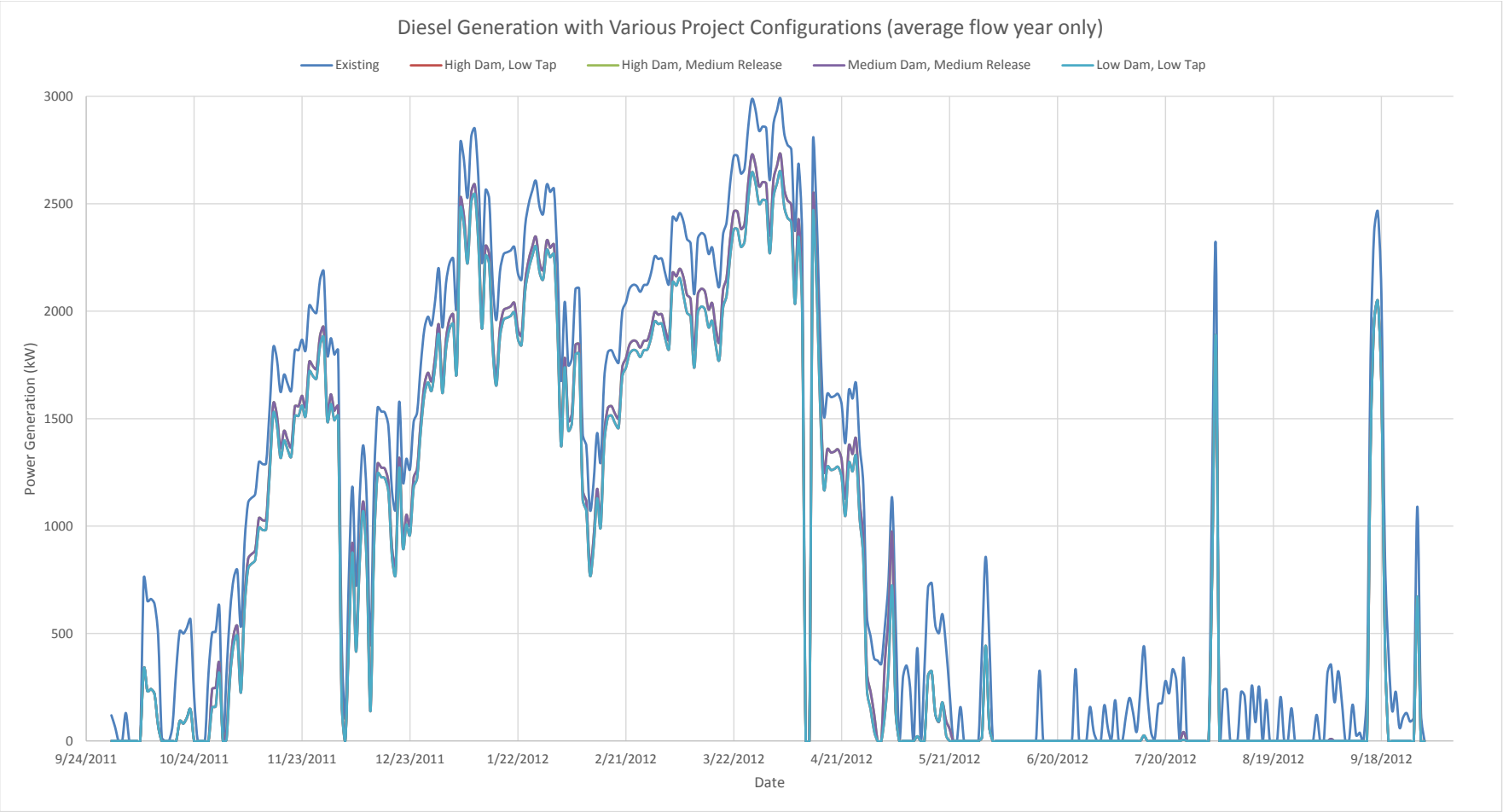
8/19/2012
9/18/2012


Diesel Generation with Various Project Configurations (average flow year only)
Existing
High Dam, Low Tap
High Dam, Medium Release
Medium Dam, Medium Release
Low Dam, Low Tap
Power Generation (kW)
3000
2500
2000
1500
1000
500
0
9/24/2011
10/24/2011
11/23/2011
12/23/2011
1/22/2012
2/21/2012
3/22/2012
4/21/2012
5/21/2012
6/20/2012
7/20/2012
8/19/2012
9/18/2012
Date

Appendix B

Conceptual Design Drawings

CORDOVA ELECTRIC COOPERATIVE AND
CITY OF CORDOVA
CRATER LAKE WATER AND POWER PROJECT
FEASIBILITY STUDY AND CONCEPTUAL DESIGN

CONCEPT DESIGN DRAWINGS
DECEMBER, 2015

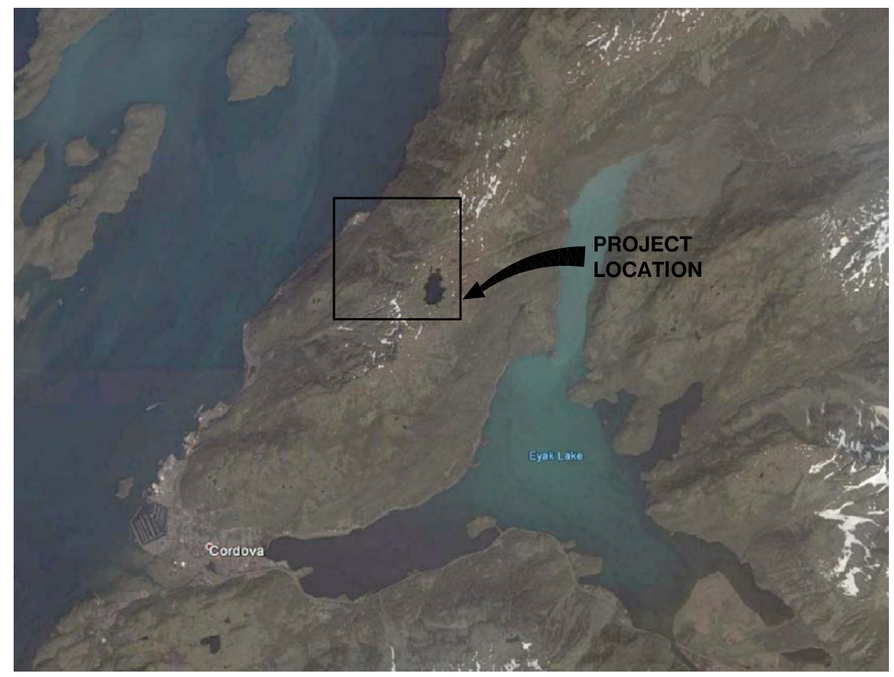
DRAFT REPORT

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA, ALASKA

CRATER LAKE WATER AND POWER PROJECT
CONCEPTUAL DESIGN DRAWINGS

LOCATION MAP
NTS

VICINITY MAP
NTS



PROJECT MAP
NTS

SHEET INDEX	
SHEET NO.	DESCRIPTION
GENERAL	
	COVER
G001	LOCATION MAP, VICINITY MAP, PROJECT MAP AND DRAWING INDEX
G002	WATER TREATMENT PLANT HYDRAULIC PROFILE
CIVIL	
C100	EXISTING SITE PLAN
C101	PROPOSED PROJECT PLAN
C102	DAM SITE PLAN 1 – BASE PROJECT HIGH DAM
C103	DAM SITE PLAN 2 – LOW DAM OPTION
C104	CONCRETE DAM PROFILE – BASE PROJECT HIGH DAM
C105	CONCRETE DAM PROFILE – LOW DAM OPTION
C106	SPILLWAY SECTIONS AND DETAILS
C107	LAKE TAP PLAN AND PROFILE
C108	PENSTOCK PLAN AND PROFILE 1
C109	PENSTOCK PLAN AND PROFILE 2
C110	PENSTOCK PLAN AND PROFILE 3
C111	PENSTOCK PLAN AND PROFILE 4
C112	PENSTOCK PLAN AND PROFILE 5
C113	PENSTOCK PLAN AND PROFILE 5 MICROTUNNEL OPTION
C114	POWERHOUSE SITE PLAN
C115	POWERHOUSE ACCESS ROAD
ARCHITECTURAL	
A101	POWERHOUSE AND WATER TREATMENT BLDG ELEVATIONS
STRUCTURAL	
S101	PENSTOCK ANCHORAGE ELEVATION AND SECTIONS
MECHANICAL	
M101	POWERHOUSE UPPER FLOOR PLAN
M102	POWERHOUSE LOWER FLOOR PLAN
M103	POWERHOUSE BLDG SECTION 1
M104	POWERHOUSE BLDG SECTION 2
ELECTRICAL	
E101	ELECTRICAL ONE–LINE DIAGRAM

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

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

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

LOCATION MAP, VICINITY MAP,
PROJECT MAP AND DRAWING INDEX

DESIGNED M. MOUGHAMIAN
DRAWN J. LAHMON
CHECKED K. TILFORD
ISSUED DATE 12/14/15

DRAWING
G001

SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_G001.dwg Plot date: Dec 15, 2015 01:24pm, CAD User: johnlahmon

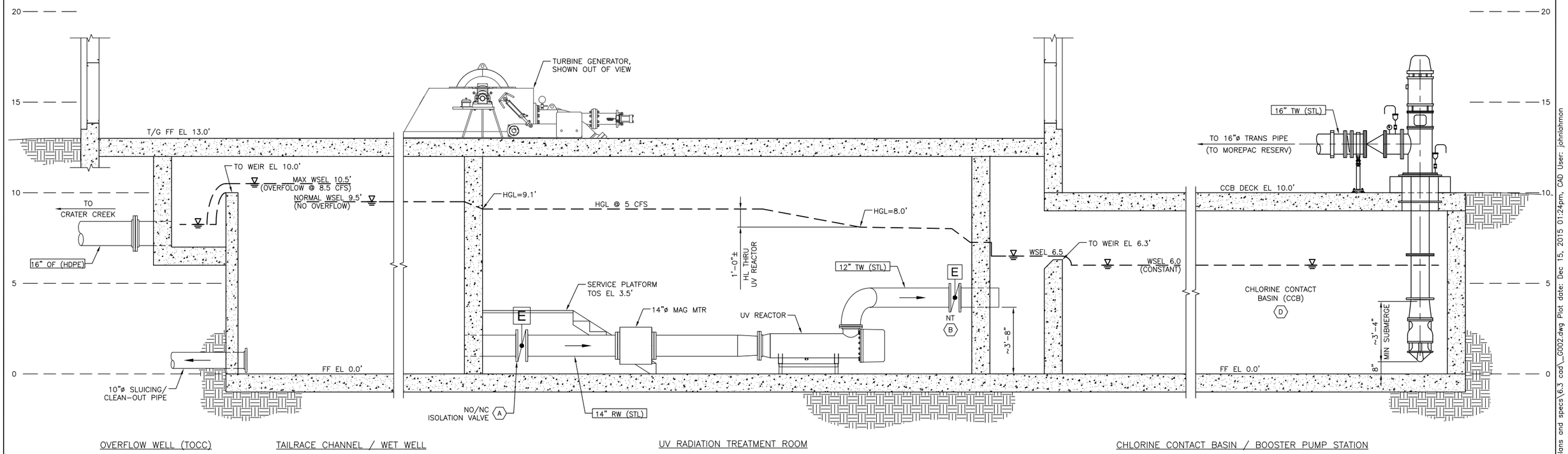
SHEET KEY NOTES:

A ISOLATION VALVE SERVES AS FULL OPEN/CLOSE SERVICE ONLY. CLOSE VALVE WHEN UV REACTOR IS OFF-LINE.

B THROTTLING VALVE (PLC TO MODULATE VALVE TO ACHIEVE DESIRED FLOW THRU UV REACTOR).

C VFD ON DUTY PUMP TO MAINTAIN CONSTANT WSEL IN CCB AT ALL TIMES.

D CCB SIZED FOR ~11.3 MIN HRT @ 5 CFS.



WATER TREATMENT HYDRAULIC PROFILE (@ 5 CFS MAX TREATMENT FLOW)

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

0' 2' 4'

PRELIMINARY
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REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

WATER TREATMENT PLANT HYDRAULIC PROFILE

DESIGNED M. MOUGHAMIAN

DRAWN J. LAHMON

CHECKED D. JARRETT

ISSUED DATE 12/14/15

DRAWING

G002

SCALE: AS NOTED

JOB NO: 000000

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SHEET NOTES:

1. BASE MAP REF: TOPOGRAPHY BY E-TERRA, 2015.

EXISTING SITE PLAN

SCALE: 1"= 200'

0" 200' 400'

N

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

EXISTING SITE PLAN

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

DRAWING

C100

SCALE: AS NOTED

JOB NO: 000000

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SHEET NOTES:

1. BASE MAP REF: TOPOGRAPHY BY E-TERRA, 2015.

PROPOSED PROJECT PLAN

SCALE: 1"= 200'

0" 200' 400'

N

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PROPOSED PROJECT PLAN

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

DRAWING

C101

SCALE: AS NOTED

JOB NO: 000000

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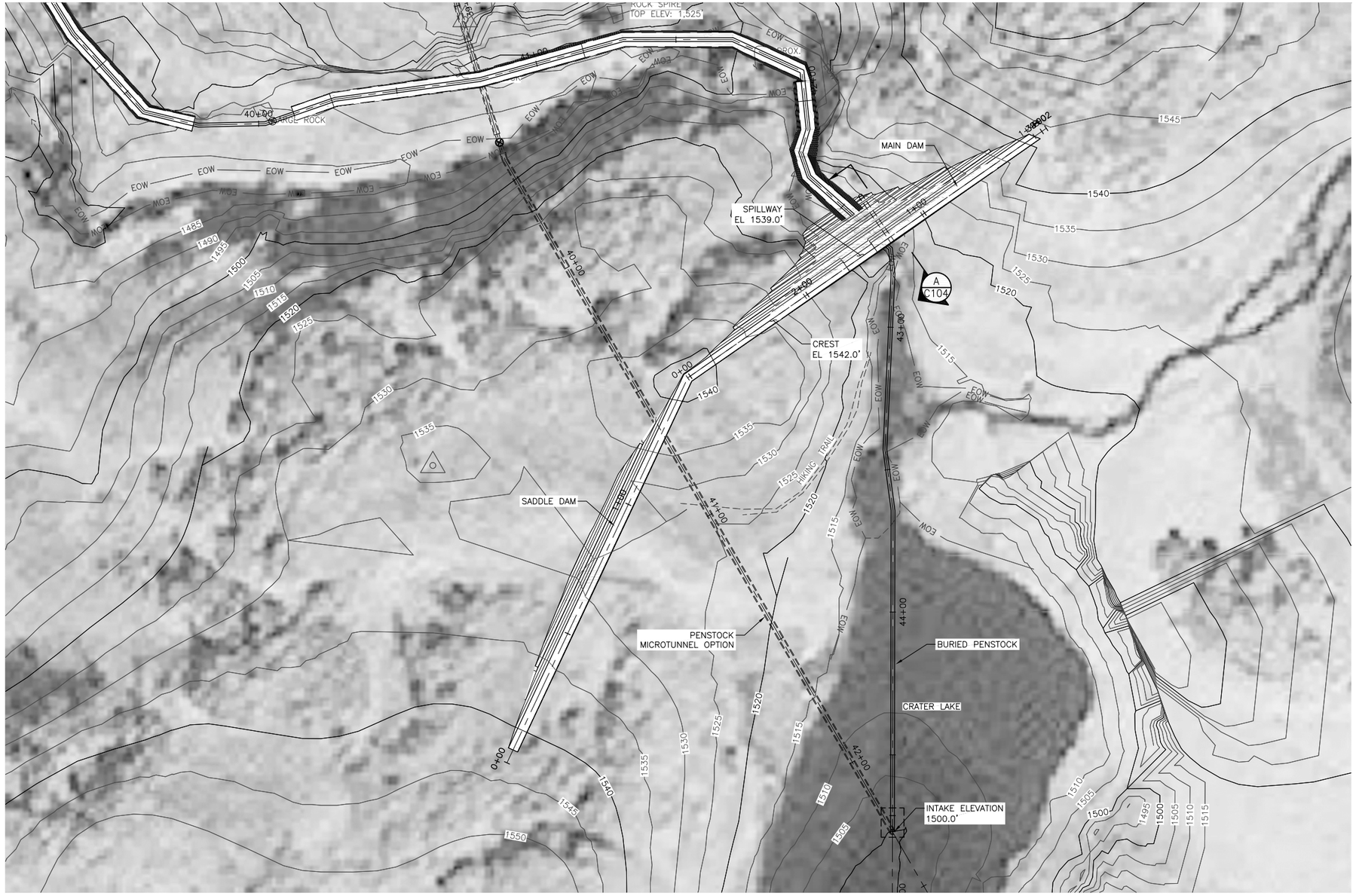

DAM SITE PLAN

SCALE: 1"= 20'

0" 20' 40'

N

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

DAM SITE PLAN 1 – BASE PROJECT HIGH DAM

DESIGNED P. GABY

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

DRAWING

C102

SCALE: AS NOTED

JOB NO: 000000

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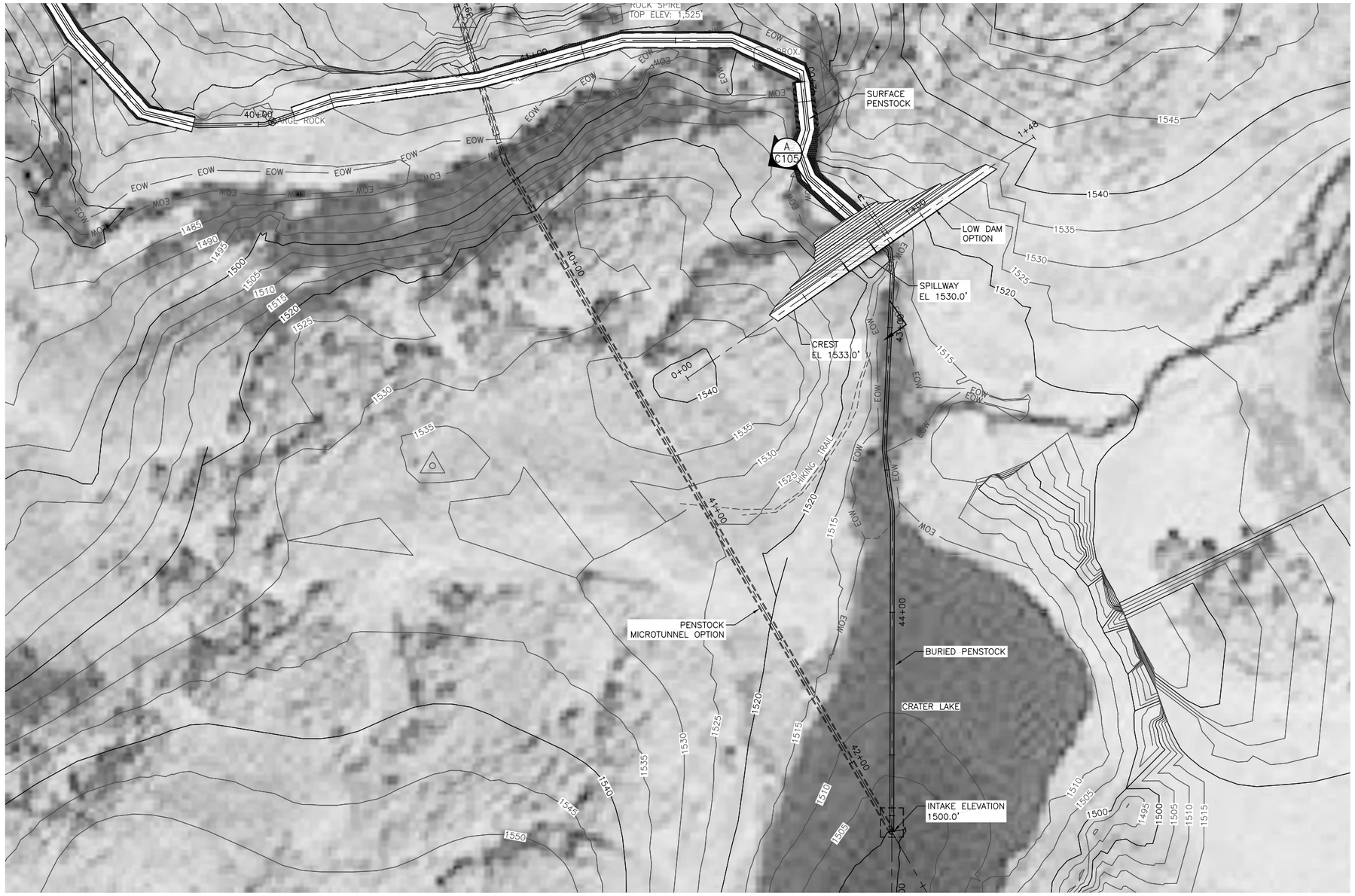

DAM SITE PLAN

SCALE: 1"= 20'

0" 20' 40'

N

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

DAM SITE PLAN 2 – LOW DAM OPTION

DESIGNED K. TILFORD

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

DRAWING

C103

SCALE: AS NOTED

JOB NO: 000000

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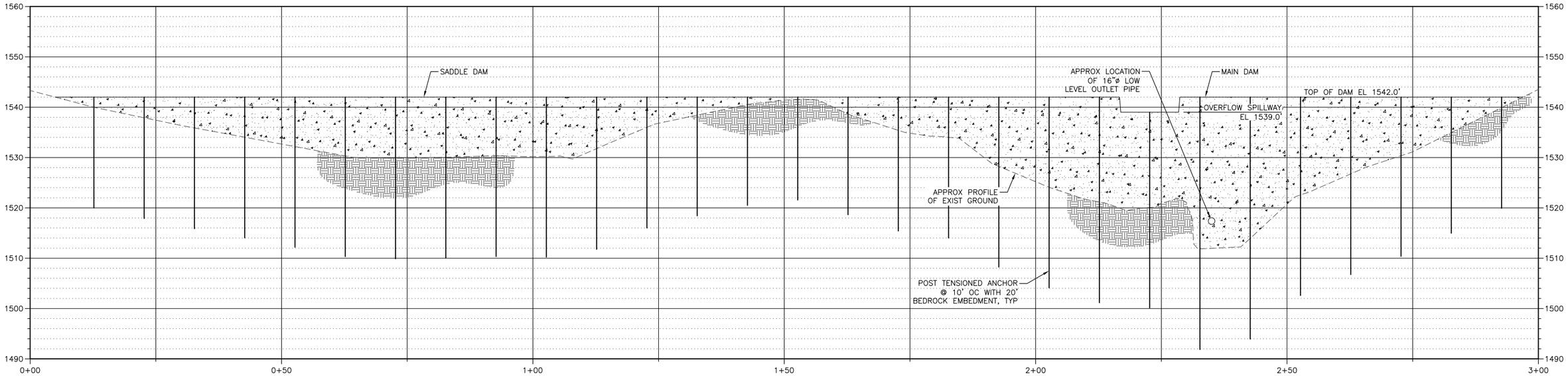
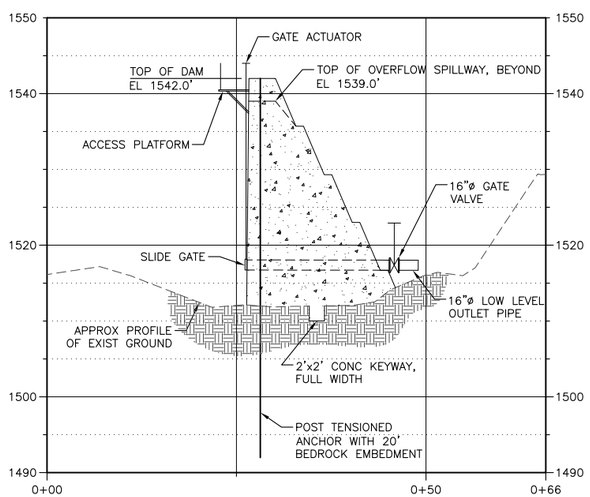


CONCRETE DAM PROFILE

SCALE: 1"= 10' 0" 10' 20'



CONCRETE DAM SECTION

SCALE: 1"= 10' 0" 10' 20' A C102

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

CONCRETE DAM PROFILE – BASE PROJECT HIGH DAM

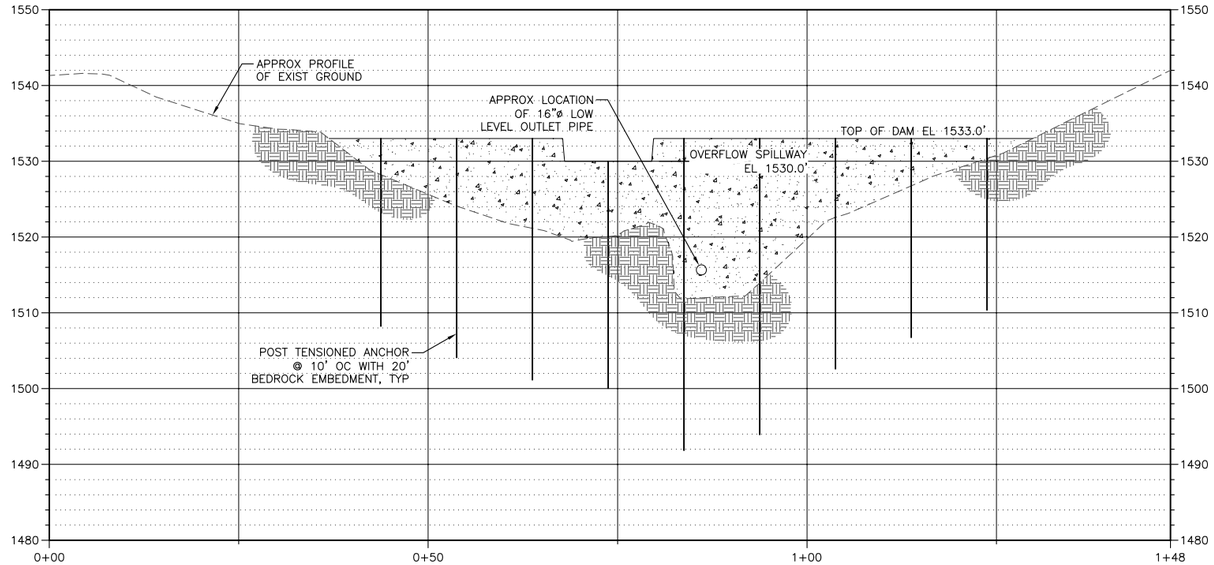
DESIGNED P. GABY
DRAWN J. LAHMON
CHECKED K. TILFORD
ISSUED DATE 12/14/15

DRAWING C104

SCALE: AS NOTED

JOB NO: 000000

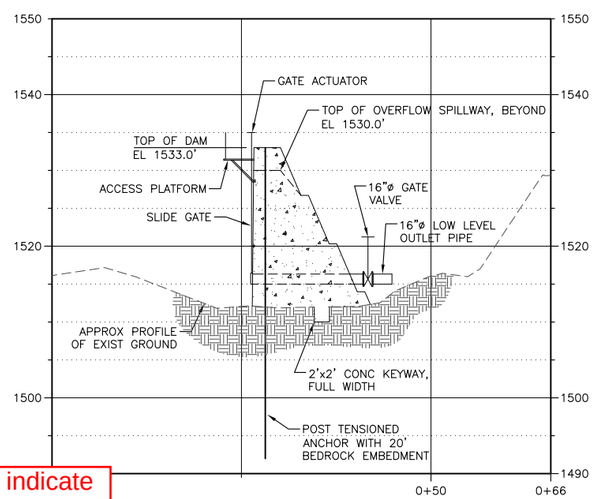
Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C104.dwg Plot date: Dec 15, 2015 01:32pm, CAD User: johnlahmon



EMBANKMENT DAM PROFILE

SCALE: 1"= 5' 0" 5' 10'

Correct to Indicate Option Low Concrete Dam Profile



Correct to indicate Option Low Concrete Dam Section

BANKMENT DAM SECTION (A / C103)

1"= 10' 0" 10' 20'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

CONCRETE DAM PROFILE – LOW DAM OPTION

DESIGNED P. GABY

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

DRAWING C105

SCALE: AS NOTED

JOB NO: 000000

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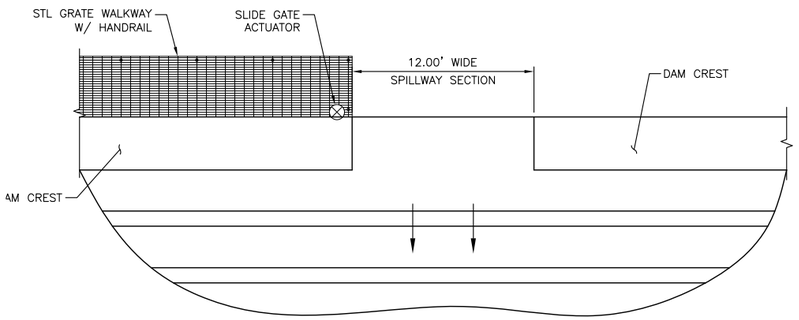
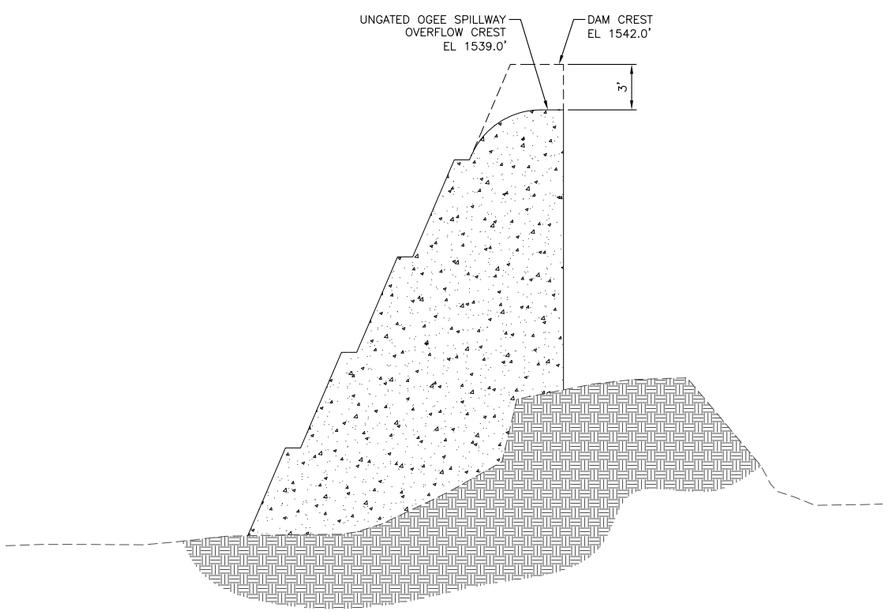


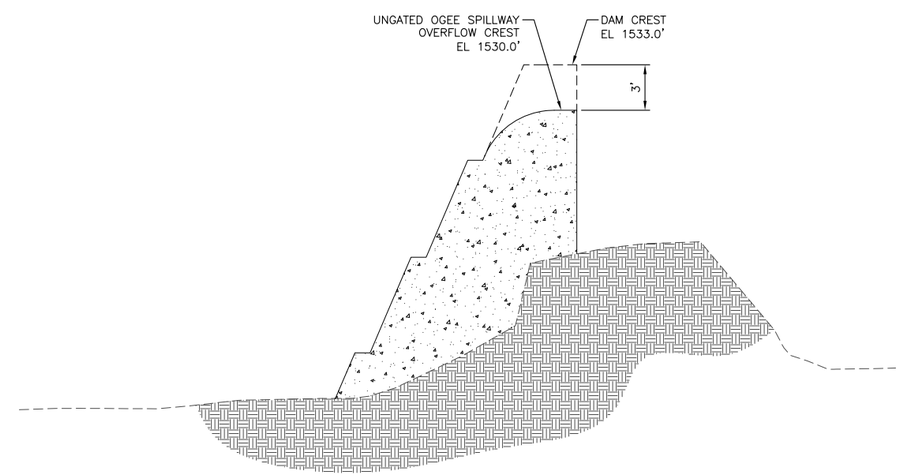
PLAN VIEW – SPILLWAY & LLO VALVE ACCESS PLATFORM

SCALE: 1"= 5'



HIGH DAM SPILLWAY SECTION

SCALE: 1"= 5'



LOW DAM OPTION SPILLWAY SECTION

SCALE: 1"= 5'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

SPILLWAY SECTIONS AND DETAILS

DESIGNED P. GABY

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

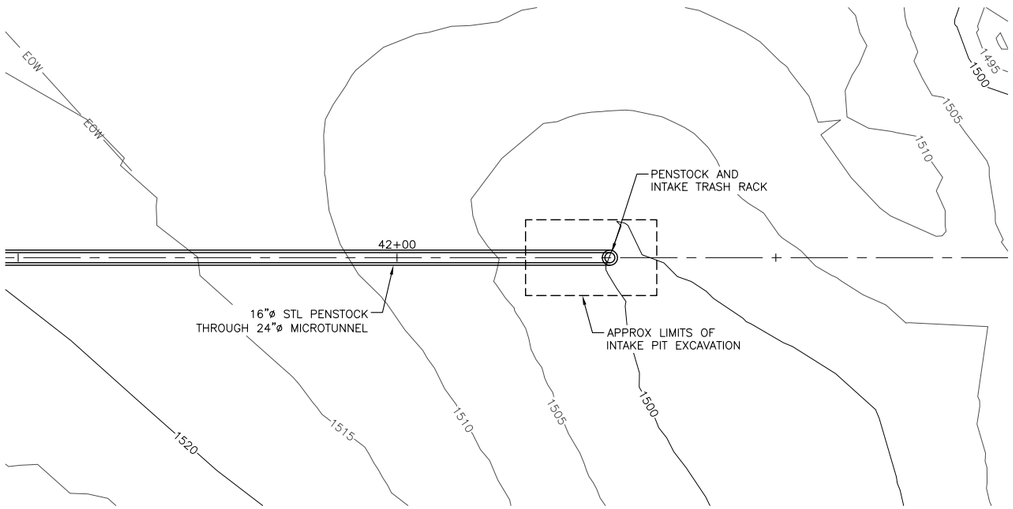
DRAWING

C106

SCALE: AS NOTED

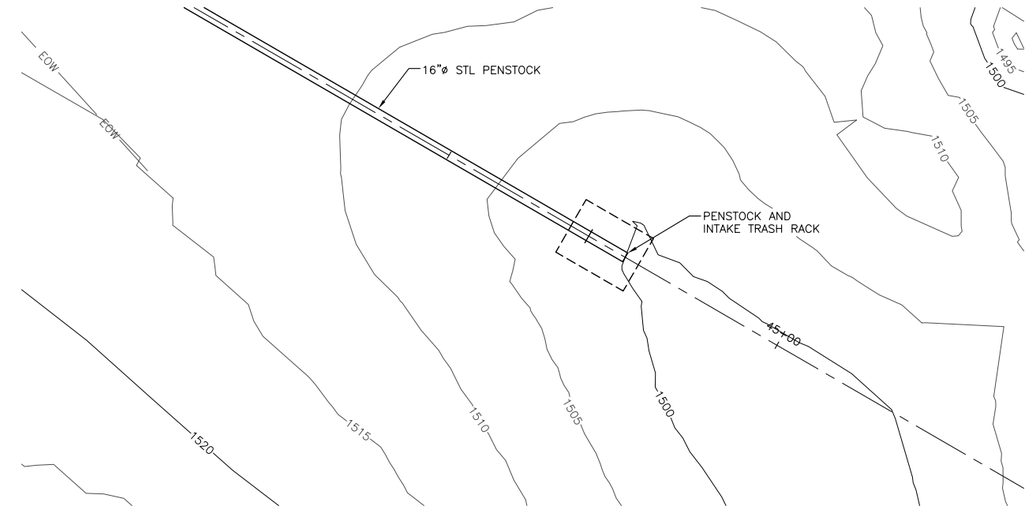
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C106.dwg Plot date: Dec 15, 2015 01:34pm, CAD User: johnlahmon



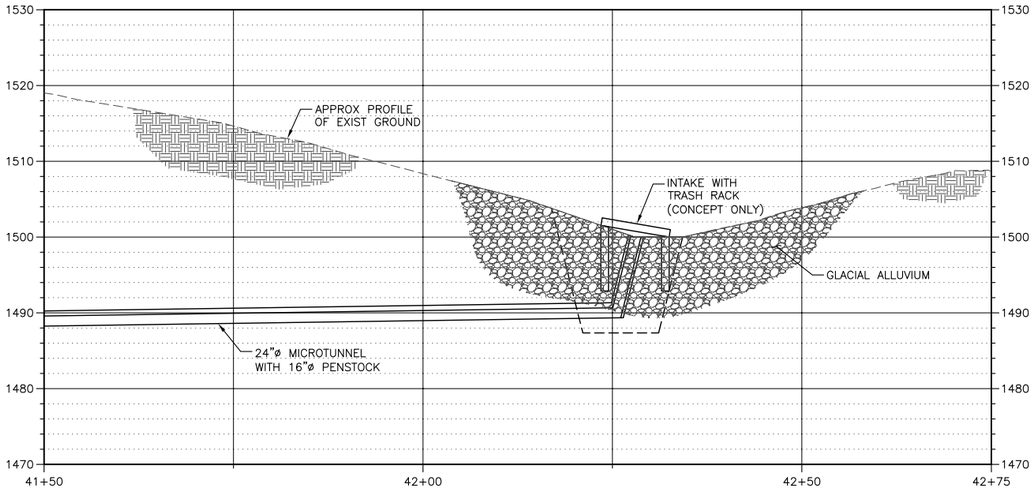
MICROTUNNEL LAKE TAP PLAN

SCALE: 1"= 10'



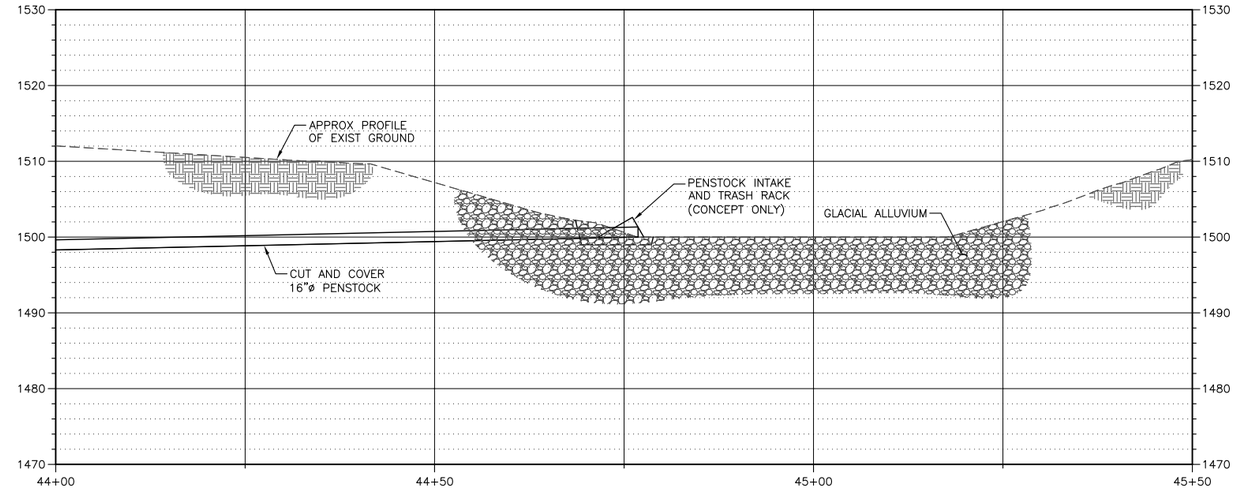
SURFACE PENSTOCK LAKE TAP PLAN

SCALE: 1"= 10'



MICROTUNNEL OPTION LAKE TAP PROFILE

SCALE: 1"= 10'



SURFACE PENSTOCK LAKE TAP PROFILE

SCALE: 1"= 10'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

LAKE TAP PLAN AND PROFILE

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

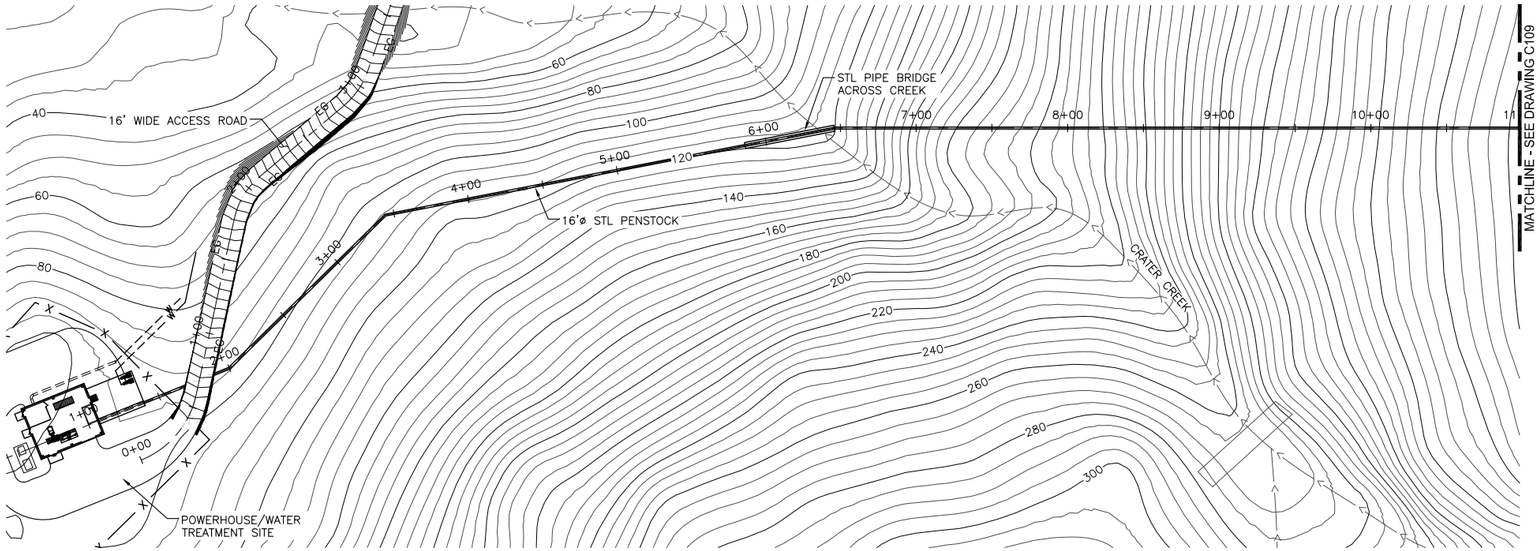
DRAWING

C107

SCALE: AS NOTED

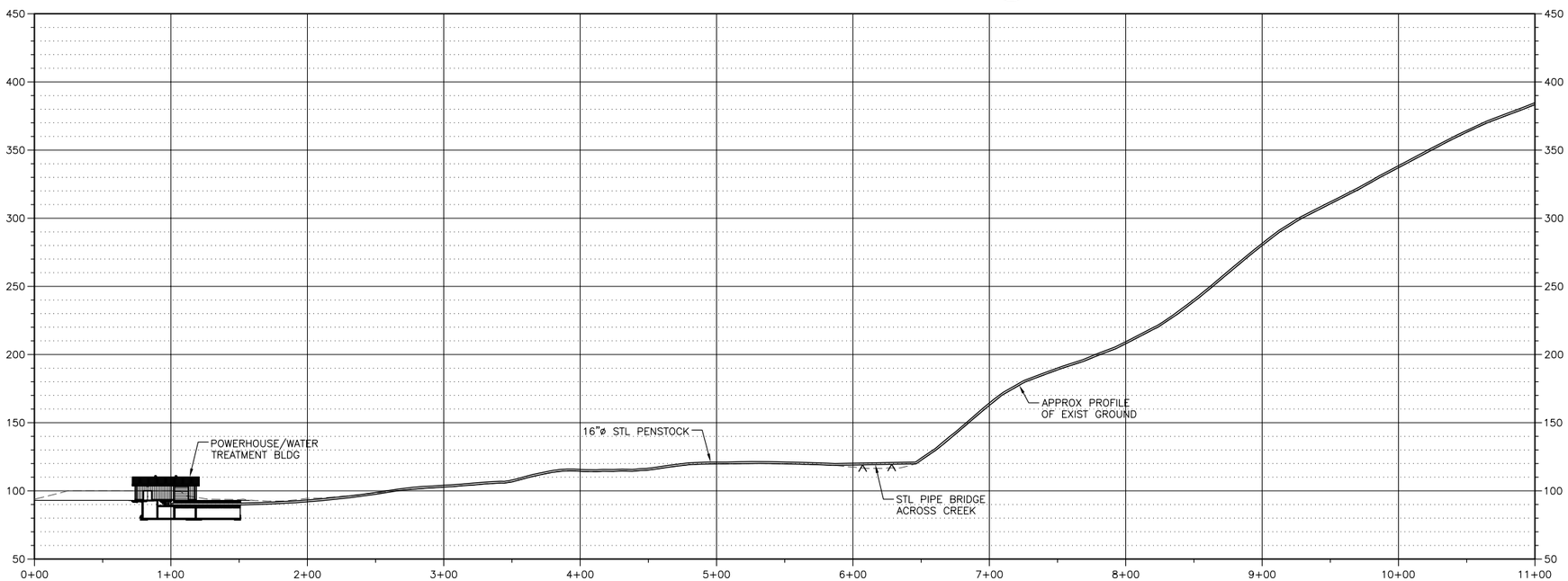
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C107.dwg Plot date: Dec 15, 2015 01:35pm, CAD User: johnlahmon



PENSTOCK PLAN

SCALE: 1"= 50'



PENSTOCK PROFILE

SCALE: 1"= 50'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PENSTOCK PLAN AND PROFILE 1

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

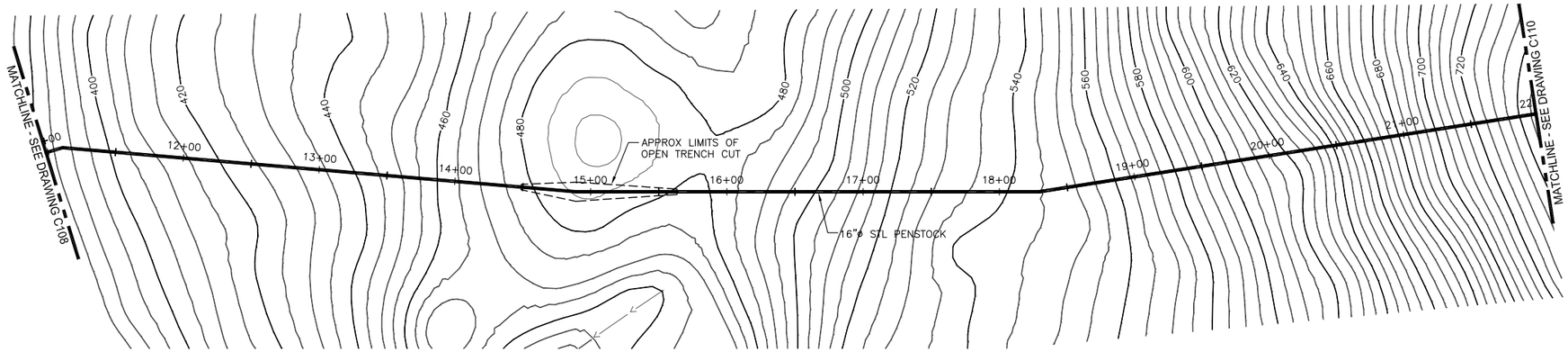
DRAWING

C108

SCALE: AS NOTED

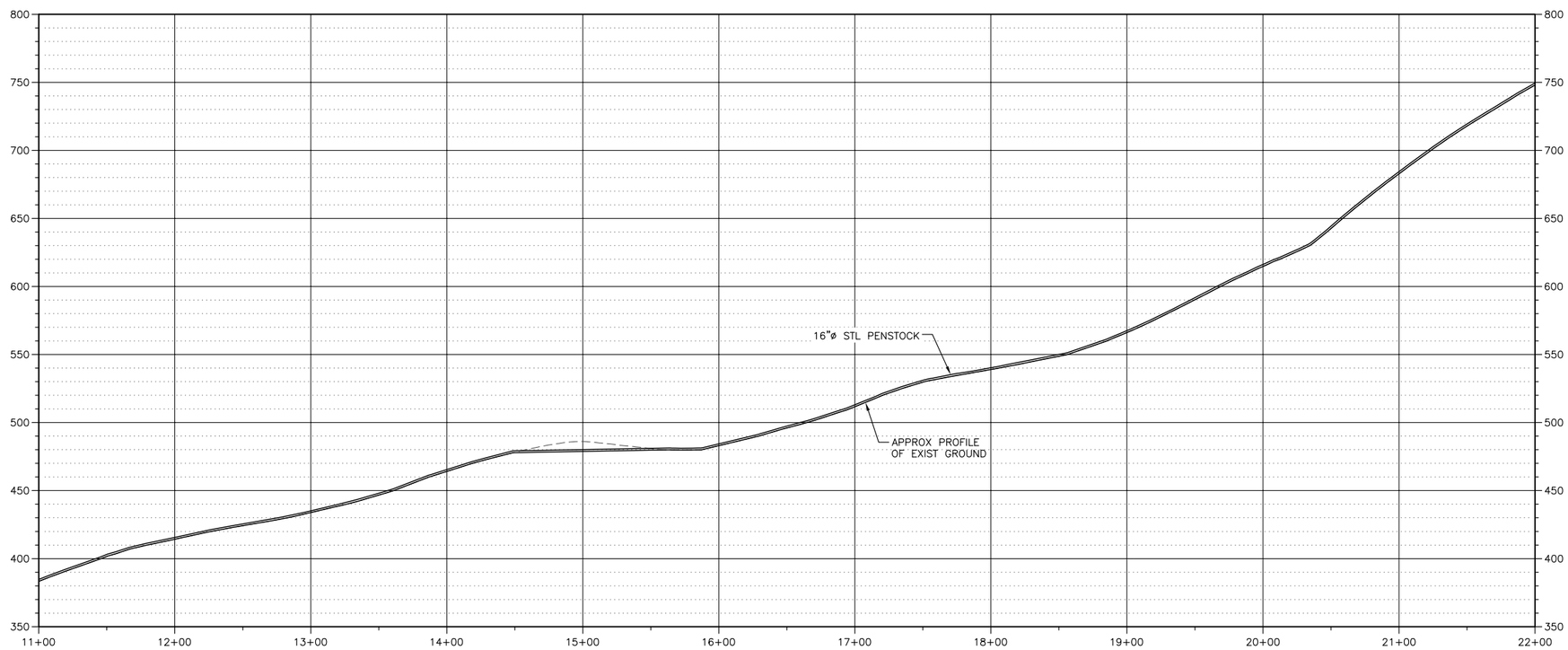
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C108.dwg Plot date: Dec 15, 2015 01:36pm, CAD User: johnlahmon



PENSTOCK PLAN

SCALE: 1"= 50'



PENSTOCK PROFILE

SCALE: 1"= 50'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PENSTOCK PLAN AND PROFILE 2

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

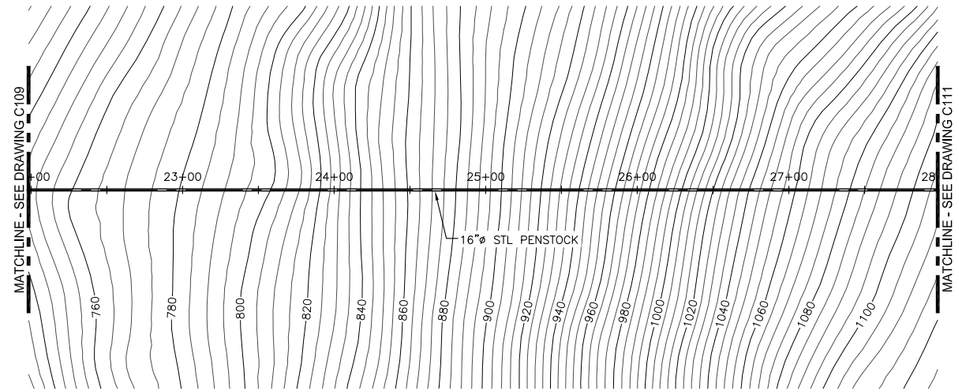
DRAWING

C109

SCALE: AS NOTED

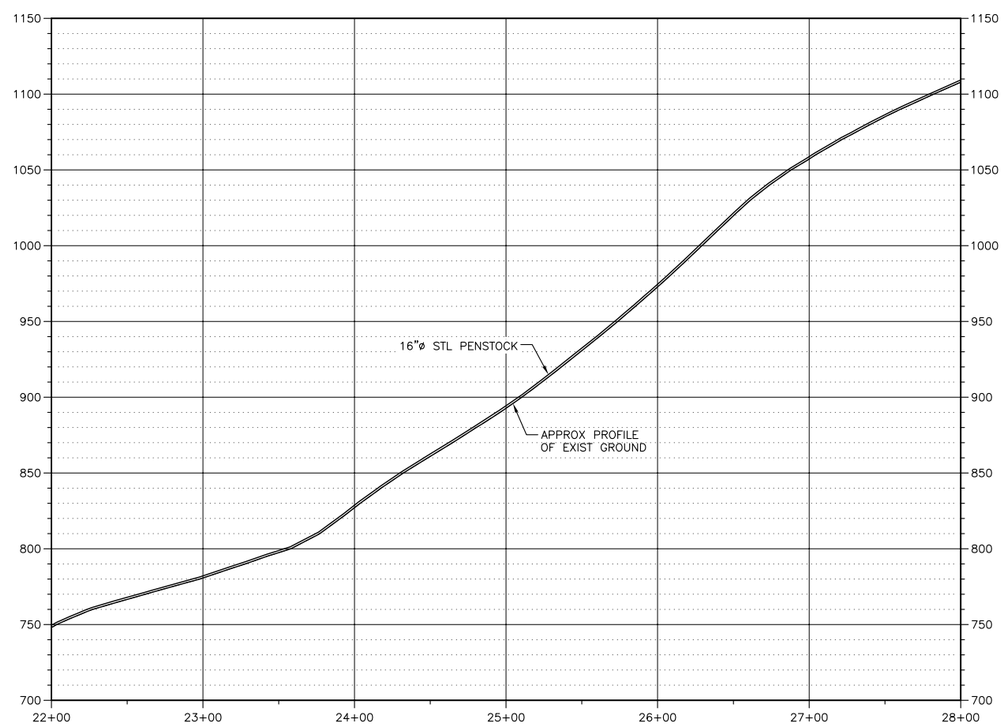
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C109.dwg Plot date: Dec 15, 2015 01:37pm, CAD User: johnlahmon



PENSTOCK PLAN

SCALE: 1"= 50'



PENSTOCK PROFILE

SCALE: 1"= 50'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PENSTOCK PLAN AND PROFILE 3

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

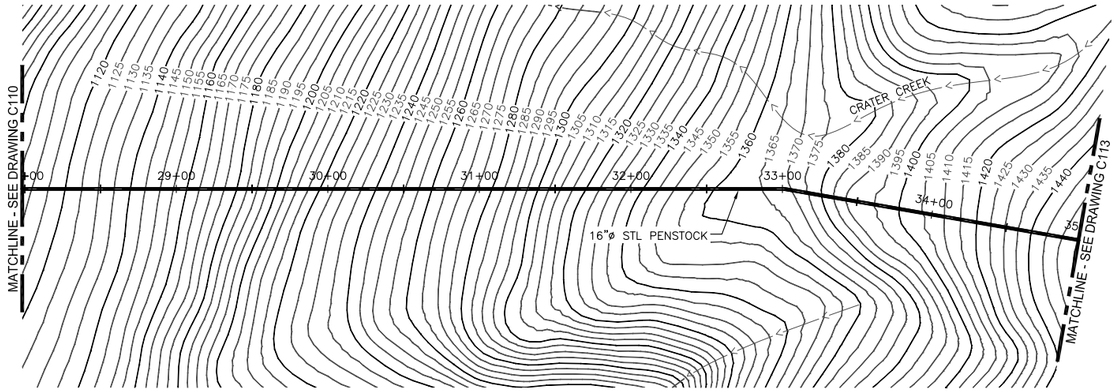
DRAWING

C110

SCALE: AS NOTED

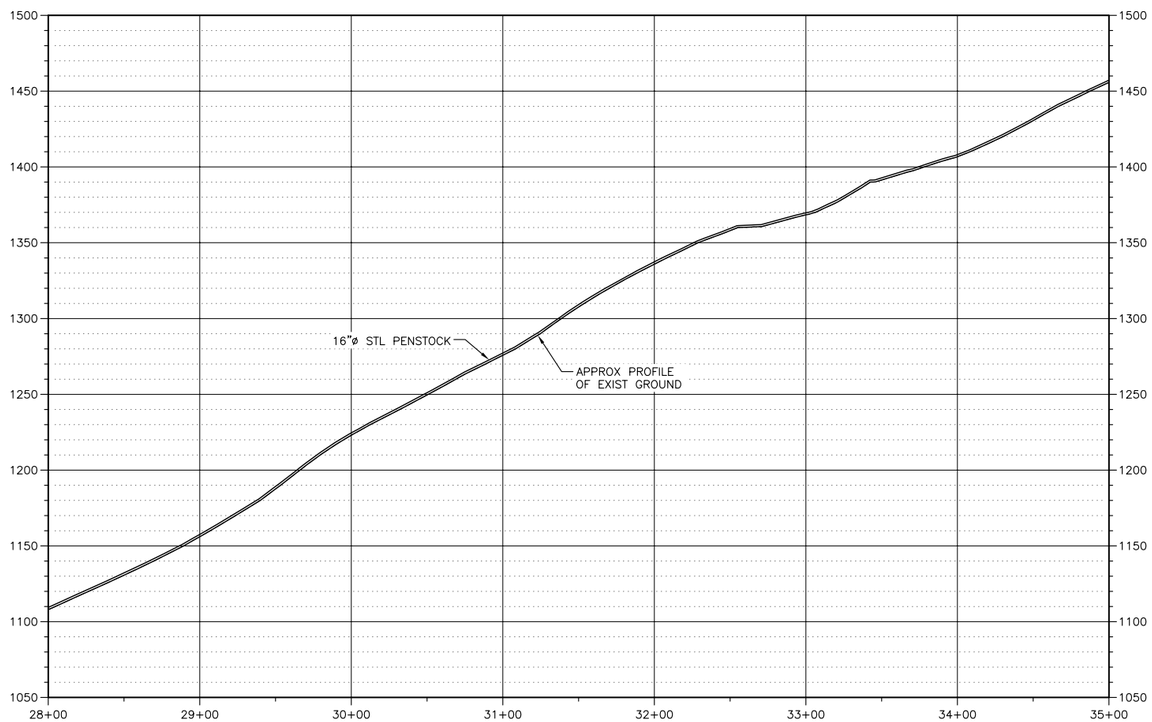
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C110.dwg Plot date: Dec 15, 2015 01:38pm, CAD User: johnlahmon



PENSTOCK PLAN

SCALE: 1"= 50'



PENSTOCK PROFILE

SCALE: 1"= 50'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PENSTOCK PLAN AND PROFILE 4

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

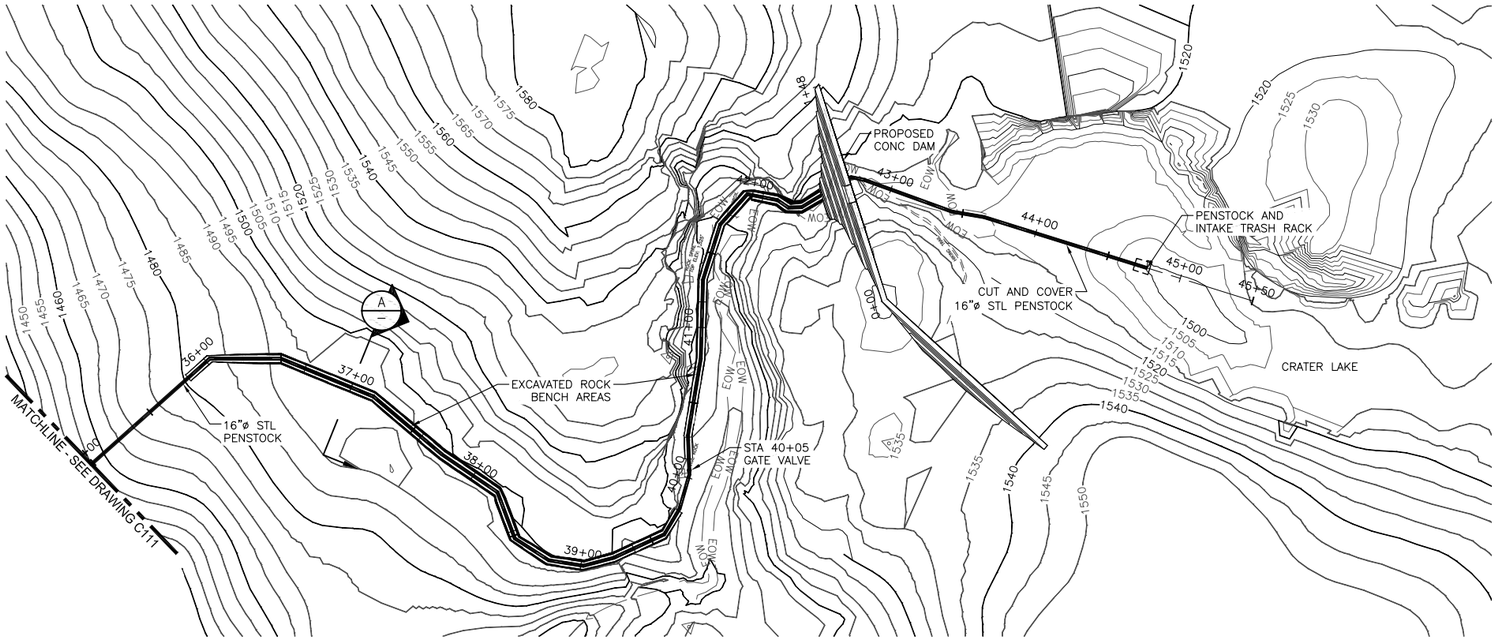
DRAWING

C111

SCALE: AS NOTED

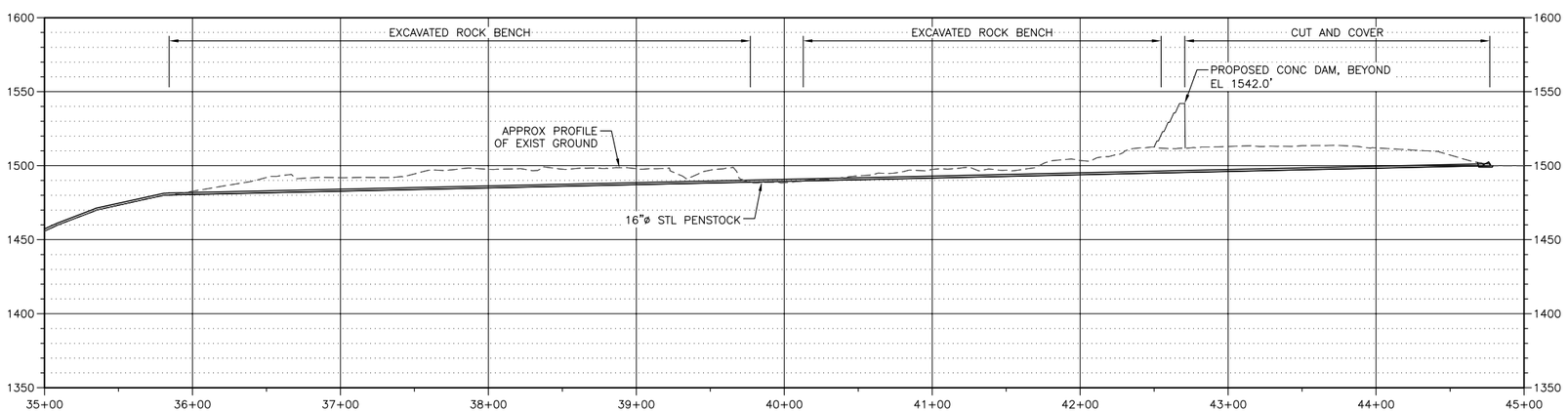
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C111.dwg Plot date: Dec 15, 2015 01:39pm, CAD User: johnlahmon



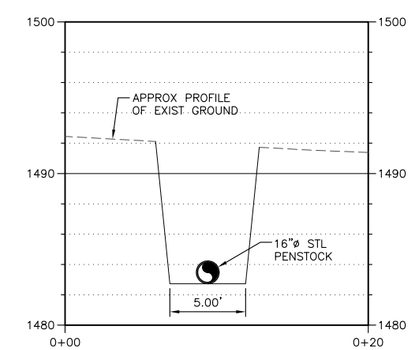
PENSTOCK PLAN

SCALE: 1"= 50'



PENSTOCK PROFILE

SCALE: 1"= 50'



TYPICAL SECTION

SCALE: 1"= 5'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PENSTOCK PLAN AND PROFILE 5

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

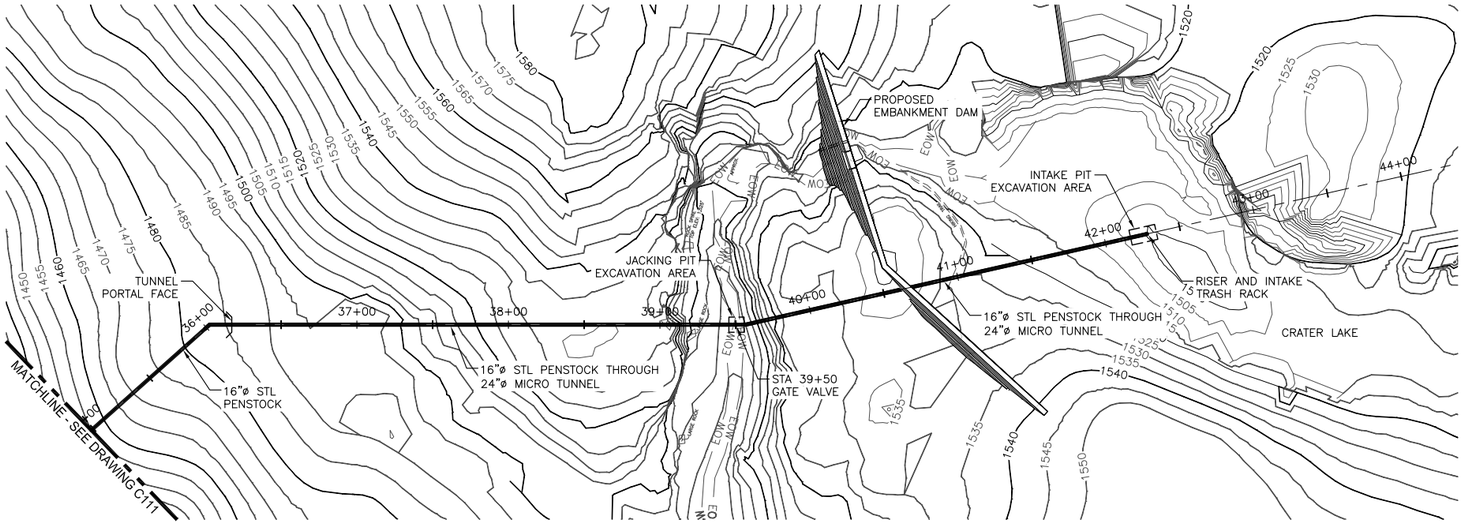
ISSUED DATE 12/14/15

DRAWING C112

SCALE: AS NOTED

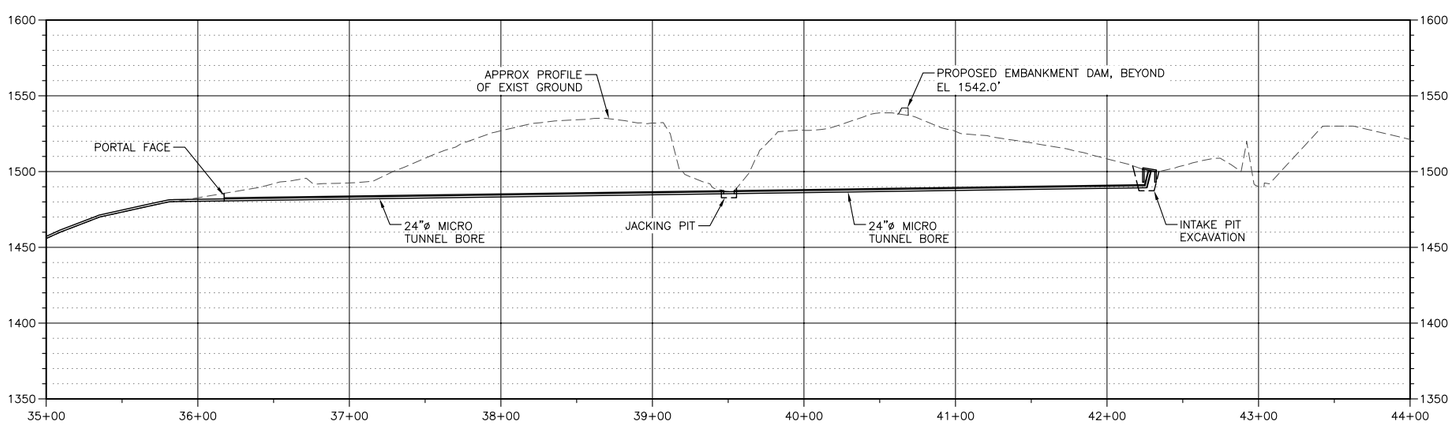
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C112.dwg Plot date: Dec 15, 2015 01:40pm, CAD User: johnlahmon



PENSTOCK PLAN

SCALE: 1"= 50'



PENSTOCK PROFILE

SCALE: 1"= 50'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PENSTOCK PLAN AND PROFILE 5 MICROTUNNEL OPTION

DESIGNED J. LAHMON

DRAWN J. LAHMON

CHECKED K. TILFORD

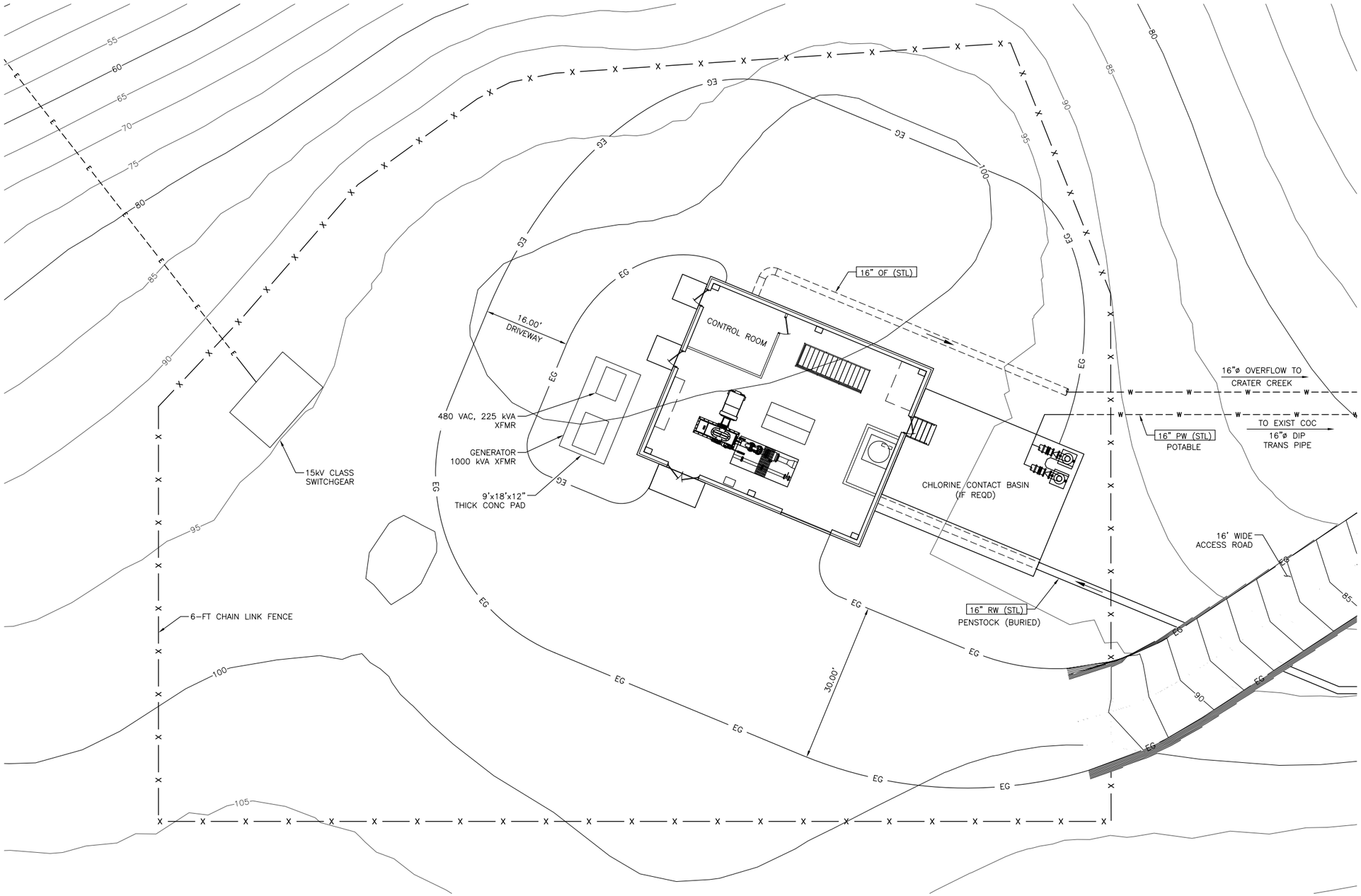
ISSUED DATE 12/14/15

DRAWING C113

SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C113.dwg Plot date: Dec 15, 2015 01:41pm, CAD User: johnlahmon



POWERHOUSE SITE PLAN

SCALE: 1"= 10'

0" 10' 20'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

POWERHOUSE SITE PLAN

DESIGNED M. MOUGHAMIAN

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

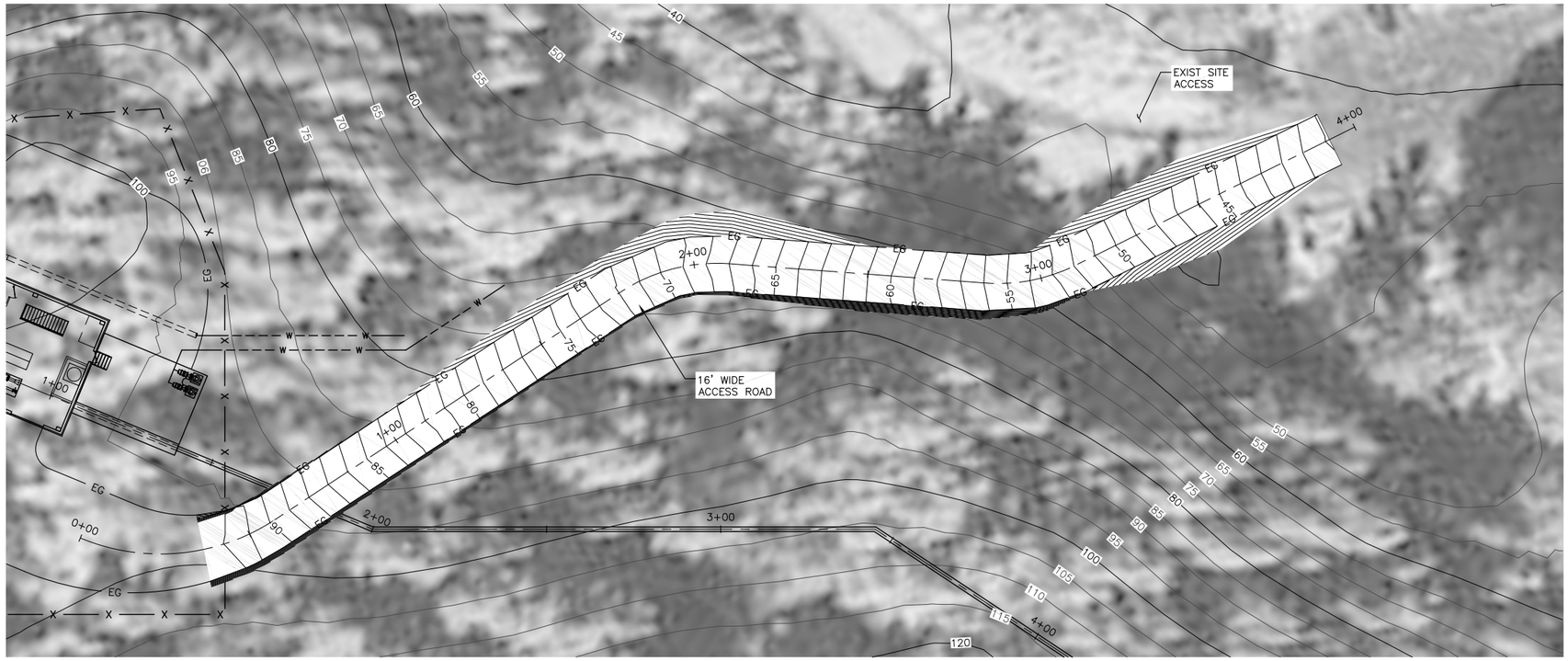
DRAWING

C114

SCALE: AS NOTED

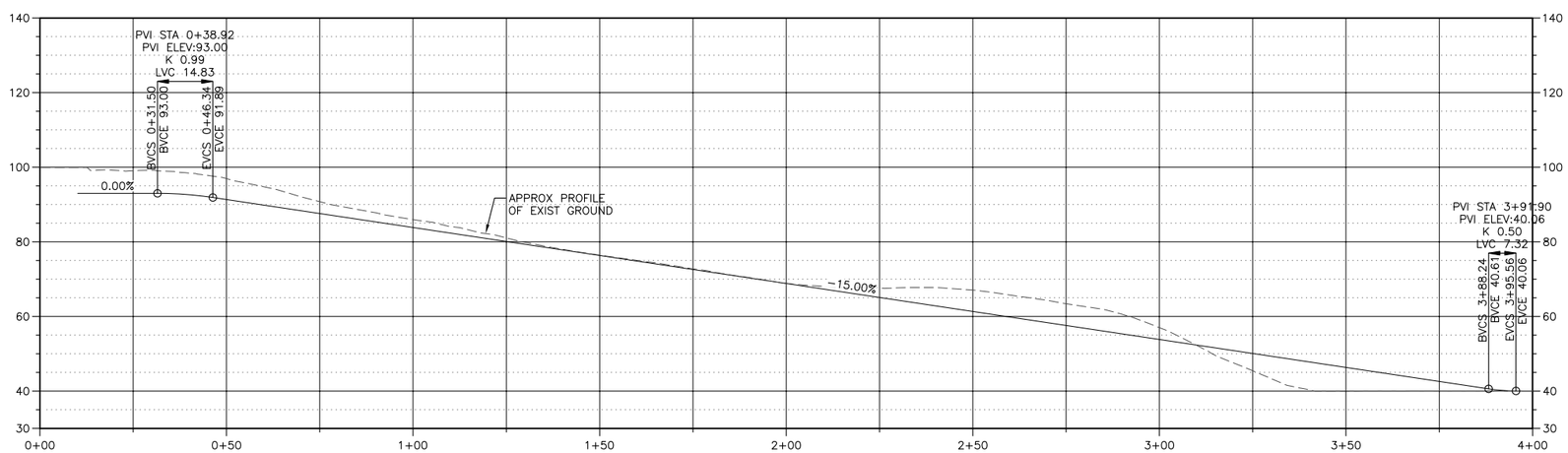
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C114.dwg Plot date: Dec 15, 2015 01:42pm, CAD User: johnlahmon



PLAN

SCALE: 1"= 20'



PROFILE

SCALE: 1"= 20'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

POWERHOUSE ACCESS ROAD

DESIGNED M. MOUGHAMIAN

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

DRAWING

C115

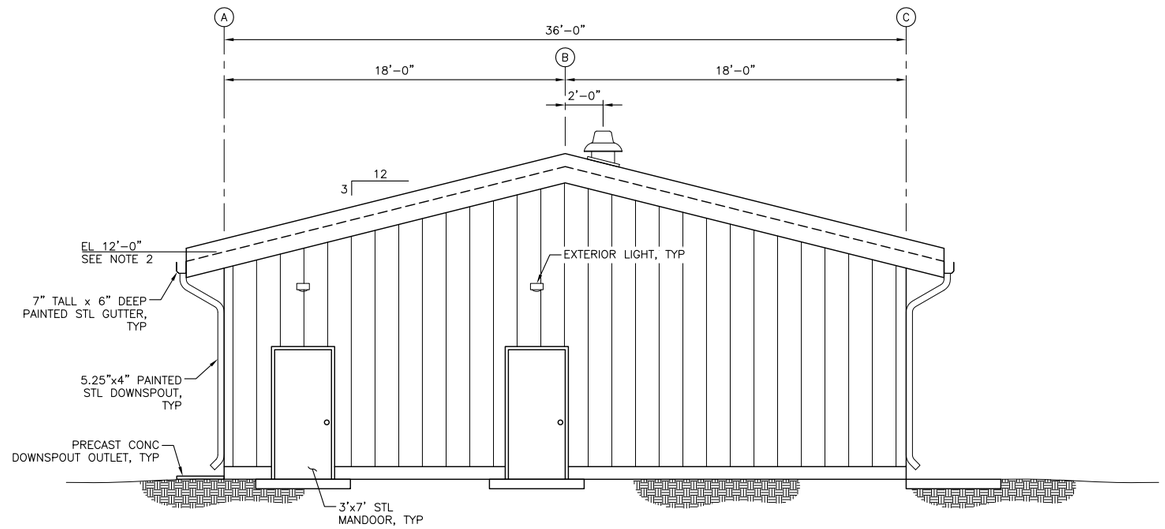
SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_C115.dwg Plot date: Dec 15, 2015 01:45pm, CAD User: johnlahmon

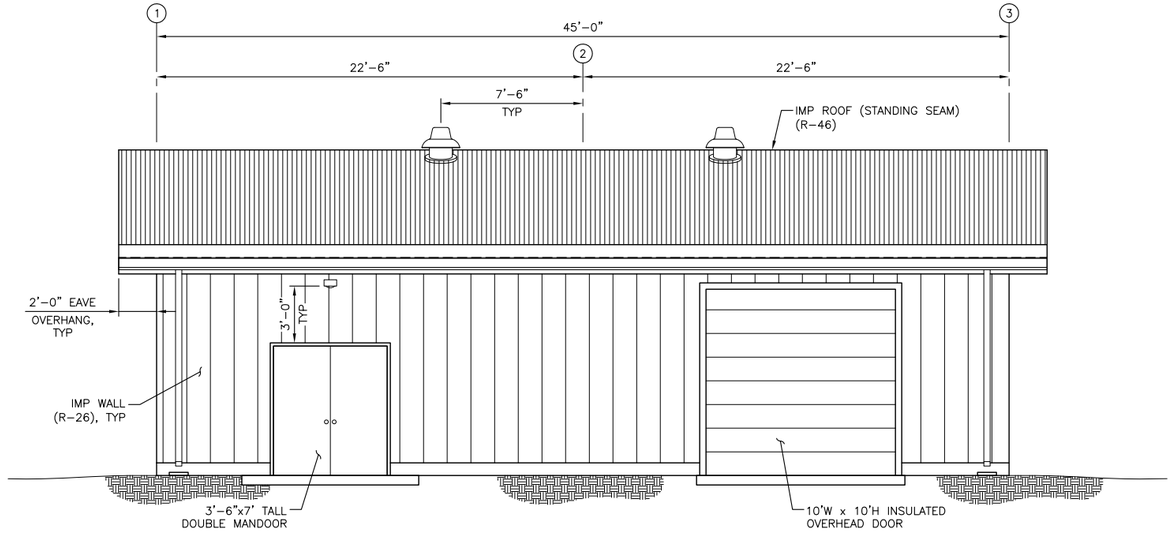
SHEET NOTES:

1. GRIDLINES ARE OUT–TO–OUT OF GIRTS AND DOES NOT INCLUDE THICKNESS OF EXTERIOR PANELS.
2. EAVE HEIGHT TAKEN AS TOP OF PURLIN CAVITY AT GRIDLINES.



WEST ELEVATION

SCALE: 1/4"= 1'–0"



SOUTH ELEVATION

SCALE: 1/4"= 1'–0"

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

POWERHOUSE AND WATER TREATMENT BLDG ELEVATIONS

DESIGNED M. MOUGHAMIAN

DRAWN J. LAHMON

CHECKED K. TILFORD

ISSUED DATE 12/14/15

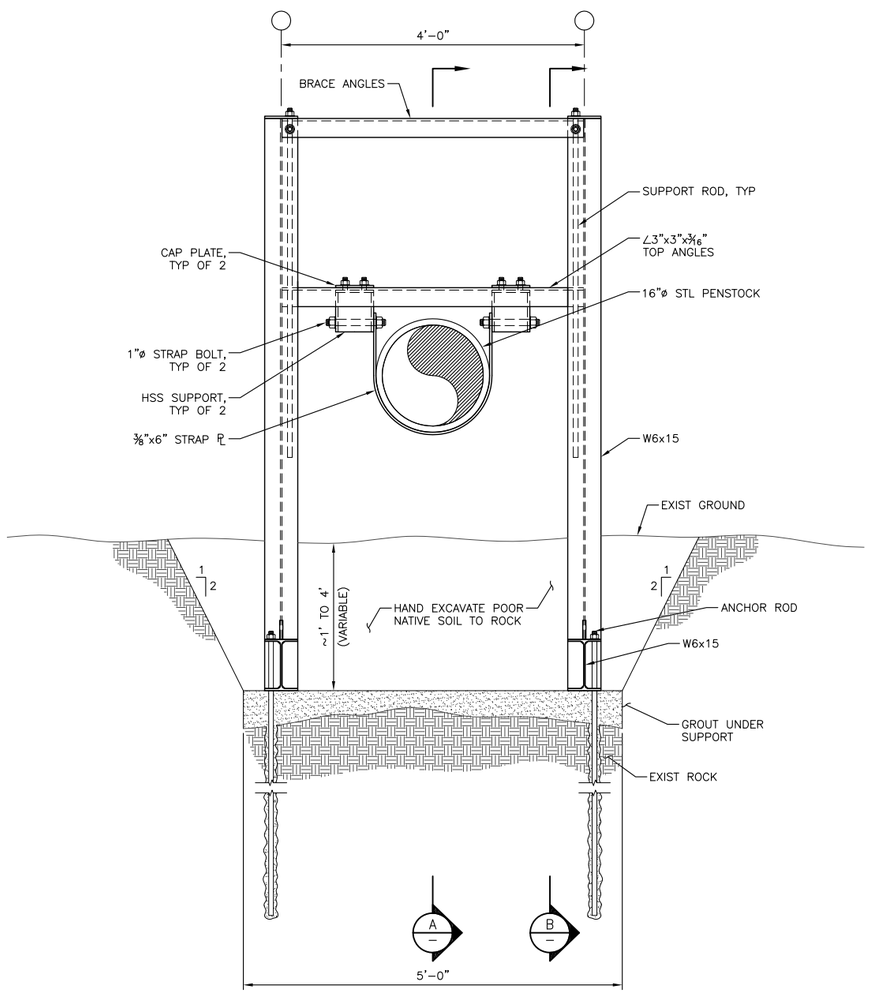
DRAWING

A101

SCALE: AS NOTED

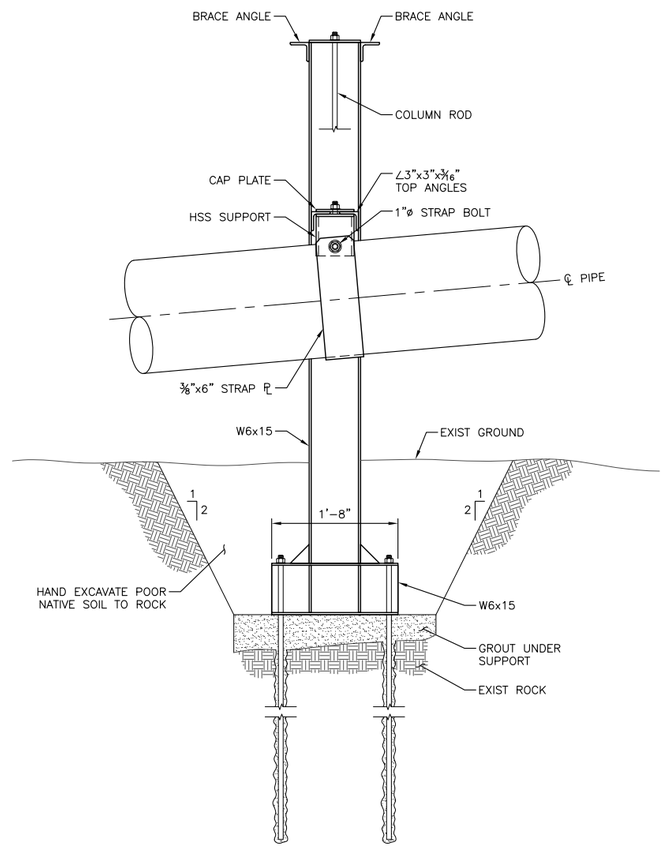
JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_A101.dwg Plot date: Dec 15, 2015 01:46pm, CAD User: johnlahmon



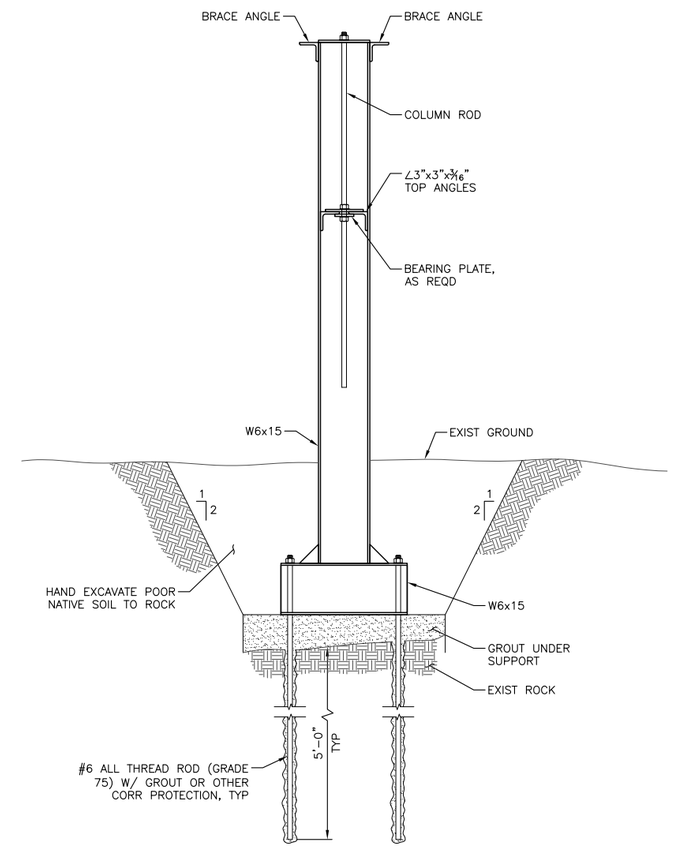
PENSTOCK SUPPORT ELEVATION 1

SCALE: 1"= 1'-0"



SECTION A

SCALE: 1"= 1'-0"



SECTION B

SCALE: 1"= 1'-0"

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

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McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

PENSTOCK ANCHORAGE ELEVATION AND SECTIONS

DESIGNED G. HORECZY

DRAWN J. LAHMON

CHECKED M. MOUGHAMIAN

ISSUED DATE 12/14/15

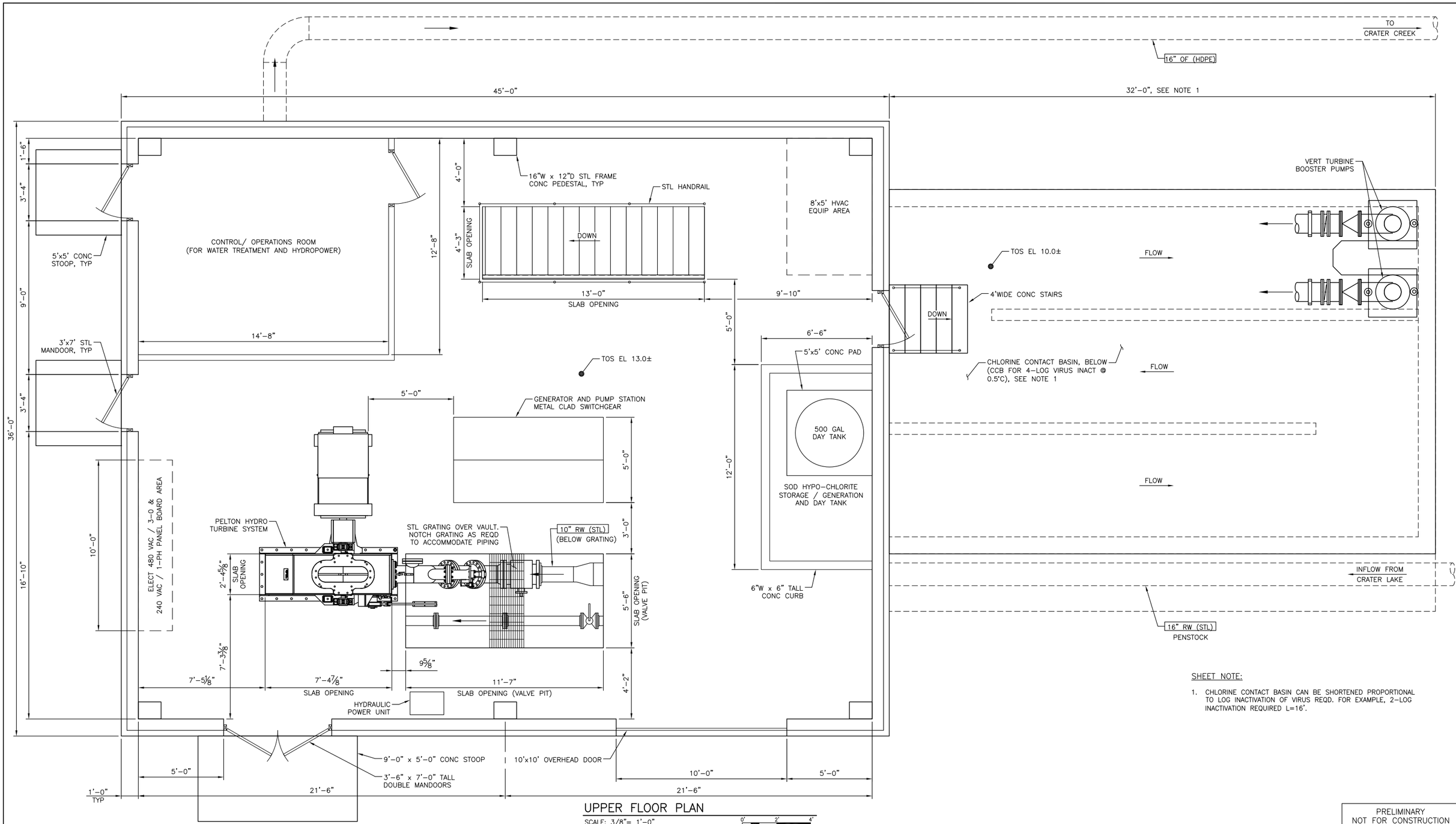
DRAWING

S101

SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_S101.dwg Plot date: Dec 15, 2015 01:47pm, CAD User: johnlahmon



UPPER FLOOR PLAN

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

0' 2' 4'

SHEET NOTE:

1. CHLORINE CONTACT BASIN CAN BE SHORTENED PROPORTIONAL TO LOG INACTIVATION OF VIRUS REQD. FOR EXAMPLE, 2-LOG INACTIVATION REQUIRED L=16'.

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

POWERHOUSE UPPER FLOOR PLAN

DESIGNED M. MOUGHAMIAN

DRAWN J. LAHMON

CHECKED D. JARRETT

ISSUED DATE 12/14/15

DRAWING

M101

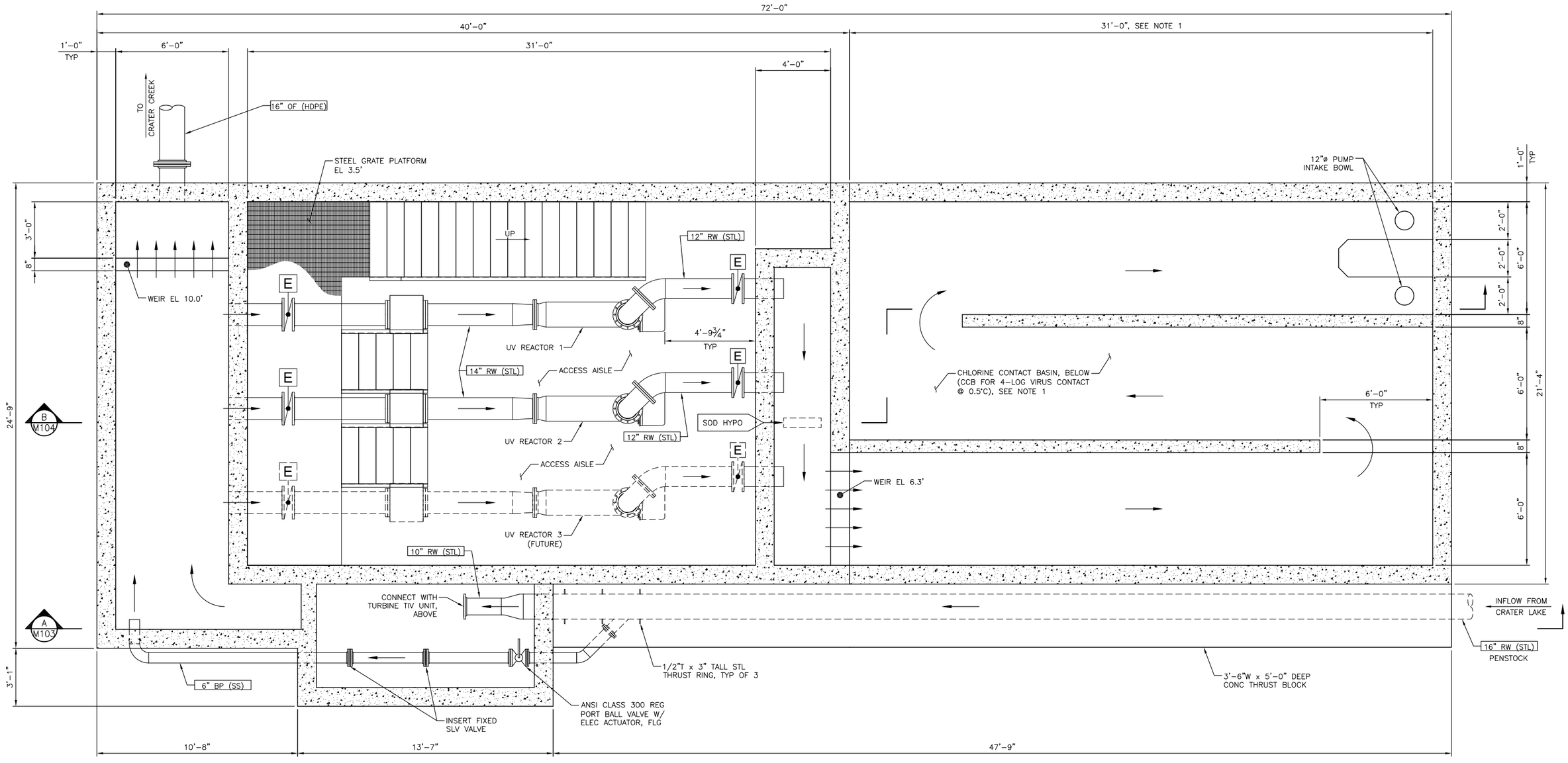
SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_M101.dwg Plot date: Dec 15, 2015 01:47pm, CAD User: johnlahmon

SHEET NOTE:

1. CHLORINE CONTACT BASIN CAN BE SHORTENED PROPORTIONAL TO LOG INACTIVATION OF VIRUS REQD. FOR EXAMPLE, 2-LOG INACTIVATION REQUIRED L=16'.



LOWER FLOOR PLAN

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

0' 2' 4'

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

POWERHOUSE LOWER FLOOR PLAN

DESIGNED M. MOUGHAMIAN

DRAWN J. LAHMON

CHECKED D. JARRETT

ISSUED DATE 12/14/15

DRAWING

M102

SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_M102.dwg Plot date: Dec 15, 2015 01:48pm, CAD User: johnlahmon

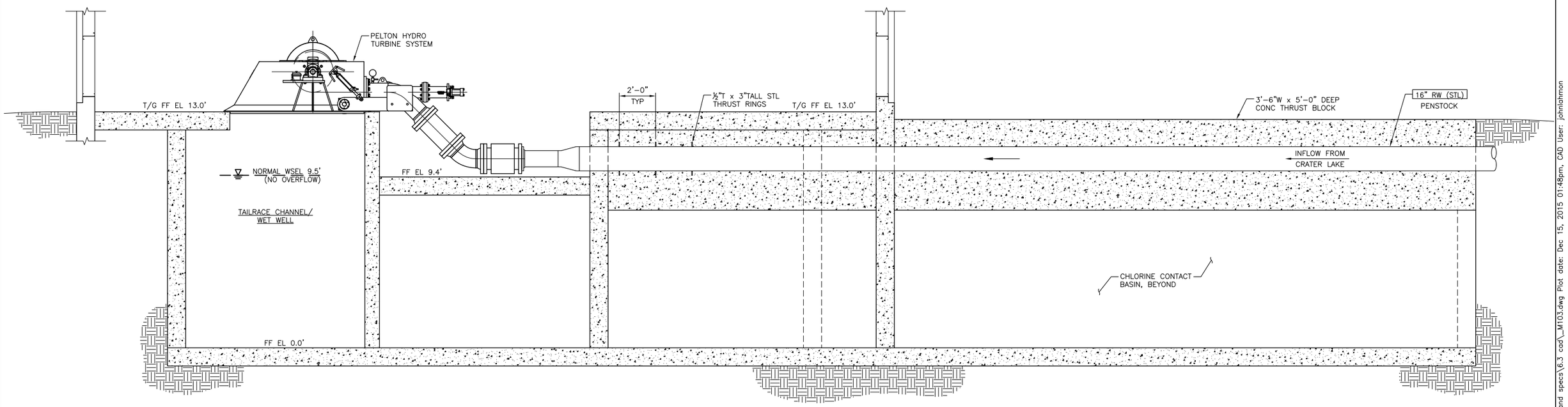
SHEET KEY NOTES:

A ISOLATION VALVE SERVES AS FULL OPEN/CLOSE SERVICE ONLY. CLOSE VALVE WHEN UV REACTOR IS OFF-LINE.

B THROTTLING VALVE (PLC TO MODULATE VALVE TO ACHIEVE DESIRED FLOW THRU UV REACTOR).

C VFD ON DUTY PUMP TO MAINTAIN CONSTANT WSEL IN CCB AT ALL TIMES.

D CCB SIZED FOR ~11.3 MIN HRT @ 5 CFS DIMENSIONS = 6'x6'Wx94'L.



SECTION A M102

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

0' 2' 4'

PRELIMINARY NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

POWERHOUSE BLDG SECTION 1

DESIGNED M. MOUGHAMIAN

DRAWN J. LAHMON

CHECKED D. JARRETT

ISSUED DATE 12/14/15

DRAWING

M103

SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_M103.dwg Plot date: Dec 15, 2015 01:48pm, CAD User: johnlahmon

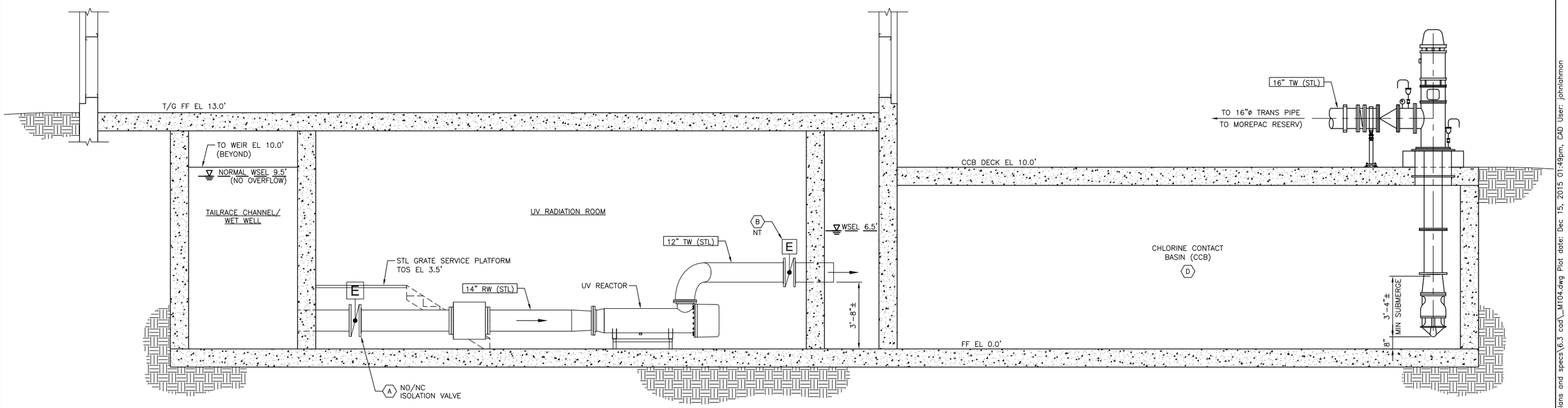
SHEET KEY NOTES:

A ISOLATION VALVE SERVES AS FULL OPEN/CLOSE SERVICE ONLY. CLOSE VALVE WHEN UV REACTOR IS OFF-LINE.

B THROTTLING VALVE (PLC TO MODULATE VALVE TO ACHIEVE DESIRED FLOW THRU UV REACTOR).

C VFD ON DUTY PUMP TO MAINTAIN CONSTANT WSEL IN CCB AT ALL TIMES.

D CCB SIZED FOR ~11.3 MIN HRT @ 5 CFS DIMENSIONS = 6'x6'Wx94'L.



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

B M102

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

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

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

POWERHOUSE BLDG SECTION 2

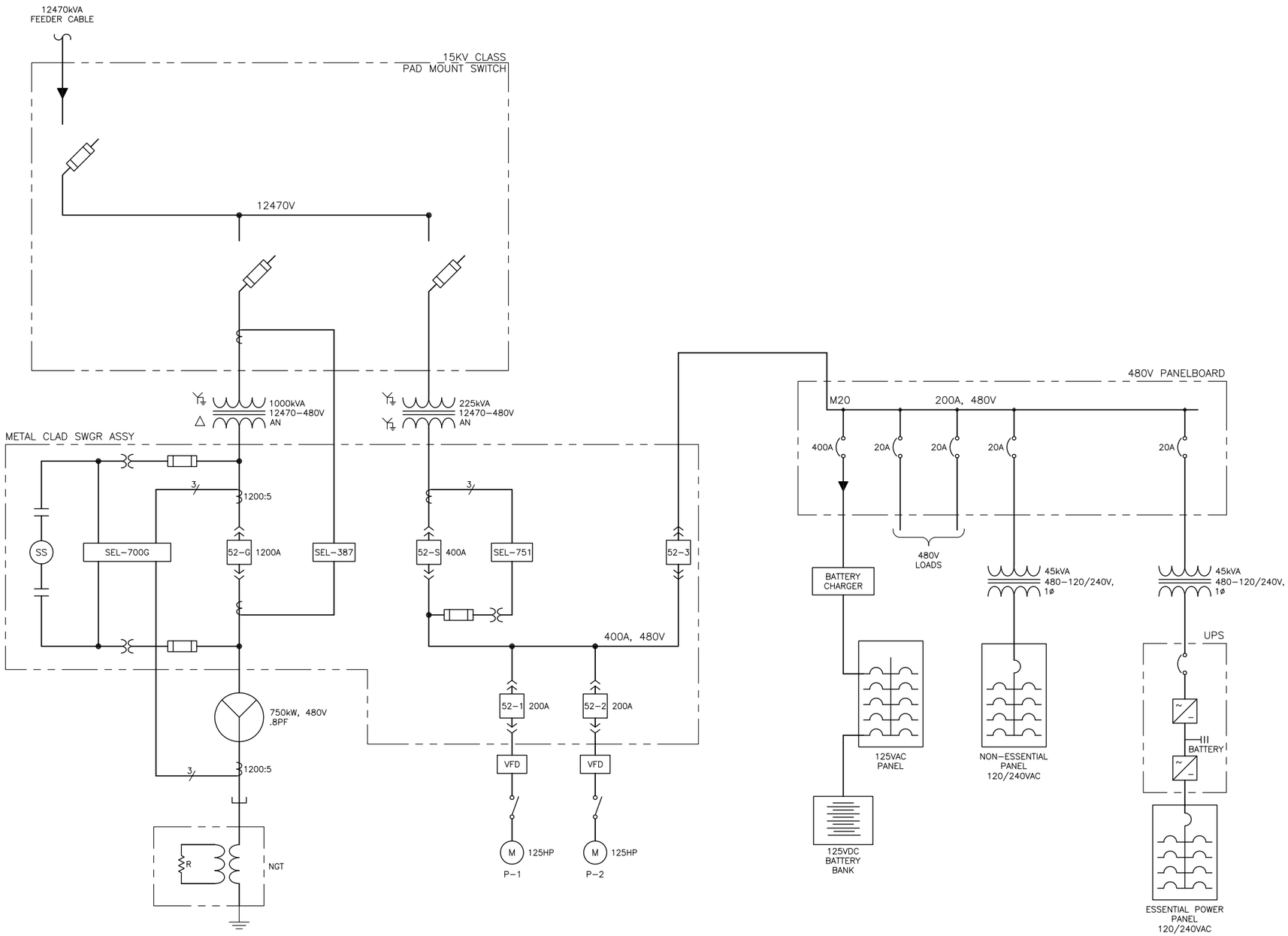
DESIGNED M. MOUGHAMIAN
DRAWN J. LAHMON
CHECKED D. JARRETT
ISSUED DATE 12/14/15

DRAWING
M104

SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_M104.dwg Plot date: Dec 15, 2015 01:49pm, CAD User: johnlahmon



SHEET NOTES:

1. PAD MOUNT SWITCH IS 15kV CLASS DISTRIBUTION PER CEC STANDARDS.
2. METAL CLAD SWITCHGEAR SHALL BE ONE ASSEMBLY WITH BKR 52G ISOLATED FROM STATION SERVICE BREAKERS.
3. STATION SERVICE 480 FEED AND SWGR BREAKERS SHALL USE SEL–751 RELAYS FOR CIRCUIT PROTECTION.
4. ESSENTIAL POWER REQUIRED FOR WATER TREATMENT PLANT OPERATION AND PLC CONTROLLER.
5. HYDROELECTRIC OPERATION AND CONTROL SHALL USE 125VDC POWER.

LEGEND

52G	GENERATOR BREAKER
52S	STATION SERVICE BREAKER
NGT	NEUTRAL GROUNDING TRANSFORMER
SS	SYNCH SCOPE
SEL–700G	GENERATOR RELAY
SEL–751	FEEDER/STATION SERVICE RELAY
SEL–387	DIFFERENTIAL RELAY
VFD	VARIABLE FREQUENCY DRIVE

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION
A	12/14/15	KT	CONCEPTUAL DESIGN

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN JACOBS ASSOCIATES

CORDOVA ELECTRIC COOPERATIVE AND CITY OF CORDOVA

CRATER LAKE WATER AND POWER FEASIBILITY STUDY REPORT

ELECTRICAL ONE–LINE DIAGRAM

DESIGNED M. LAWSON
DRAWN J. LAHMON
CHECKED K. TILFORD
ISSUED DATE 12/14/15

DRAWING
E101

SCALE: AS NOTED

JOB NO: 000000

Path: P:\cordova electric cooperative\crater lake feasibility study\6.0 plans and specs\6.3 cad_E101.dwg Plot date: Dec 15, 2015 01:49pm, CAD User: johnlahmon

Appendix C

Canyon Hydro Budget Estimate – Turbine Generator

November 17, 2015

Kelly Tilford
McMillen Jacobs Associates
tilford@mcmjac.com
208-985-1522

Dear Mr. Tilford,

Thank you for the design flow update on the Cordova, AK project. Canyon Hydro specializes in manufacturing Pelton turbines and providing complete powerhouse equipment packages for the conditions at this site. We are pleased to offer our continued assistance as the project moves forward.

Canyon Hydro has been building high quality turbine systems in the USA for 39 years. From day one, we have remained committed to three guiding principles:

1. **Efficiency:** Efficiency has undergone continual refinement over the years, and we believe our turbines match or exceed the efficiency of any other turbine manufacturer. Our entire staff recognizes the critical nature of the hydraulic design resulting in the best possible performance.
2. **Durability:** We recognize that a turbine system must run continuously for years at a time. For this reason, we use only the highest quality alloys, bearings, and controls.
3. **Customer Support:** We are often told our customer support is the best in the business. We work closely with you throughout the process, and if an outage should occur, system recovery becomes our highest priority.

We understand this site offers a net head of 1450 feet and design flow rate of 8.0 cfs. For these conditions we recommend an equipment package based on a Canyon Hydro single nozzle horizontal Pelton turbine. Our equipment package includes: 12" ball type turbine inlet valve with gear operator, 12” 45 degree elbow, Canyon Hydro custom Pelton turbine with hydraulic actuation, 900kW-480VAC synchronous generator, hydraulic power unit, controls and switchgear for islanded system operation. Based on the site conditions above expected system output will be 825 kW.

Budget estimate for the equipment package described…….$460,000.00

Normal Terms	10% to begin final design
	30% to begin construction following final design approval
	25% mid-project due upon approval of runner material at Canyon Hydro
	25% payment upon notice of readiness to ship
	10% payment on successful start up or 120 days from notice of readiness, whichever is first
Normal Delivery	6 months following design approval and receipt of scheduled payments

The equipment package offered will be custom designed to meet the particular requirements of the Cordova site and project. As the project progresses and requirements are defined, we will be pleased to refine our estimate or offer a firm quotation. Budget estimates are offered for planning purposes only but are typically within 10% of an actual quotation for the same site conditions and scope of supply.

I look forward to discussing this project with you further and offer my assistance as questions arise or additional project information becomes available.

Sincerely,

Eric Melander

Canyon Hydro– the water power division of Canyon Industries, Inc. • 5500 Blue Heron Lane • P.O. Box 36 • Deming WA 98244
360.592-5552 • Fax: 360.592.2235 • email: turbines@canyonhydro.com • www.canyonhydro.com

Appendix D

Cost/Benefit Model Spreadsheets (electronic model file delivered to client)

CRATER LAKE HYDROELECTRIC PROJECT: ECONOMIC EVALUATION MODEL

General Information: This model estimates the benefits and costs to Cordova Electric Cooperative and the City of Cordova of ownership and operation of the proposed Carter Lake Hydroelectric Project. Various assumptions may be made to test the impact of variables upon the economics of the project. Assumption will carry through for each proposed project configuration: Base Project, Option 1 and Option 2. All available variables are input on the Assumptions and Results sheet.

Fixed Inputs:

Cost of the Project, 2015$
Term of Borrowing, 30 yrs. (CEC and COC are financed similarly)
Project Service Life, 50 yrs.
Annual Electric Generation
Real Diesel Fuel Prices (from AEA REF9 Application)
Annual O&M -- % of capital cost (from AEA REF9 Application)

Available User Inputs on Assumptions and Results Sheet:

	Cell	Color
Case Identfication:	E-5	
General Inflation	E-7	
Discount Rate	E-8	
Fish Tax Escalator	E-9	
CEC Project Share	E-10	
CEC Fuel Efficiency	E-11	
CEC Load Growth	E-12	
% Financed	E-14	
Interest Rate	E-15	

Summary Results: Scenario Results for each Project Configuration are provided as inputs are modified, on the Assumptions and Results Sheet

Outputs: Scenario Outputs are detailed on Sheets: Base Project, Option 1 and Option 2

CRATER LAKE HYDROELECTRIC PROJECT: PRELIMINARY ECONOMIC EVALUATION
Cordova Electric Cooperative, Inc. & City of Cordova Public Works (Water)

CASE NAME:	Modified AEA
Assumptions:	
General Inflation	0.0%
Discount Rate	3.0%
Fish Tax Escalator	0.0%
CEC Project Share	52%
CEC Fuel Efficiency, kWh/gal.	14.5
CEC Load Growth	0.0%
Both CEC & COC:	
% Financed	100.0%
Interest Rate	3.0%
Term of Note, Yrs. (fixed)	30

Crater Lake Preliminary Economic Feasibility - CEC and COC ($000)

Modified AEA

Crater Lake	CEC NPV Benefit $	CEC NPV Cost $	CEC B/C Ratio	COC NPV Benefit $	COC NPV Cost $	COC B/C Ratio
Base Project	15,353	11,315	**1.36**	8,629	10,445	**0.83**
Option 1	15,353	12,910	**1.19**	8,629	11,917	**0.72**
Option 2	15,353	8,837	**1.74**	8,629	8,158	**1.06**

CRATER LAKE HYDROELECTRIC PROJECT: PRELIMINARY ECONOMIC EVALUATION - Cordova Electric Cooperative, Inc. & City of Cordova Public Works (Water)

Case: Modified AEA **Results For:** Base Project

Load Growth	0.00%	Project Cost	$ 17,306,696	% Financed	100.00%
General Inflation	0.00%	Generation, kWh	2,008,696	Interest Rate	3.00%
Discount Rate	3.00%	CEC Share	52.00%	Term (years)	30.00
Diesel Generation		CEC cost	$ 8,999,482		
Fuel Cost	AEA est.	COC cost	$ 8,307,214		
Fuel Efficiency (kWh/gal)	14.50				
Fish Tax Escalator	0.00%	Annual O&M	$ 173,067 (per AEA)		

NPV Crater CEC Cost	$11,315,027	NPV Crater COC Cost	$10,444,641
Diesel Savings	$15,352,965	System Gains	$8,629,472
B/C	1.36	B/C	0.83

2016 Cost of Diesel $0.21 2018 Levelized cost of power: $0.27

Crater Lake On-line	Calendar Year	Fuel Cost ($/gal)	Inflated Fuel Cost ($/gal)	Energy Requirements, kWh AVERAGE Water (2010-2011) CEC Diesel	Crater Lake Energy	Net CEC Diesel	Crater Lake - CEC Cost Loan Principal	Loan Interest	O&M Share	CEC Annual Cost	Crater Lake - COC Cost Loan Principal	Loan Interest	O&M Share	COC Annual Cost	CEC Diesel Savings kWh Diesel Reduction	Gallons @ eff.	$	COC Water System Gains Reduced Eyak Expense	Added Processor Revenue	Added Fish Tax	Total
	2015																				
	2016	3.09	3.09	9,290,789		9,290,789									-	0	0				
	2017	3.25	3.25	9,290,789		9,290,789									-	0	0				
1	2018	3.26	3.26	9,290,789	2,008,696	7,282,093	189,162	269,984	89,995	549,142	174,611	249,216	83,072	506,900	2,008,696	138,531	452,068	26,000	15,016	66,876	107,892
2	2019	3.32	3.32	9,290,789	2,008,696	7,282,093	194,837	264,310	89,995	549,142	179,850	243,978	83,072	506,900	2,008,696	138,531	459,756	26,000	30,033	133,753	189,786
3	2020	3.37	3.37	9,290,789	2,008,696	7,282,093	200,682	258,464	89,995	549,142	185,245	238,583	83,072	506,900	2,008,696	138,531	467,485	26,000	45,049	200,630	271,679
4	2021	3.45	3.45	9,290,789	2,008,696	7,282,093	206,703	252,444	89,995	549,142	190,803	233,025	83,072	506,900	2,008,696	138,531	477,948	26,000	60,066	267,506	353,572
5	2022	3.53	3.53	9,290,789	2,008,696	7,282,093	212,904	246,243	89,995	549,142	196,527	227,301	83,072	506,900	2,008,696	138,531	489,164	26,000	60,066	267,506	353,572
6	2023	3.61	3.61	9,290,789	2,008,696	7,282,093	219,291	239,856	89,995	549,142	202,423	221,405	83,072	506,900	2,008,696	138,531	500,780	26,000	60,066	267,506	353,572
7	2024	3.70	3.70	9,290,789	2,008,696	7,282,093	225,870	233,277	89,995	549,142	208,495	215,333	83,072	506,900	2,008,696	138,531	512,643	26,000	60,066	267,506	353,572
8	2025	3.79	3.79	9,290,789	2,008,696	7,282,093	232,646	226,501	89,995	549,142	214,750	209,078	83,072	506,900	2,008,696	138,531	524,562	26,000	60,066	267,506	353,572
9	2026	3.88	3.88	9,290,789	2,008,696	7,282,093	239,625	219,522	89,995	549,142	221,193	202,635	83,072	506,900	2,008,696	138,531	537,259	26,000	60,066	267,506	353,572
10	2027	3.97	3.97	9,290,789	2,008,696	7,282,093	246,814	212,333	89,995	549,142	227,828	196,000	83,072	506,900	2,008,696	138,531	550,266	26,000	60,066	267,506	353,572
11	2028	4.07	4.07	9,290,789	2,008,696	7,282,093	254,219	204,928	89,995	549,142	234,663	189,165	83,072	506,900	2,008,696	138,531	563,593	26,000	60,066	267,506	353,572
12	2029	4.17	4.17	9,290,789	2,008,696	7,282,093	261,845	197,302	89,995	549,142	241,703	182,125	83,072	506,900	2,008,696	138,531	577,245	26,000	60,066	267,506	353,572
13	2030	4.27	4.27	9,290,789	2,008,696	7,282,093	269,700	189,446	89,995	549,142	248,954	174,874	83,072	506,900	2,008,696	138,531	591,233	26,000	60,066	267,506	353,572
14	2031	4.37	4.37	9,290,789	2,008,696	7,282,093	277,791	181,355	89,995	549,142	256,423	167,405	83,072	506,900	2,008,696	138,531	605,563	26,000	60,066	267,506	353,572
15	2032	4.48	4.48	9,290,789	2,008,696	7,282,093	286,125	173,022	89,995	549,142	264,116	159,712	83,072	506,900	2,008,696	138,531	620,245	26,000	60,066	267,506	353,572
16	2033	4.59	4.59	9,290,789	2,008,696	7,282,093	294,709	164,438	89,995	549,142	272,039	151,789	83,072	506,900	2,008,696	138,531	635,266	26,000	60,066	267,506	353,572
17	2034	4.69	4.69	9,290,789	2,008,696	7,282,093	303,550	155,597	89,995	549,142	280,200	143,628	83,072	506,900	2,008,696	138,531	650,032	26,000	60,066	267,506	353,572
18	2035	4.80	4.80	9,290,789	2,008,696	7,282,093	312,657	146,490	89,995	549,142	288,606	135,222	83,072	506,900	2,008,696	138,531	665,567	26,000	60,066	267,506	353,572
19	2036	4.92	4.92	9,290,789	2,008,696	7,282,093	322,036	137,111	89,995	549,142	297,264	126,564	83,072	506,900	2,008,696	138,531	681,530	26,000	60,066	267,506	353,572
20	2037	5.03	5.03	9,290,789	2,008,696	7,282,093	331,697	127,449	89,995	549,142	306,182	117,646	83,072	506,900	2,008,696	138,531	697,189	26,000	60,066	267,506	353,572
21	2038	5.15	5.15	9,290,789	2,008,696	7,282,093	341,648	117,498	89,995	549,142	315,368	108,460	83,072	506,900	2,008,696	138,531	714,022	26,000	60,066	267,506	353,572
22	2039	5.29	5.29	9,290,789	2,008,696	7,282,093	351,898	107,249	89,995	549,142	324,829	98,999	83,072	506,900	2,008,696	138,531	732,180	26,000	60,066	267,506	353,572
23	2040	5.41	5.41	9,290,789	2,008,696	7,282,093	362,455	96,692	89,995	549,142	334,574	89,254	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
24	2041	5.41	5.41	9,290,789	2,008,696	7,282,093	373,328	85,818	89,995	549,142	344,611	79,217	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
25	2042	5.41	5.41	9,290,789	2,008,696	7,282,093	384,528	74,619	89,995	549,142	354,949	68,879	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
26	2043	5.41	5.41	9,290,789	2,008,696	7,282,093	396,064	63,083	89,995	549,142	365,598	58,230	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
27	2044	5.41	5.41	9,290,789	2,008,696	7,282,093	407,946	51,201	89,995	549,142	376,566	47,262	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
28	2045	5.41	5.41	9,290,789	2,008,696	7,282,093	420,184	38,962	89,995	549,142	387,863	35,965	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
29	2046	5.41	5.41	9,290,789	2,008,696	7,282,093	432,790	26,357	89,995	549,142	399,498	24,329	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
30	2047	5.41	5.41	9,290,789	2,008,696	7,282,093	445,774	13,373	89,995	549,142	411,483	12,345	83,072	506,900	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
31	2048	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
32	2049	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
33	2050	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
34	2051	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
35	2052	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
36	2053	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
37	2054	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
38	2055	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
39	2056	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
40	2057	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
41	2058	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
42	2059	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
43	2060	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
44	2061	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
45	2062	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
46	2063	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
47	2064	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
48	2065	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
49	2066	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
50	2067	5.41	5.41	9,290,789	2,008,696	7,282,093			89,995	89,995			83,072	83,072	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572

CRATER LAKE HYDROELECTRIC PROJECT: PRELIMINARY ECONOMIC EVALUATION - Cordova Electric Cooperative, Inc. & City of Cordova Public Works (Water)

Case: Modified AEA **Results For:** Option 1

Load Growth	0.00%	Project Cost	$ 19,746,881	% Financed	100.00%
General Inflation	0.00%	Generation, kWh	2,008,696	Interest Rate	3.00%
Discount Rate	3.00%	CEC Share	52.00%	Term (years)	30.00
Diesel Generation		CEC cost	$ 10,268,378		
Fuel Cost	AEA est.	COC cost	$ 9,478,503		
Fuel Efficiency (kWh/gal)	14.50				
Fish Tax Escalator	0.00%	Annual O&M	$ 197,469 (per AEA)		

NPV Crater CEC Cost	$12,910,408	NPV Crater COC Cost	$11,917,299
Diesel Savings	$15,352,965	System Gains	$8,629,472
B/C	1.19	B/C	0.72

2016 Cost of Diesel $0.21 2018 Levelized cost of power: $0.31

Crater Lake On-line	Calendar Year	Fuel Cost ($/gal)	Inflated Fuel Cost ($/gal)	Energy Requirements, kWh AVERAGE Water (2010-2011)			Crater Lake - CEC Cost				Crater Lake - COC Cost				CEC Diesel Savings			COC Water System Gains			
				CEC Diesel	Crater Lake Energy	Net CEC Diesel	Loan Principal	Loan Interest	O&M Share	CEC Annual Cost	Loan Principal	Loan Interest	O&M Share	COC Annual Cost	kWh Diesel Reduction	Gallons @ eff.	$	Reduced Eyak Expense	Added Processor Revenue	Added Fish Tax	Total
	2015																				
	2016	3.09	3.09	9,290,789		9,290,789									-	0	0				
	2017	3.25	3.25	9,290,789		9,290,789									-	0	0				
1	2018	3.26	3.26	9,290,789	2,008,696	7,282,093	215,834	308,051	102,684	626,569	199,231	284,355	94,785	578,371	2,008,696	138,531	452,068	26,000	15,016	66,876	107,892
2	2019	3.32	3.32	9,290,789	2,008,696	7,282,093	222,309	301,576	102,684	626,569	205,208	278,378	94,785	578,371	2,008,696	138,531	459,756	26,000	30,033	133,753	189,786
3	2020	3.37	3.37	9,290,789	2,008,696	7,282,093	228,978	294,907	102,684	626,569	211,364	272,222	94,785	578,371	2,008,696	138,531	467,485	26,000	45,049	200,630	271,679
4	2021	3.45	3.45	9,290,789	2,008,696	7,282,093	235,847	288,038	102,684	626,569	217,705	265,881	94,785	578,371	2,008,696	138,531	477,948	26,000	60,066	267,506	353,572
5	2022	3.53	3.53	9,290,789	2,008,696	7,282,093	242,923	280,962	102,684	626,569	224,236	259,350	94,785	578,371	2,008,696	138,531	489,164	26,000	60,066	267,506	353,572
6	2023	3.61	3.61	9,290,789	2,008,696	7,282,093	250,210	273,675	102,684	626,569	230,963	252,623	94,785	578,371	2,008,696	138,531	500,780	26,000	60,066	267,506	353,572
7	2024	3.70	3.70	9,290,789	2,008,696	7,282,093	257,717	266,168	102,684	626,569	237,892	245,694	94,785	578,371	2,008,696	138,531	512,643	26,000	60,066	267,506	353,572
8	2025	3.79	3.79	9,290,789	2,008,696	7,282,093	265,448	258,437	102,684	626,569	245,029	238,557	94,785	578,371	2,008,696	138,531	524,562	26,000	60,066	267,506	353,572
9	2026	3.88	3.88	9,290,789	2,008,696	7,282,093	273,412	250,473	102,684	626,569	252,380	231,206	94,785	578,371	2,008,696	138,531	537,259	26,000	60,066	267,506	353,572
10	2027	3.97	3.97	9,290,789	2,008,696	7,282,093	281,614	242,271	102,684	626,569	259,951	223,635	94,785	578,371	2,008,696	138,531	550,266	26,000	60,066	267,506	353,572
11	2028	4.07	4.07	9,290,789	2,008,696	7,282,093	290,062	233,823	102,684	626,569	267,750	215,836	94,785	578,371	2,008,696	138,531	563,593	26,000	60,066	267,506	353,572
12	2029	4.17	4.17	9,290,789	2,008,696	7,282,093	298,764	225,121	102,684	626,569	275,782	207,804	94,785	578,371	2,008,696	138,531	577,245	26,000	60,066	267,506	353,572
13	2030	4.27	4.27	9,290,789	2,008,696	7,282,093	307,727	216,158	102,684	626,569	284,056	199,530	94,785	578,371	2,008,696	138,531	591,233	26,000	60,066	267,506	353,572
14	2031	4.37	4.37	9,290,789	2,008,696	7,282,093	316,959	206,926	102,684	626,569	292,578	191,009	94,785	578,371	2,008,696	138,531	605,563	26,000	60,066	267,506	353,572
15	2032	4.48	4.48	9,290,789	2,008,696	7,282,093	326,468	197,417	102,684	626,569	301,355	182,231	94,785	578,371	2,008,696	138,531	620,245	26,000	60,066	267,506	353,572
16	2033	4.59	4.59	9,290,789	2,008,696	7,282,093	336,262	187,623	102,684	626,569	310,396	173,191	94,785	578,371	2,008,696	138,531	635,266	26,000	60,066	267,506	353,572
17	2034	4.69	4.69	9,290,789	2,008,696	7,282,093	346,350	177,535	102,684	626,569	319,707	163,879	94,785	578,371	2,008,696	138,531	650,032	26,000	60,066	267,506	353,572
18	2035	4.80	4.80	9,290,789	2,008,696	7,282,093	356,740	167,145	102,684	626,569	329,299	154,288	94,785	578,371	2,008,696	138,531	665,567	26,000	60,066	267,506	353,572
19	2036	4.92	4.92	9,290,789	2,008,696	7,282,093	367,442	156,443	102,684	626,569	339,178	144,409	94,785	578,371	2,008,696	138,531	681,530	26,000	60,066	267,506	353,572
20	2037	5.03	5.03	9,290,789	2,008,696	7,282,093	378,466	145,419	102,684	626,569	349,353	134,233	94,785	578,371	2,008,696	138,531	697,189	26,000	60,066	267,506	353,572
21	2038	5.15	5.15	9,290,789	2,008,696	7,282,093	389,820	134,065	102,684	626,569	359,834	123,753	94,785	578,371	2,008,696	138,531	714,022	26,000	60,066	267,506	353,572
22	2039	5.29	5.29	9,290,789	2,008,696	7,282,093	401,514	122,371	102,684	626,569	370,629	112,958	94,785	578,371	2,008,696	138,531	732,180	26,000	60,066	267,506	353,572
23	2040	5.41	5.41	9,290,789	2,008,696	7,282,093	413,560	110,325	102,684	626,569	381,747	101,839	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
24	2041	5.41	5.41	9,290,789	2,008,696	7,282,093	425,966	97,919	102,684	626,569	393,200	90,386	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
25	2042	5.41	5.41	9,290,789	2,008,696	7,282,093	438,745	85,140	102,684	626,569	404,996	78,590	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
26	2043	5.41	5.41	9,290,789	2,008,696	7,282,093	451,908	71,977	102,684	626,569	417,146	66,440	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
27	2044	5.41	5.41	9,290,789	2,008,696	7,282,093	465,465	58,420	102,684	626,569	429,660	53,926	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
28	2045	5.41	5.41	9,290,789	2,008,696	7,282,093	479,429	44,456	102,684	626,569	442,550	41,036	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
29	2046	5.41	5.41	9,290,789	2,008,696	7,282,093	493,812	30,073	102,684	626,569	455,826	27,760	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
30	2047	5.41	5.41	9,290,789	2,008,696	7,282,093	508,626	15,259	102,684	626,569	469,501	14,085	94,785	578,371	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
31	2048	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
32	2049	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
33	2050	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
34	2051	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
35	2052	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
36	2053	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
37	2054	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
38	2055	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
39	2056	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
40	2057	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
41	2058	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
42	2059	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
43	2060	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
44	2061	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
45	2062	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
46	2063	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
47	2064	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
48	2065	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
49	2066	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
50	2067	5.41	5.41	9,290,789	2,008,696	7,282,093			102,684	102,684			94,785	94,785	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572

CRATER LAKE HYDROELECTRIC PROJECT: PRELIMINARY ECONOMIC EVALUATION - Cordova Electric Cooperative, Inc. & City of Cordova Public Works (Water)

Case: Modified AEA **Results For:** Option 2

Load Growth	0.00%	Project Cost	$ 13,516,934	% Financed	100.00%
General Inflation	0.00%	Generation, kWh	2,008,696	Interest Rate	3.00%
Discount Rate	3.00%	CEC Share	52.00%	Term (years)	30.00
Diesel Generation		CEC cost	$ 7,028,806		
Fuel Cost	AEA est.	COC cost	$ 6,488,128		
Fuel Efficiency (kWh/gal)	14.50				
Fish Tax Escalator	0.00%	Annual O&M	$ 135,169 (per AEA)		

NPV Crater CEC Cost	$8,837,301	NPV Crater COC Cost	$8,157,508
Diesel Savings	$15,352,965	System Gains	$8,629,472
B/C	1.74	B/C	1.06

2016 Cost of Diesel $0.21 2018 Levelized cost of power: $0.21

Crater Lake On-line	Calendar Year	Fuel Cost ($/gal)	Inflated Fuel Cost ($/gal)	Energy Requirements, kWh AVERAGE Water (2010-2011)			Crater Lake - CEC Cost				Crater Lake - COC Cost				CEC Diesel Savings			COC Water System Gains			
				CEC Diesel	Crater Lake Energy	Net CEC Diesel	Principal	Loan Interest	O&M Share	CEC Annual Cost	Principal	Loan Interest	O&M Share	COC Annual Cost	kWh Diesel Reduction	Gallons @ eff.	$	Reduced Eyak Expense	Added Processor Revenue	Added Fish Tax	Total
	2015																				
	2016	3.09	3.09	9,290,789		9,290,789									-	0	0				
	2017	3.25	3.25	9,290,789		9,290,789									-	0	0				
1	2018	3.26	3.26	9,290,789	2,008,696	7,282,093	147,740	210,864	70,288	428,893	136,376	194,644	64,881	395,901	2,008,696	138,531	452,068	26,000	15,016	66,876	107,892
2	2019	3.32	3.32	9,290,789	2,008,696	7,282,093	152,172	206,432	70,288	428,893	140,467	190,553	64,881	395,901	2,008,696	138,531	459,756	26,000	30,033	133,753	189,786
3	2020	3.37	3.37	9,290,789	2,008,696	7,282,093	156,738	201,867	70,288	428,893	144,681	186,339	64,881	395,901	2,008,696	138,531	467,485	26,000	45,049	200,630	271,679
4	2021	3.45	3.45	9,290,789	2,008,696	7,282,093	161,440	197,165	70,288	428,893	149,021	181,998	64,881	395,901	2,008,696	138,531	477,948	26,000	60,066	267,506	353,572
5	2022	3.53	3.53	9,290,789	2,008,696	7,282,093	166,283	192,321	70,288	428,893	153,492	177,528	64,881	395,901	2,008,696	138,531	489,164	26,000	60,066	267,506	353,572
6	2023	3.61	3.61	9,290,789	2,008,696	7,282,093	171,271	187,333	70,288	428,893	158,097	172,923	64,881	395,901	2,008,696	138,531	500,780	26,000	60,066	267,506	353,572
7	2024	3.70	3.70	9,290,789	2,008,696	7,282,093	176,410	182,195	70,288	428,893	162,840	168,180	64,881	395,901	2,008,696	138,531	512,643	26,000	60,066	267,506	353,572
8	2025	3.79	3.79	9,290,789	2,008,696	7,282,093	181,702	176,903	70,288	428,893	167,725	163,295	64,881	395,901	2,008,696	138,531	524,562	26,000	60,066	267,506	353,572
9	2026	3.88	3.88	9,290,789	2,008,696	7,282,093	187,153	171,451	70,288	428,893	172,757	158,263	64,881	395,901	2,008,696	138,531	537,259	26,000	60,066	267,506	353,572
10	2027	3.97	3.97	9,290,789	2,008,696	7,282,093	192,768	165,837	70,288	428,893	177,939	153,080	64,881	395,901	2,008,696	138,531	550,266	26,000	60,066	267,506	353,572
11	2028	4.07	4.07	9,290,789	2,008,696	7,282,093	198,551	160,054	70,288	428,893	183,277	147,742	64,881	395,901	2,008,696	138,531	563,593	26,000	60,066	267,506	353,572
12	2029	4.17	4.17	9,290,789	2,008,696	7,282,093	204,507	154,097	70,288	428,893	188,776	142,244	64,881	395,901	2,008,696	138,531	577,245	26,000	60,066	267,506	353,572
13	2030	4.27	4.27	9,290,789	2,008,696	7,282,093	210,642	147,962	70,288	428,893	194,439	136,580	64,881	395,901	2,008,696	138,531	591,233	26,000	60,066	267,506	353,572
14	2031	4.37	4.37	9,290,789	2,008,696	7,282,093	216,962	141,643	70,288	428,893	200,272	130,747	64,881	395,901	2,008,696	138,531	605,563	26,000	60,066	267,506	353,572
15	2032	4.48	4.48	9,290,789	2,008,696	7,282,093	223,470	135,134	70,288	428,893	206,280	124,739	64,881	395,901	2,008,696	138,531	620,245	26,000	60,066	267,506	353,572
16	2033	4.59	4.59	9,290,789	2,008,696	7,282,093	230,175	128,430	70,288	428,893	212,469	118,551	64,881	395,901	2,008,696	138,531	635,266	26,000	60,066	267,506	353,572
17	2034	4.69	4.69	9,290,789	2,008,696	7,282,093	237,080	121,525	70,288	428,893	218,843	112,177	64,881	395,901	2,008,696	138,531	650,032	26,000	60,066	267,506	353,572
18	2035	4.80	4.80	9,290,789	2,008,696	7,282,093	244,192	114,412	70,288	428,893	225,408	105,611	64,881	395,901	2,008,696	138,531	665,567	26,000	60,066	267,506	353,572
19	2036	4.92	4.92	9,290,789	2,008,696	7,282,093	251,518	107,087	70,288	428,893	232,170	98,849	64,881	395,901	2,008,696	138,531	681,530	26,000	60,066	267,506	353,572
20	2037	5.03	5.03	9,290,789	2,008,696	7,282,093	259,063	99,541	70,288	428,893	239,136	91,884	64,881	395,901	2,008,696	138,531	697,189	26,000	60,066	267,506	353,572
21	2038	5.15	5.15	9,290,789	2,008,696	7,282,093	266,835	91,769	70,288	428,893	246,310	84,710	64,881	395,901	2,008,696	138,531	714,022	26,000	60,066	267,506	353,572
22	2039	5.29	5.29	9,290,789	2,008,696	7,282,093	274,840	83,764	70,288	428,893	253,699	77,321	64,881	395,901	2,008,696	138,531	732,180	26,000	60,066	267,506	353,572
23	2040	5.41	5.41	9,290,789	2,008,696	7,282,093	283,086	75,519	70,288	428,893	261,310	69,710	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
24	2041	5.41	5.41	9,290,789	2,008,696	7,282,093	291,578	67,026	70,288	428,893	269,149	61,870	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
25	2042	5.41	5.41	9,290,789	2,008,696	7,282,093	300,326	58,279	70,288	428,893	277,224	53,796	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
26	2043	5.41	5.41	9,290,789	2,008,696	7,282,093	309,335	49,269	70,288	428,893	285,540	45,479	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
27	2044	5.41	5.41	9,290,789	2,008,696	7,282,093	318,615	39,989	70,288	428,893	294,107	36,913	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
28	2045	5.41	5.41	9,290,789	2,008,696	7,282,093	328,174	30,431	70,288	428,893	302,930	28,090	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
29	2046	5.41	5.41	9,290,789	2,008,696	7,282,093	338,019	20,585	70,288	428,893	312,018	19,002	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
30	2047	5.41	5.41	9,290,789	2,008,696	7,282,093	348,160	10,445	70,288	428,893	321,378	9,641	64,881	395,901	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
31	2048	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
32	2049	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
33	2050	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
34	2051	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
35	2052	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
36	2053	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
37	2054	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
38	2055	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
39	2056	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
40	2057	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
41	2058	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
42	2059	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
43	2060	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
44	2061	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
45	2062	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
46	2063	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
47	2064	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
48	2065	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
49	2066	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572
50	2067	5.41	5.41	9,290,789	2,008,696	7,282,093			70,288	70,288			64,881	64,881	2,008,696	138,531	749,111	26,000	60,066	267,506	353,572