Chikuminuk Lake Hydroelectric Project

Interim Feasibility Report
Volume I – Technical Considerations
Volume II – Existing Environmental Conditions

Prepared for:

NUVISTA LIGHT & ELECTRIC COOPERATIVE, INC.

HATCH

April 2014

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Interim Feasibility Report

Foreword

Nuvista Light and Electric Cooperative, Inc. is a non-profit electric cooperative founded and led by non-profit, tribal, and Alaska Native stakeholders in the Yukon-Kuskokwim Delta region. Nuvista's stated mission is to improve the energy economics in rural Alaska by creating energy generation and transmission infrastructure to serve, connect and enable the region to attain affordable, long-term energy sustainability and self-sufficiency.

The motivation to explore new energy solutions is clear. The Yukon-Kuskokwim region, like many other rural regions of Alaska, suffers from staggering energy costs. High and rising electric, fuel and heating costs undermine the foundations of life in rural communities. Low-income families are hardest hit by the high cost of diesel-generated energy, with some households paying more than 50 percent of their monthly income for heat and electricity.[1] The State of Alaska attempts to relieve the exorbitant prices that rural families face through continued support for the power cost equalization (PCE) program; but even with the PCE program, residents of rural Alaska pay more than twice their urban neighbors for electricity. Further, PCE subsidies do not extend to businesses; resulting in electric bills that are four to five times those of urban Alaska.

Nuvista recognizes that the volatility of the petro-based fuel system punishes business and family finances, ultimately threatening the future of cultures and the solvency of communities in our region. We were created specifically to identify the most pressing energy problems and develop projects that offer the best possible solutions. Given this mission, and the large-scale energy problems, we sought to explore a promising, large-scale solution.

Beginning in 2010, Nuvista worked with local communities to investigate possible solutions to the region's energy challenges. From the many alternatives considered, hydroelectric generation at Chikuminuk Lake, which sits at the upper reaches of the Nuyakuk-Nushagak drainage in northern Wood Tikchik State Park, was selected as a promising energy solution by representatives of YK regional organizations over a series of meetings in fall of 2011. Chikuminuk has several advantages over other potential regional sites; records indicate it receives limited recreation or subsistence activity, preliminary studies show it does not support a salmon run, and it can generate year-round water flows capable of meeting the electricity demand among communities throughout the Yukon-Kuskokwim and Bristol Bay regions.

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[1] Commonwealth North, Energy for a Sustainable Alaska – The Rural Conundrum presentation of ISER February 2010 Study Data.

The Chikuminuk Lake Hydroelectric Project presents an opportunity to provide affordable electricity from a stable and sustainable source, as well as a source that does not contribute to climate change already threatening the future of our region's coastal villages.

In 2011, under the continued guidance of the Board of Directors and through the support of funding from the Alaska Legislature, Nuvista began studying the feasibility of hydroelectric generation at Chikuminuk Lake. Following the Federal Energy Regulatory Commission's (FERC) guidelines, Nuvista began preliminary studies of the site to develop baseline understanding of the area, assess potential capacity, and evaluate potential impacts. Initial studies focused on:

- Geology of the lake basin
- Water use and quality, water flow
- Aquatic Resources
- Terrestrial Resources
- Cultural and Subsistence Resources
- Recreation and Visual Resources
- Socioeconomic Resources
- Electric generation capability of the site
- Potential costs to construct and operate

Results of the studies, to date, are presented in this interim feasibility assessment. Independent of any insights about the hydroelectric project, this research produced the first ever thorough investigation of the environment and human uses of this remote landscape. The information gathered provides valuable, but preliminary, data on the Chikuminuk project area and the project's potential impacts. Early results are encouraging, suggesting that adverse environmental impacts would be modest, and that the project is technically feasible and can provide long-term affordable stable, renewable, clean power. However, due to limited access while conducting field work and certain land use restrictions, we do not yet believe we have compiled enough information to recommend a decision on the project to Nuvista leadership, stakeholders, and the Alaska Legislature.

The information Nuvista has been able to gather to this point definitely shows the Chikuminuk Lake Hydroelectric Project has merit today, and may someday become essential. Particularly intriguing is the potential for per kilowatt hour costs following construction, shown on Pages 24-25, alongside the diesel price projections.

We understand the challenges before the state legislature concerning capital funding for any project, small or large-scale. We also understand the concerns voiced by some regional residents that this project could disrupt the watersheds that support subsistence and our way of life. We are residents of the region, and would not support a project that would jeopardize those resources. Further, Nuvista's Board understands that there are unanswered environmental and economic questions, as well as political issues, that may prevent this particular hydroelectric project from being a practical solution to Western Alaska's energy problems at this time. On the other hand, there may be a point, in the not too distant future, at which hydroelectric generation at Chikuminuk Lake will be an essential element of the region's energy solutions. Accordingly, we remain proud of the work we have conducted to analyze the project and the conditions at the site as a base-line for any future review of the hydroelectric potential of Chikuminuk Lake.

The path to regional energy solutions is not clear and no initiative is perfect, but we must position ourselves to begin pursuing opportunities available to our communities. Nuvista is poised to consider any option "on the table" and hydroelectric generation at Chikuminuk Lake was just one such option. The bottom line is that new energy solutions are needed in Western Alaska, solutions founded on thorough investigation, working with the people who are most affected by these decisions. Nuvista continues to work to improve the energy economics for the people of Western Alaska.

Ultimately, we see access to affordable energy as being a component of self-determination for our people and self-sufficiency for our businesses and families. Nuvista's role is to speak up for, and work on behalf of, the people we are trying to help. We will have succeeded when we have attained affordable, sustainable energy choices for every community in our region.

We submit the following report as a contribution to the science and understanding of the Chikuminuk area and hope that it fosters greater understanding of this magnificent resource.

Tiffany Zulkosky
Executive Director
Nuvista Light & Electric Cooperative, Inc.

Chikuminuk Lake Hydroelectric Project

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HATCH™

April 2014

Prepared for:

Nuvista

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Nuvista Electric Cooperative
Chikuminuk Lake Hydroelectric Project

Interim Feasibility Report

Vol. 1 Technical Considerations

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1. Introduction

The cost of electricity in western Alaska is high, due to most of the electricity being generated by expensive diesel fuel. Previous studies have identified Chikuminuk Lake as a potential hydropower site, which would provide the Dillingham and Bethel region with less expensive renewable energy and energy storage. In this study, two sites on the Allen River at the outlet of the lake were reviewed and one ultimately selected to be most feasible based on lowest cost and least visual impact.

This **Volume 1** of the Interim Feasibility Report (Report) presents the results of the engineering investigations by Hatch and its subconsultants. It includes presentation of the site selection analysis, project arrangement description, hydrology, geology, reservoir operations, opinion of probable cost, and economic analysis. **Volume 2** of the Report presents the existing environmental considerations and a general geologic overview.

The purpose of this interim report is to provide Nuvista Electric Cooperative (Nuvista) with the information necessary to assess the viability of this project and to identify any additional information or studies required to complete a final feasibility report.

1.1 Project Access

Appendix B includes a technical analysis of construction access (R&M, 2013) to the Project, including cost estimates and the following Project access alternatives:

- An overland road from Dillingham
- A winter (ice) road from Dillingham
- Barge access to Dillingham combined with an overland road or winter road from Dillingham.
- An airstrip for aircraft access only.

The analysis concludes that a Lockheed Hercules C-130 cargo plane is the only reliable means of access for construction, based on a lack of a connection with a navigable waterway or established overland route (permanent or winter). Therefore, the project will require an approximately 5,000 feet long runway during construction that will allow landings and takeoffs by the Hercules.
After construction is complete, the runway would be minimally maintained to allow smaller aircraft to provide the primary means of access for maintenance and permanent personnel. In case of large equipment delivery needs beyond the capacity of a helicopter, the runway could be restored to temporarily allow a Hercules to land and take off.

The Hercules has the following approximate payload and cargo size limitations (Lynden Air Cargo), which was used to estimate the number of flights required for construction of the Project:

- Max payload = 48,000 lb
- Max cargo height = 9 ft
- Max cargo width = 10 ft
- Max cargo length = 55 ft

1.2 Project Capacity

The selected project capacity of 22 MW was determined by adding up the expected average annual load demand of potential communities to be served by the project in the Calista and Bristol Bay regions (76.4 GWh) and then applying an average peak load factor. A review of available statistics from the local utilities indicated that a annual average peak load factor of approximately 0.4 would be appropriate for the Project.

1.3 Turbine Selection

Based on a rated head of (95 ft) and total plant capacity of 22 MW, which results in a rated discharge for the powerhouse of approximately 3,000 cfs, either Francis units or Kaplan units may be used. Four vertical Francis units were ultimately selected based on: expectation of maintenance costs, weight considerations for shipping, and powerhouse footprint requirements.

The rotor would be shipped with its poles and shaft separate, but the stator would be shipped in one piece. The estimated stator weight for one unit is 46,800 lb (23.4 tons), which is just within the capacity of the C-130 cargo plane.

Table 1.1 summarizes the turbine parameters and associated values for the selected vertical Francis units.

Table 1.1 Selected Turbine Parameters (estimated)

Parameter	Value
Type of turbine	Vertical Francis
Total plant flow (cfs)	3000
Number of units	4
Flow per unit (cfs)	750
Rated head (ft)	95
Full load turbine efficiency (%)	91
Turbine power (MW)	5.5
Runner diameter (ft)	6.0
Power factor	0.9
Gen output (MVA)	5.9
Gen rotor weight (tons)	31.2
Stator weight (tons)	23.4

1.4 Project Alternative Selection

A total of four project arrangements were qualitatively reviewed on a cost basis to facilitate selection of a preferred project arrangement: an Upstream and a Downstream dam site with either a roller compacted concrete (RCC) dam or a concrete faced rockfill dam (CFRD). The Upstream and Downstream dam sites are located approximately 1,500 feet and 4,500 feet downstream from the lake outlet, respectively.

Appendix C includes the technical memorandum that presents the analysis in more detail, including figures of the four alternatives. Only the major features (dam, spillway, and tunnel) of the Project costs were considered in the analysis, assuming that the powerhouse costs, and other costs, would be small or similar for all alternatives. **Table 1.2** summarizes the results from the technical memorandum.

Based on its lowest anticipated construction costs, the Lower site with an RCC dam was selected as the preferred project arrangement, for which the design and construction cost estimate would be further refined and developed.

Table 1.2 Summary of Qualitative Costs Comparison of Project Arrangement Alternatives ($',000)

Feature	Upper CFR Dam	Upper RCC Dam	Lower CFR Dam	Lower RCC Dam
Dam	$9,700	$17,500	$16,100	$24,100
Spillway	$19,300	$0	$21,400	$0
Diversion Tunnel	$5,200	$5,200	$5,900	$2,300
Power Tunnel	$26,500	$25,500	$12,700	$9,000
TOTAL	$60,700	$48,200	$56,300	$35,400

1.5 Preferred Project Arrangement

Figures 1 through 12 located herein **Volume I** at page 29 present the preferred project arrangement which is described below. **Table 1.3** summarizes selected design parameters and values.

Table 1.3 Selected Design Parameters and Values

Parameter	Value
Powerhouse	
Type	Above-ground
Plant rated capacity	22 MW
Normal tailwater level	544 ft
Rated head	95 ft
Plant hydraulic capacity	3,100 cfs
Powerhouse size	160 x 60
Switchyard size	100x75 ft
Synchronous Bypass	None
No. of turbine units	4
Turbine type	Vertical Francis
Rated unit discharge	775 cfs
Reservoir and Spillway	
Inflow Design Flood (IDF)	PMF
Spillway Crest EL/Normal max reservoir level	660 ft
Normal min reservoir level	643 ft
Spillway length	100 ft
IDF peak outflow	17,000 cfs
IDF peak head on spillway	12.6 ft
Reservoir surface area @ EL 660	31,300 ac
Reservoir storage volume @ EL 660	1,630,000 ac-ft
Lake Chikuminuk Characteristics	
Existing Lake Level	613 ft
Surface Area at EL 613	~24,000 ac
Volume at EL 613	
Hydrology	
10-yr peak outflow	9,900 cfs
25-yr peak outflow	10,000 cfs
100-yr peak inflow	23,600 cfs
PMF inflow	110,000 cfs
Access	
Design aircraft	Lockheed Hercules C-130
Design aircraft max payload capacity	48,000 lbs
Design aircraft max cargo dimensions	width = 10 ft; height = 9 ft; length = 55 ft
Landing strip	Length = 5,000 ft, Width = 125 ft
Helipad	Yes

Parameter	Value
Airport access road width	20 ft
Local access road width	15 ft
Coffer Dam	
Service Life, t	1 yr
Design Event Return Period, T	5-yr
Probability (p) of flow exceeding design event (T) during service life (t)	20 %
Dam	
Type	RCC
IDF Flood Reservoir EL	672.4
Freeboard above IDF Flood Elev.	2 ft
Top of Dam EL	674.4
Top of Dam Length	TBD
Diversion/Power Tunnel	
Type	Concrete-lined horseshoe tunnel
Length	900 ft
Design Flow	Diversion: 14,000 cfs, Power: 3,000 cfs
Horseshoe tunnel size	B = 13.0 ft, H = 13.0 ft
Fish Passage Facilities	
Upstream and downstream	No
Minimum Flows at Dam	
Minimum instream flows (normal operating conditions)	50 cfs (Nov-May), 150 cfs (June – Oct)
Minimum instream flows (project offline)	600 cfs

1.5.1 Diversion During Construction

The diversion scheme was based on a 10-year recurrence interval, which has a design flow of 10,000 cfs. Embankment dams typically have a significantly higher diversion design recurrence flow, but for an RCC dam, a lower recurrence interval can be selected based on the fact the consequence of overtopping an RCC dam is much less than for an embankment dam.

Diversion schemes utilizing conveyance channels in the existing channels and embedded outlets in the dam was briefly reviewed, but the design flows would require large channels and the steep canyon topography would make construction impractical. Also this type of division would not be efficient for RCC construction and create several cold joints in the dam. Therefore, the selected diversion scheme includes a more typical arrangement of a diversion tunnel and cofferdams.

The diversion would be an approximately 900 feet long, 13 ft wide, and 19.5 ft high (finished dimensions) horseshoe tunnel, most of which would be used as power tunnel when the Project is finished. The tunnel would be constructed from downstream to upstream, with spoils being hauled out the powerhouse road.

The cofferdams are assumed to be constructed of rockfill with a slurry trench. Since the powerhouse and associated equipment installation is often a critical path item in hydropower projects, the downstream cofferdam would be constructed following the powerhouse access road completion and start of diversion tunneling. This sequence would allow the powerhouse construction to progress independent of the tunnel construction.

The gate shaft would be constructed using conventional raise boring. The power tunnel and gate shaft would be lined with reinforced concrete prior to diversion of flows. Also the intake structure would be completed prior to diversion of flows. Then the upstream cofferdam would be constructed and begin to divert flow through the diversion tunnel. A rock plug would remain at the wye of the power tunnel until flow could be spilled at the dam.

With flow diverted through the diversion tunnel, construction of the dam would commence. The gate house and powerhouse would be constructed simultaneously with the dam. Following completion of the dam and spillway, the diversion tunnel would be closed, and primary flow diversion would then be over the spillway. The rock plug at the power tunnel would be excavated and the final steel lining of the power tunnel and connection to the penstocks would be completed. The steel liner construction would include a concrete tunnel plug in the diversion tunnel.

1.5.2 Intake and Tunnel

The geotechnical information available is limited, but exposed rock in the river canyon indicate that it is highly jointed and that the joint planes run roughly parallel to the tunnel alignment. We have therefore assumed that the power tunnel will need to be fully lined with reinforced concrete. The power tunnel was sized for a velocity of approximately 15 ft/s for the total plant flow of 3,000 cfs. Access to the power tunnel following project completion will be through a penstock access vault near the downstream power tunnel portal.

Two types of intake and tunnel gated control systems were reviewed: 1) a tower with a vertical gate at the intake, and 2) a vertical gate in a shaft approximately 200 feet inside the tunnel. The vertical gate in an excavated shaft was the preferred option. The intake gate tower, which would also have included an access bridge from shore, would likely require significant reinforcement to meet seismic and ice load design criteria.

The vertical gate shaft would include both gate and stoplog slots with a hoist located in a gate house above on the surface.

We have assumed a trashrack with a 2 inch bar spacing at the intake. Stoplog slots would be included at the intake structure for emergency dewatering of the entire power tunnel, including the section upstream of the gate. These stoplogs could either be lowered by crane from shore or from a barge in the reservoir and installed with the aid of divers, but their installation is expected to be very infrequent. Also, due to ice in the reservoir, the intake structure could not reliably be accessed during winter months. A stoplog slot was included in the gate shaft as the primary means of dewatering the tunnel for inspection and for gate maintenance.

1.5.3 Surge Chamber

We have assumed that control of transient pressures and unit frequency will be achieved using additional flywheel weights on the generators. We expect that the increased cost of the generating equipment will more than offset the cost of constructing a surge chamber, the diameter of which above normal minimum water level would be approximately 40 feet. Also, the location of a surge chamber should ideally be close to the powerhouse. However, the topography near the powerhouse is such that a surge chamber would essentially be a tall tower above ground, which would likely require a significant structure to meet seismic, ice, and wind loading criteria. It would also have a significant negative visual effect. A more realistic location would be further upstream where the chamber could be completely below ground, but its effect on reducing transient pressures and maintaining frequency stability would be reduced.

1.5.4 Dam and Spillway

The dam would be a roller compacted concrete (RCC) dam with approximately 35,000 CY of concrete. The dam would be approximately 123 ft high with a dam crest at elevation 676 ft and a crest length of approximately 465 ft.

The dam has a crest width of 20' with access from the left abutment. The downstream face of the dam is sloped at 0.8H:1V, while the upstream face is vertical. A layer of conventional concrete is placed at the upstream face of the RCC dam to provide an impervious barrier. Curtain grouting has been assumed to extend to a depth below the foundation of 60% of the dam height, while drain holes have been assumed to extend below the foundation to 40% of the dam height. Consolidation grouting has been assume below the entire foundation at a 20 ft x 20 ft grid spacing.

A significant benefit of an RCC dam over an rockfill dam is that the spillway can be integral to the dam, which eliminates the additional excavation and concrete required for a separate spillway. The spillway would be ungated with a length of 110 feet and a crest elevation of 660 ft. We have assumed that personnel access to the right dam abutment will be provided by access galleries under the spillway. Vehicle access would be provided by a three-span precast concrete bridge over the spillway, which therefore includes two piers. The reservoir level to pass the IDF is approximately 672.3 ft with approximately 3.7 ft of freeboard. Since the dam is in a very protected location, wave runup on the reservoir would be insignificant.

The river canyon at the dam site is relatively steep, with approximately 1H:1V walls. The steep canyon helps to minimize the RCC volume, but it limits the width of the spillway and stilling basin. The spillway and stilling basin have a clear opening width of 110 ft, which approximately matches the width of the downstream river channel. A stepped spillway was assumed to improve energy dissipation on the spillway and reduce the size of the stilling basin. A Type II USBR Stilling Basin (Peterka, 1984) was selected for the design head, flow rate, and residual energy.

1.5.5 Outlet Facilities

1.5.5.1 Instream Flow Outlet

We have assumed a minimum and maximum instream flow requirement of 50 cfs (Nov – May) and 150 cfs (June – Oct), respectively, for the reach between the dam and the powerhouse. The flow would be discharged through a regulating valve on the synchronous bypass outlet (see Section 4.5.5.2 for details).

It would be possible to include a small horizontal 1,000 kW Francis unit to capture the available energy in the instream flow. Assuming an outlet elevation of approximately 581 ft for an average head of approximately 70 feet and a minimum and maximum flow of 50 and 150 cfs, respectively, the potential available annual energy would be approximately 4,100 MWh. The outlet could potentially be installed at a lower elevation closer to the invert of the apron to increase generation.

However, a turbine unit like this has not been included in the analyses and cost estimates presented herein. It would require a separate small powerhouse at the base of the dam, transformers, and transmission line to the main powerhouse.

1.5.5.2 Synchronous Bypass Outlet

A synchronous bypass outlet at the dam should be included so that a minimum flow in the Allen River can be maintained in case the powerhouse is tripped off-line. We have assumed that the minimum flow in the river at any time during the year is 600 cfs.

A hooded fixed cone valve (ring jet valve) would be installed at the end of the outlet near the end of the lower gallery access on the left abutment to dissipate the energy. Based on a minimum and maximum net head of approximately 57 ft and 75 ft, respectively, and a maximum flow of 600 cfs, we have estimated that a 48" diameter outlet and valve will be sufficient.

The fixed cone valve would normally be regulated to release only the flow required for instream flow. If the powerhouse is tripped off-line, the valve would automatically open to its full capacity to maintain a watered reach between the dam and the powerhouse.

1.5.5.3 Low-Level Outlet Facilities

We have assumed that low-level outlet facilities to evacuate the reservoir in an emergency situation would not be required based on the probable classification of the dam as low risk and low hazard, and based on the large size of the reservoir and the resulting large outlet works required to meet the evacuation criteria and guidelines by USBR (USBR, 1990) and USACE (USACE, 1975).

Concrete dams like the proposed RCC dam do not generally fail in a catastrophic manner in the same way that an impervious core rockfill dam may fail during a seismic event. The consequence of a dam failure would also likely be low, based on the attenuating effects of the large downstream lakes Lake Chauekuktuli and Tikchik/Nuyakuk Lake.

The estimated starting reservoir storage is approximately 1,600,000 acre-ft and it would require an average outflow of approximately 10,000 cfs to draw down the reservoir within the four high-inflow months of June through September. The required peak flow capacity would be significantly higher. Providing the facility with this flow capacity is not considered economical, based on the anticipated low level of risk and low hazard potential at the site.

A more detailed risk and hazard analysis should be performed during a preliminary design phase to confirm this assumption.

1.5.5.4 Powerhouse and Switchyard

Three types of powerhouse structures were considered including an above grade, cavern and shaft style. In an above grade structure the powerhouse is accessed from the turbine/generator service level and the building superstructure is full exposed. The cavern powerhouse is constructed entirely underground and access is by tunnel. The shaft style powerhouse is recessed into the ground such that much of it is below grade, with some above grade features and access can vary depending on the layout.

Although cavern and shaft style powerhouses present a lower visual impact than the above grade alternative, they require competent rock. Due the expected highly jointed nature of the rock and orientation of the joint planes at the site, these alternatives would require significant rock support and waterproofing and would present significant technical challenges and likely high construction costs. The above-ground powerhouse was, therefore, the preferred style.

The preferred location for the powerhouse is on the left bank of an existing pool just downstream of the dam. The topography of the preferred site would facilitate tailrace excavation and minimize excavation volumes. The site is located in a small existing valley and the powerhouse would only be visible by air or from the river.

A preliminary powerhouse footprint of 100 ft by 160 ft was selected to accommodate the four selected Francis turbine units and generators. We have assumed a pre-engineered superstructure with insulated wall and roof panels.

We have assumed that the switchyard would be located immediately behind the powerhouse to minimize the length of expensive high amperage cable between the powerhouse and the units. An alternative location may be up above the powerhouse above the ravine that forms the river.

1.5.6 Fish Passage Facilities

There is insufficient information to determine any specific details or requirements for either upstream or downstream fish passage. Therefore, these details are not included in this report. However, a lump sum line item in the cost estimate has been included to account for the potential need to include upstream and downstream fish passage structures after further studies have been completed.

1.5.7 Transmission

Alternative transmission line routes to Dillingham and Bethel have been identified. These alternative routes are described in more detail in separate technical memoranda in **Appendix B**.

The alternatives were segmented into terrain and access types for construction and O&M expenses. Finally, a range of construction costs was developed for each alternative.

These analyses did not consider other possible impacts such as environmental; however most impacts are directly proportional to the miles of line.

1.5.7.1 Project to Bethel

Three separate transmission line routes were identified based on maps, agency requests and knowledge of best transmission route selection for Alaskan conditions: West; North; and North Alternative.

Based on the comparisons, the West Route is the most reasonable choice. The estimated costs are only for the direct construction of the transmission line itself. The North and North Alternative routes will add between 50% and 70% more to the financed cost of power in Bethel compared to the West Route.

1.5.7.2 Project to Dillingham

Two separate transmission line routes were identified based on maps, agency requests and knowledge of best transmission route selection for Alaskan conditions: a South route and a South Loop route.

Based on the analyzed comparisons and estimated costs, the South Route is the most reasonable choice. The estimated costs presented in the memorandum support the South Route and are only for the direct construction of the transmission line itself, other costs will be required. The South Loop route will approximately double the financed cost of power in Dillingham compared to the South Route.

2. Geology

Geotechnical studies were intended to be completed, however the permit application that would have allowed these studies was not approved by the State. Therefore, except for a 2-day reconnaissance level visual walk-through inspection of the site and desk studies, this report and analysis presented herein are relying on previous studies and reports. Unfortunately, none of the referenced historical studies include more detailed (subsurface) investigations, rather they also rely on visual above-surface investigations. **Appendix A** includes the referenced historical investigations and the studies performed by Hatch and our subconsultants. A more general description of the geology and physical setting of the project area is presented in **Volume 2**.

The geology and geotechnical studies presented to Alaska Power Authority in the Bethel Area Power Plan Feasibility Assessment by Harza (Harza, 1982) form the primary geotechnical basis for the discussions presented herein. In addition, the geotechnical discussions in the final feasibility report presented to Association of Village Council Presidents Regional Housing Authority by Harza (MWH, 2011) was also reviewed and used as geotechnical basis where applicable.

An additional planning-level geologic evaluation was performed on an area known as Y-pass (Banks, 2013). The Y-Pass is a U-shaped glacially carved valley located on the south shore of Chikuminuk Lake approximately 10 miles west of the proposed dam site. The result of the preliminary evaluation of both the western and eastern fork of Y-Pass indicates a potential for bedrock to lie at an elevation which could reduce or preclude seepage of the proposed reservoir through permeable soil units. However, prior to the final feasibility/design phase of the project, a geophysical survey in conjunction with a drilling program should be performed within the Y-Pass area to better define the depth to bedrock in critical areas.

In summary, the geotechnical information at the site can be summarized as follows, with more detailed descriptions available in the attached reference materials in **Appendix A**.

The hard sedimentary rock should provide favorable tunneling conditions. Shear zones or fault lines approximately parallel to proposed tunnel alignments may require additional support steel sets and lining.

It is expected that the foundation rock will be adequate to support the loads of either a rockfill or gravity dam.

The rock characteristics appear to not support an underground powerhouse. A surface powerhouse is favored.

The morainal ridges around the lake, such as the Y-pass, need additional studies to determine their water retaining capacity. The concept of a slurry wall to reduce seepage has been proposed but its length and depth cannot be determined without additional studies.

Additional geological studies recommended to assess final feasibility of Project:

- Subsurface investigations to evaluate permeability, ground water conditions, etc.
- Need for a slurry cut-off wall to reduce or eliminate seepage through moraine at the site
- Assessment of effect of local permafrost on Project design
- Investigations to assess suitability of aggregate sources for fill, concrete aggregate, etc.

3. Hydrology

3.1 Chikuminuk Lake Drainage Basin

The area of drainage basin is approximately 353 mi^2, including Chikuminuk Lake, which is part of a series of land-locked fiords and is approximately 16 miles long with an average width of about 2.5 miles. The natural normal water surface elevation of Chikuminuk Lake is El. 613[1] with a surface area of about 24,640 acres (41.6 mi^2). The southeastern arm of the lake has a recessional moraine over shallow rock with a box canyon that forms the lake outlet to the 11.6 miles long Allen River. The Allen River flows to the southeast to Lake Chauekuktuli, which in turn drains into Nuyakuk/Tikchik Lake through the informally named Northwest Passage. The drainage areas of each lake are presented in **Table 3.1**.

A more detailed description of the drainage basin is presented in **Volume II** of this Interim Feasibility Report.

Table 3.1 Drainage Areas

Drainage Basin	Drainage Area (mi^2)	Total Drainage Area (mi^2)	Comment
Lake Chikuminuk	348	348	USGS gage 15301500
Lake Chauekuktuli	259	607	Location of R&M stream gage on Northwest Passage
Tikchik/Nuyakuk Lake	883	1490	USGS gage 15302000

3.2 Stream Flow Record

The United States Geological Survey (USGS) has maintained a gage just downstream from the outlet of Lake Chikuminuk on the Allen River near the location of the proposed project (USGS 15301500 ALLEN R NR ALEKNAGIK AK), but its flow record is limited to average daily flows between July 1963 and September 1966, between October 2011 September 2012, and between July 2013 to today. The average daily flow data for 2013 are still provisional and have not been approved.

A much longer streamflow record is available from the USGS gage just downstream from the outlet of Tikchik/Nuyakuk Lake on the Nuyakuk River (USGS 15302000 NUYAKUK R NR DILLINGHAM AK). Average daily flow data have been recorded at this gage from June 1953 to September 1995, July 2002 to September 2004, July 2007 to September 2012, and May 2013 to today.

Hatch and R&M Engineering Consultants also installed two additional gages: one on Allen River downstream from the proposed project location (Hatch/R&M ALLEN R), and one in the channel (Northwest Passage) between Lake Chauekuktuli and Nuyakuk Lake (Hatch/R&M NW PASSAGE). However, both gages were destroyed by ice in the fall and winter 2012-2013 and have only short partial records.

Table 3.2 summarizes the available gage flow data and clearly shows the periods of concurrent flow records for the USGS gages near the project area.

[1] Surveyed by R&M (NAVD88).

Table 3.2 Summary of Available Average Daily Flow Data

Stream Gage	Wateryear (Oct 1 – Sep 30)																			
	1953	1954	-	1962	1963	1964	1965	1966	1967	-	1996	1997	-	2001	2002	-	2011	2012	2013	2014
USGS 15301500 ALLEN R																				
Hatch/R&M ALLEN R																				
Hatch/R&M NW PASSAGE																				
USGS 15302000 NUYAKUK R																				

Notes:
green = full record
yellow = partial record

3.3 Stream Flow Extension for Chikuminuk Lake

Only about four full years of data are available at the USGS Allen River gage, but a long term stream flow record is necessary to perform the power studies to estimate the potential energy from the proposed hydroelectric project and the effect of flow regulation on downstream resources. The long unbroken flow record at the downstream gage on the Nuyakuk River provides a convenient index-station to which flows on the Allen River can be correlated. The Nuyakuk River has a similar hydrological response to snow melt and precipitation as the Allen River. **Figure 3.1** shows the correlation of concurrent average daily flows measured at the USGS gages on the Allen and Nuyakuk Rivers. The figure and the best-fit line clearly show the high correlation, but also that the regression could be improved with separate low and high flow periods.

Hatch used the Streamflow Record Extension Facilitator (SREF) Version 1.0, which is a software program by the USGS for extending and augmenting streamflow records using available daily data from nearby gaging stations, to extend the flow record on the Allen River. In addition to the maintenance of variance extension type 1 (MOVE.1) and type 3 (MOVE.3) regression analyses, the SREF program can also use a single or multi-segment regression model using the nonparametric Kendall-Theil Robust Line (KTRLine) program. The output from SREF includes an extended record data file in a format similar to the USGS standard NWISWeb daily value RDB input.

KTRLine was selected because it conveniently facilitates a multi-segment regression, which allows the low and high flow periods to have separate regression equations. **Figure 3.1** clearly indicates that a multi-segment line is appropriate. Iterations included the default 1-segment line, then several attempts at multi-segment lines, increasing the model one segment at a time until the best fit was obtained with the fewest possible segments. The breakpoints for the multi-segment lines were visually selected based on the data scatter plot then adjusted until improvements diminished.

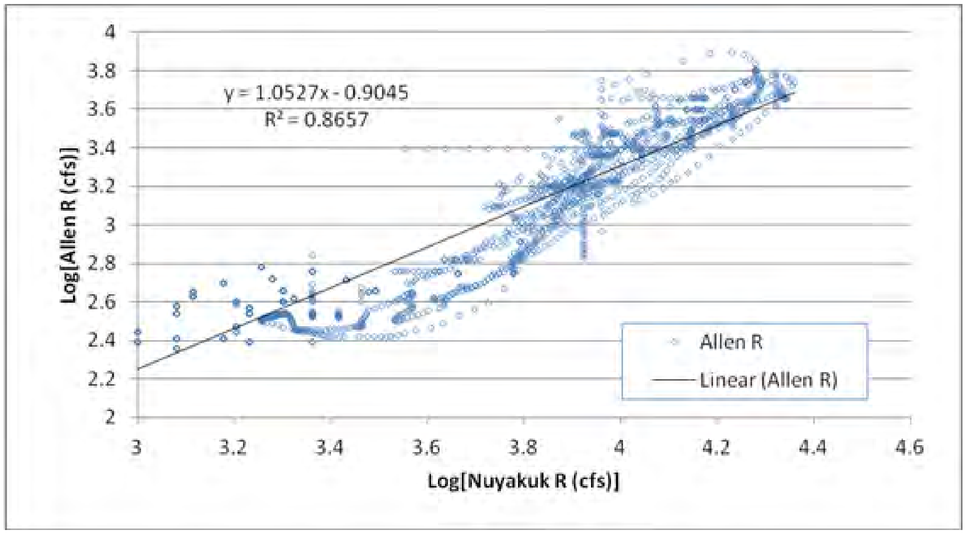

Figure 3.1 Correlation of Available Concurrent Average Daily Flows at Allen River (Usgs 15301500) and Nuyakuk River (Usgs 15302000)

The final multi-segment regression from KTRLine is presented in **Figure 3.2** on top of the scatter plot of concurrent daily flows. The root mean square error (RMSE) of the multi-segment fit is 0.122. The values of each regression equation for each segment are presented in **Table 3.3** and were entered into SREF, which computed the extended discharge values and retransformed them from logarithmic values to produce a complete record of measured and extended daily flows for the period. **Table 3.4** presents the resulting extended average monthly flows used for all subsequent analysis presented herein.

3.4 Flood Hydrology

The flood hydrology characteristics of the drainage basin at the dam site is important for sizing the spillway, sizing the diversion facilities, and to estimate the risk of overtopping the diversion facilities during construction.

3.4.1 Inflow Design Flood

Based on the high value of the project, we have assumed that the probable maximum flood (PMF) is appropriate as the project inflow design flood (IDF), which determines the minimum flow capacity of the spillway. Because of the large surface area and storage volume of Chikuminuk Lake, the lake will cause significant attenuation of large floods, including the PMF. In their feasibility report (MWH, 2011), therefore, MWH presents the results of routing an estimated 72-hr hydrograph of the probable maximum precipitation (PMP) through Chikuminuk Lake for various spillway lengths. The results, which were adopted by Hatch for the purpose of these studies, are presented in **Table 3.5**.

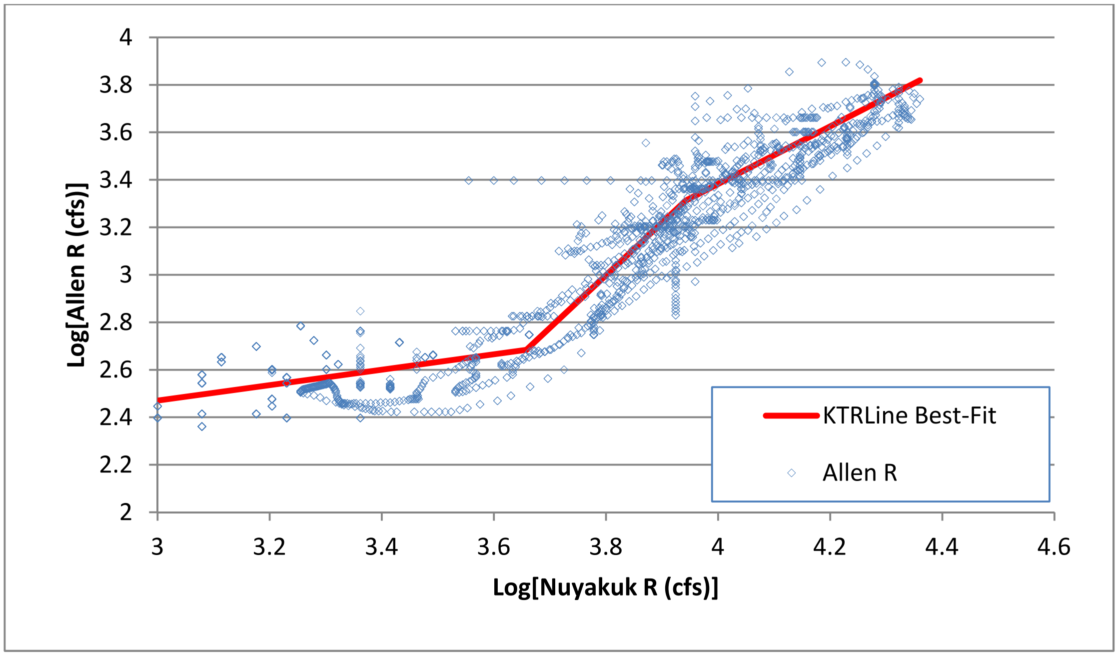

Figure 3.2 Scatter-plot and Multi-segment Best-fit Line of Measured Concurrent Average Daily Flows at Allen River and Nuyakuk River.

Table 3.3 Values of Slope, Intercept and Bias Correction Factor for the Multi-segment Regression by KTRline of the Discharge at Allen River Using Nuyakuk River as Index Station.

Segment No.	Slope	Intercept	Bias Correction Factor
1	0.324	1.497	1.042
2	2.210	-5.400	1.028
3	1.212	-1.464	0.978

Notes: Values represent logarithms of discharge in cubic feet per second

Table 3.4 Estimated Average Monthly Flows at Dam Site, Using Measured Values if Available (Cfs)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1953						3996	2954	262	1189	896	472	425	
1954	392	366	344	335	677	2469	1239	679	788	631	968	486	781
1955	440	409	392	386	531	2894	5609	3187	1510	1163	475	409	1460
1956	373	344	335	344	546	4407	2901	1302	2154	808	455	425	1197
1957	373	344	344	366	939	3271	1396	477	2780	1499	2037	738	1211
1958	444	407	392	389	559	5520	6106	2789	1343	1034	459	420	1663
1959	404	366	335	344	571	3466	2639	891	706	2009	664	449	1074
1960	417	376	347	287	989	4382	3144	2238	1323	1111	787	487	1325
1961	448	425	386	366	1262	4153	3087	2310	2038	1097	486	396	1375
1962	379	373	359	359	678	4112	3995	1207	718	686	463	435	1150
1963	445	449	442	379	562	3620	2966	1492	2239	1071	478	571	1228
1964	474	406	314	255	339	4870	2908	1986	2039	1571	625	520	1358
1965	460	400	370	348	494	4702	3476	2132	4554	1576	569	460	1628

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1966	400	350	300	260	367	3900	3226	2010	2300	2497	910	480	1421
1967	437	407	386	375	404	2699	2209	1059	1164	987	438	382	914
1968	357	348	344	344	708	2659	1429	1689	1016	477	418	397	849
1969	378	359	351	351	771	6650	4145	1167	805	2781	1858	489	1678
1970	402	378	366	359	790	3915	3279	2209	1852	593	442	391	1251
1971	368	354	348	346	559	3618	4935	3523	1377	1095	552	441	1468
1972	403	374	351	346	412	2987	4211	1687	1390	1258	974	472	1241
1973	421	389	367	354	563	3697	4242	1574	1691	1284	472	408	1293
1974	375	355	351	352	657	2907	2274	840	1097	1255	573	426	957
1975	390	373	364	363	549	3521	3709	1322	1164	1614	611	425	1205
1976	372	339	307	299	434	2616	2614	1857	2329	2770	1037	489	1291
1977	450	423	387	361	446	5117	7611	6897	2281	902	473	416	2162
1978	406	391	379	379	2716	3826	4018	1975	1926	938	706	527	1523
1979	455	405	378	404	1356	5006	3722	3708	2007	2963	2092	654	1937
1980	431	424	414	414	1400	5523	5026	2476	885	1486	1031	440	1666
1981	428	433	421	415	1452	4934	3073	1935	1096	526	530	444	1310
1982	404	419	401	384	626	4829	5152	1800	2772	2959	584	454	1738
1983	432	408	380	381	1278	5216	3537	1348	494	496	481	1108	1300
1984	494	428	392	374	697	3283	3450	1106	503	640	437	402	1019
1985	398	416	374	339	367	3564	4426	2714	1748	1798	594	465	1440
1986	431	399	385	374	433	2565	3919	2666	2489	2159	1544	458	1491
1987	425	398	389	381	500	4623	6438	3210	1181	1698	862	453	1723
1988	420	412	398	384	877	5638	5131	3031	2750	1765	1076	480	1865
1989	429	388	386	373	499	4214	3434	2154	4519	3273	1038	452	1766
1990	428	400	378	395	533	3273	1793	1448	1540	1536	529	430	1058
1991	410	397	389	404	749	3778	2159	1374	2185	3390	1162	426	1405
1992	386	377	368	373	1015	3744	3388	2450	2323	587	434	398	1321
1993	381	373	374	422	2182	5274	3200	1935	2490	2394	744	467	1691
1994	438	418	391	402	881	4910	3975	2492	1475	2722	948	498	1636
1995	448	409	384	406	2171	4891	3181	1933	2759	2727	1253	459	1756
1996	405	390	402	394	1254	2541	2018	1090	612				
2002							3164	1303	637	1692	3294	2696	
2003	743	486	451	406	595	3222	2944	1717	876	1592	831	443	1196
2004	409	390	377	393	1761	3736	1930	1092	485				
2007							2005	2032	2422	1624	774	493	
2008	423	394	387	373	825	4321	3734	1370	1909	1566	442	412	1347
2009	384	375	368	370	2084	4893	2498	3236	1322	2662	1335	460	1673
2010	412	394	377	365	800	4428	3236	3537	1893	649	488	439	1423
2011	410	380	367	359	1159	4453	3153	1684	1540	870	431	390	1269
2012	303	322	340	314	535	4795	3933	1564	1920				
2013					499	4074	2368	2890	1451	2144	1610	541	
Avg	**419**	**391**	**373**	**365**	**864**	**4071**	**3450**	**2032**	**1705**	**1559**	**842**	**516**	**1386**
Min	**303**	**322**	**300**	**255**	**339**	**2469**	**1239**	**477**	**485**	**477**	**418**	**382**	**781**
Max	**743**	**486**	**451**	**422**	**2716**	**6650**	**7611**	**6897**	**4554**	**3390**	**3294**	**2696**	**2162**

Table 3.5 Chikuminuk Lake Dam PMF Routing Summary (MWH, 2011)

Spillway Crest Length (ft)	Peak Project Inflow (cfs)	Peak Project Outflow (cfs)	Head on Spillway (ft)
50	110,000	9,830	13.9
100	110,000	17,000	12.6
150	110,000	22,600	11.6
200	110,000	27,300	10.9

A more detailed PMF analysis per FERC engineering guidelines (FERC, 2001) should be completed if project advances to a more detailed design phase.

3.4.2 Flood Recurrence

The estimated peak flood recurrence flows at the Nuyakuk gage site are shown in **Table 3.6**. Considering the considerably larger drainage area of the Nuyakuk gage (1490 mi^2) compared to the drainage area at the Chikuminuk Lake dam site (348 mi^2), the 100-yr flow estimate by MWH seems high. Applying the regressions equations and procedures published by USGS (Curran, Meyer, & Tasker, 2003) for estimating peak flows and recurrence intervals at ungaged sites in Alaska results in the estimated recurrence interval flood flows at the Chikuminuk Lake dam site as shown in **Table 3.7**. These flood frequencies and flows were adopted by Hatch for the purpose of the studies presented herein.

Table 3.6 Estimated Flood Recurrence Flows at Nuyakuk River (USGS 15302000)

Recurrence Interval, T (yrs)	Recurrence Flow (cfs)
5	23,200
10	25,400
25	28,000
50	29,600
100	31,200

Table 3.7 Estimated Flood Recurrence Flows at Chikuminuk Lake Dam Site

Recurrence Interval, T (yrs)	Recurrence Flow (cfs)
5	8,400
10	9,900
25	11,800
50	13,300
100	14,700

4. Reservoir Operations Studies and Project Energy Estimation

A reservoir model was set up using the computer program HEC-ResSim 3.0, which facilitated the estimation of the regulated reservoir operations, including energy generation and outflow estimation. The regulated outflow results from the HEC-ResSim model were also used to estimate pre-project (unregulated) and post-project (regulated) lake water levels of the two downstream lakes, Lake Chauekuktuli and Tikchik/Nuyakuk Lake. **Appendix C** includes a more detailed description of the reservoir operations studies and the project impact on the downstream lake levels, but the following is a summary of the results.

4.1 Energy Potential and Reservoir Operations

- The average annual energy potential of the Project, based on the estimated long term (42 years) reservoir inflow record, is approximately **78.1 GWh**.
- A conservation zone at elevation 641 ft, below which flow to the turbines is limited to reservoir inflow, was necessary reduce risk of emptying the reservoir during periods of low inflow.
- The simulated average monthly reservoir level is 652.1 ft, which reflects the need to maintain available storage for large runoff events to fully utilize the energy potential of the site and minimize spill.
- On average: 1) project generation will likely not meet the estimated average monthly demand in the winter and spring months of November through May; 2) project generation will likely be able to meet the demand during the summer months (June through October).
- Project will likely meet the annual average demand approximately 70 percent of the time.

4.2 Project Impact on Downstream Lake Levels

- The water levels in the downstream lakes will likely increase in the winter and decrease in the summer due to the storing of runoff during spring and summer and release of reservoir water in the fall, winter, and spring for power generation.
- The average water level of Lake Chauekuktuli may increase about 2.5 feet in the winter and spring and decrease up to 3.5 ft in the early summer.
- The average water level of Tikchik/Nuyakuk Lake will likely increase about 1 ft in the winter and spring and a decrease about 1 ft in the early summer.
- Reestablishment of the stream gage in the NW Passage is recommended to facilitate a more detailed and accurate routing analysis of flows to Lake Chauekuktuli and Tikchik/Nuyakuk Lake.
- Development of lake outlet rating curves at both Lake Chauekuktuli and Tikchik/Nuyakuk Lake are recommended to facilitate more accurate estimates of lake levels.

5. Opinion of Probable Total Construction Cost and Schedule

5.1 Introduction

Effective cost estimating involves the use of data derived from the most current pricing for materials, appropriate wages and salaries, accepted productivity standards, and customary construction practices, procurement methods, equipment needs, and site conditions. Cost estimates are by definition prepared with less than complete information and have inherent levels of risk and uncertainties.

In both the public and private sectors, many levels or types of classifications of cost estimates exist. No matter the organization, the levels of engineer cost estimating begin at initial planning or design and end with a 100 percent design that is biddable and constructible. With each increasing level of design and cost estimate, the likelihood that the cost estimate reflects the actual project costs increases. This leads to increased confidence in both the design and the estimated project cost resulting expected project cost.

The Association for the Advancement of Cost Engineering International (AACE International) is an international non-profit professional educational association that provides services related to cost estimating, cost/schedule control, and project management to a wide range of professions and industries. AACE International (AACE, 2011) defines five levels of cost estimates for a project as shown in **Table 5.1** that is used herein to guide the development of the current estimated cost of the Project.

Table 5.1 Cost Estimate Classification

AACE Class	Methodology	Design %	Accuracy Range %	Typical Contingency %
5	Parametric/Stochastic	< 5	-35 to +50	20 to 40
4	Semi-detailed Unit Price	< 15	-25 to +35	10 to 30
3	Detailed Crew Analysis	10 - 40	-15 to +20	5 to 20
2	Detailed Crew Analysis w/ Budget Quotes	50 - 99	-10 to +15	0 to 10
1	Detailed Crew Analysis w/ Firm Quotes	100	+/- 5	0 to 5

(reference: AACE International Recommended Practice No. 18R-97).

5.2 Probable Total Construction Cost

5.2.1 Direct Construction Cost

All cost estimates are based on January 2013 bid price levels. The Probable Direct Construction Cost is the total of all costs directly chargeable to the construction of the project and in essence represents and is presented in the form of an estimate of contractor's bid. At the current phase of the Project, the level of information that is available to support level of the design in accordance with the AACE criteria shown in **Table 5.1** above varies from feature to feature. Accordingly, each feature was independently evaluated to establish an appropriate AACE class. **Table 5.2** provides a listing of the major features identified for the Project as defined **in Section 1** as well as the associated AACE classifications. Worksheets consistent in detail with these AACE classifications are included in **Appendix D** and are identified in accordance with the outline in **Table 5.2**.

Table 5.2 AACE Class for Major Project Features

	ITEM	AACE Class
1	**General**	5
2	**Roads and Airstrip**	5
3	**Roller Compacted Concrete Dam**	4
4	**Waterways**	
	4.1 Mobilization / Demobilization	3
	4.2 Portal Construction	3
	4.3 Tunnel Construction	3
	4.4 Gate Shaft Construction	3
	4.5 Penstock System	4
	4.6 Intake Structure and Gate	4
5	**Powerhouse**	
	5.1 Structure and Site Development	4
	5.2 Mechanical and Electrical Equipment	3
6	**Transmission Line**	
	6.1 Chikuminuk to Bethel	4
	6.2 Chikuminuk to Dillingham	4

5.2.2 Indirect Costs

Indirect costs include an allowance for contingencies, engineering, and owner administration. **Table 5.3** includes the contingencies for each feature consistent within the contingency ranges in **Table 5.1** for the respective AACE class shown in **Table 5.2.**

Table 5.3 Scope and Price Contingencies for Major Project Features

	ITEM	Scope Contingency	Price Contingency
1	**General**	NA	15%
2	**Roads and Airstrip**	40%	15%
3	**Roller Compacted Concrete Dam**	30%	15%
4	**Waterways**		
	4.1 Mobilization / Demobilization	20%	15%
	4.2 Portal Construction	20%	15%
	4.3 Tunnel Construction	20%	15%
	4.4 Gate Shaft Construction	20%	15%
	4.5 Penstock System	30%	15%
	4.6 Intake Structure and Gate	30%	15%
5	**Powerhouse**		
	5.1 Structure and Site Development	30%	15%
	5.2 Mechanical and Electrical Equipment	15%	15%
6	**Transmission Line**		
	6.1 Chikuminuk to Bethel	20%	15%
	6.2 Chikuminuk to Dillingham	20%	15%

The assumed Administration and Management costs during the design and construction phase of the Project are summarized in **Table 5.4**.

Table 5.4 Administration & Management (% of DCC + Contingencies)

Item	Percent
Planning and Licensing	1.5%
Engineering	3.0%
Engineering During Construction	2.0%
Construction Oversight & Mgt	5.0%
Misc Owner's soft costs	2.0%
Land Acquisitions, Rights and Mitigation	2.0%

5.2.3 Total Construction Cost

The direct and indirect costs shown above are added together to form the Probable Total Construction Cost (PTCC) as shown in **Table 5.5** in summary form. The complete detail for each item is included in **Appendix D**.

Table 5.5 Opinion of Probable Total Construction Cost

	Item			Estimated Cost
1	**General**			**$35,000,000**
2	**Roads and Airstrip**			**$29,000,000**
3	**Roller Compacted Concrete Dam**			**$38,000,000**
4	**Waterways**			
	4.1	Mobilization / Demobilization	$5,200,000	
	4.2	Portal Construction	$9,600,000	
	4.3	Tunnel Construction	$22,800,000	
	4.4	Gate Shaft Construction	$7,600,000	
	4.5	Penstock System	$4,300,000	
	4.6	Intake Structure and Gate	$6,800,000	
				$56,000,000
5	**Powerhouse**			
	5.1	Structure and Site Development	$23,700,000	
	5.2	Mechanical and Electrical Equipment	$40,600,000	
				$64,000,000
6	**Transmission Line**			
	6.1	Chikuminuk to Bethel	$114,400,000	
	6.2	Chikuminuk to Dillingham	$30,800,000	
				$145,000,000
			Subtotal - Direct Construction Cost	**$367,000,000**
7	**Contingencies**			**$126,000,000**
8	**Administration and Management**			**$76,000,000**
	PROBABLE TOTAL CONSTRUCTION COST (2013 Dollars)			**$569,000,000**

5.3 Construction Schedule

The construction schedule is an important element is the development of the total construction cost estimate outlined above and the total investment cost as discussed below in two areas:

1. Camp infrastructure costs required to support the overall crew size on a month to month basis, and
2. The calculation of the interest during construction on the basis of the required monthly draw from the construction loan for the project.

While the construction schedule for the Chikuminuk Lake Hydroelectric Project will determined by the selected contractor, it can be expected to be heavy influenced by the combined factors of the climate and remoteness of the site. For the purposes herein as referenced above, it is generally assumed that there will limited activity at the site during the winter months. The exception would be that work that involves small crews within protected spaces such as the tunnel or powerhouse can be extended into or initiated within the winter period. On this basis, the general framework of a probable construction schedule for the project is outlined in **Table 5.1**.

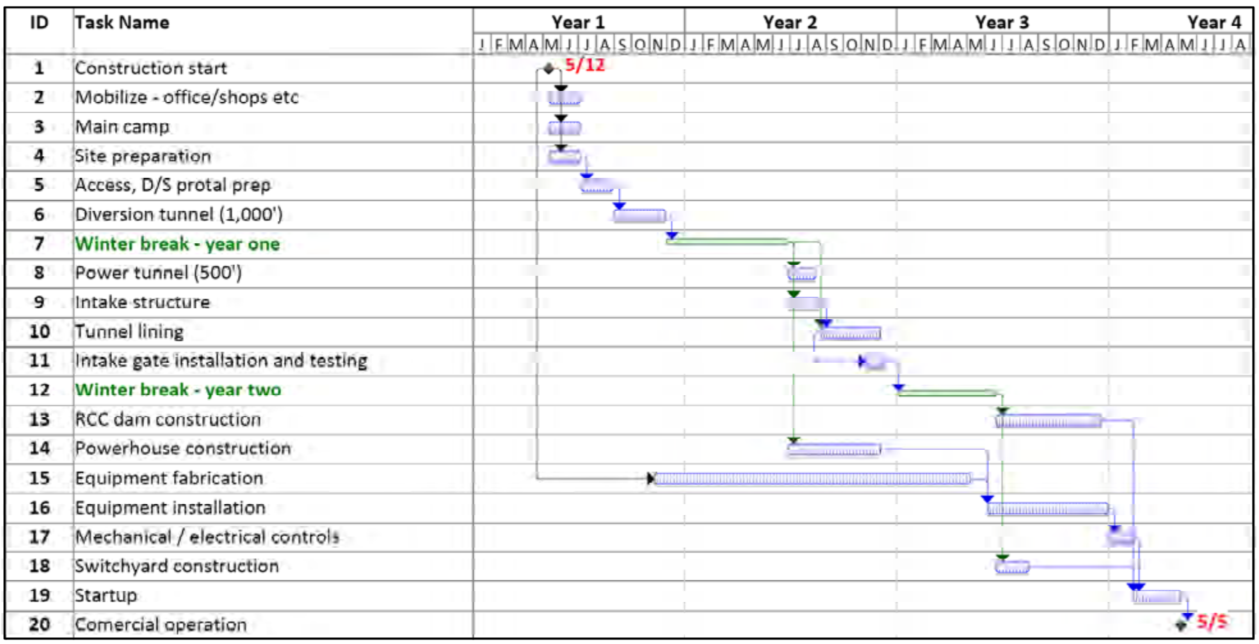

Figure 5.1 Probable Construction Schedule

6. Economic Analysis

6.1 Introduction

The present values of the unit production cost of energy at the Bethel and Dillingham load centers throughout a 50-year horizon is used herein as the metric to compare the Chikuminuk Lake Hydroelectric Project (Project) with the most viable alternative, which in this case is assumed to be an equivalent diesel plant (Diesel) at the each load center.

The comparative analysis is summarized below for three cases in relation to:

- The "Base Case" consisting of;
    - Project: "Probable" values for the energy, Probable Total Construction Cost (PTCC), financing terms, and system loads as presented herein.
    - Diesel: "Average" case for fuel prices as published by the Institute of Social and Economic Research (ISER, 2013).
- The "Lower Limit" including expected variation within the values for the above parameters combined in such a way to provide the minimum expected cost per kWh. This would include minimum values for hydro and diesel parameters except for the energy production and system load for which the expected maximum values would lead to the minimum expected cost per kWh.
- The "Upper Limit" including expected variation within the values for the above parameters combined in such a way to provide the maximum expected cost per kWh. This would include maximum values for hydro and diesel parameters except for the energy production and system loads for which the expected minimum values would lead to the maximum expected cost per kWh.

The values for all parameters used in the analysis for these three cases are included in **Table 6.1**.

6.2 Project and Diesel Cost per kWh

6.2.1 Project Cost First Year Annual Cost

In the case of the Project, the cost stream per kWh is calculated on the basis of:

- Traditional hydro project financing of the Project**,** and
- The operation and maintenance (O&M) cost for the generation facilities at Chikuminuk Lake and the transmission systems to Bethel and Dillingham.

The first year annual cost of the power from the Project for the Base, Lower Limit and Upper Limit cases is based on the above listed parameters and as summarized in **Table 6.1.** In particular, the Base Case cost power is determined by the PTCC as discussed above in **Section 5.**

The Lower and Upper Limit values for annual kWh cost of the power cases are based on an evaluation of the estimating accuracy consistent with the current status of the Project. Numerous non-governmental organizations and for-profit companies offer graphs, charts, and tips related to cost estimate accuracy. An internet search of "estimating accuracy" yields a plethora of options for additional information in this regard. One of the better illustrations as endorsed by the United States Society of Dams titled Estimating Accuracy Trumpet (USSD, 2012),, has been developed by R. Max Wideman. The illustration has been modified to serve the purposes herein in relation to the current status of the Project as shown in **Figure 6.1**.

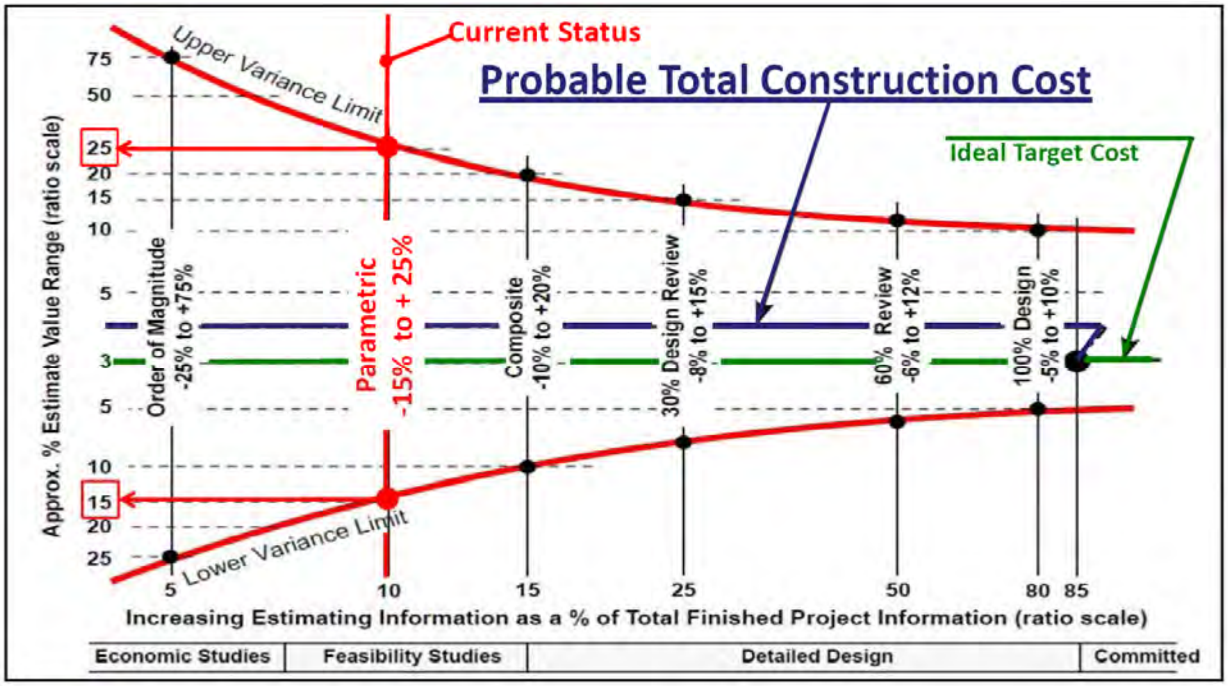

Figure 6.1 Estimating Accuracy Trumpet

6.2.2 *Diesel Cost per Gallon*

The unit production cost over the 50-year horizon for the Diesel alternative is dependent upon the cost of diesel fuel to feed the plant.. The cost per gallon of diesel fuel for the Bethel / Dillingham load centers, being the primary cost for element this alternative over the life of the Project, is based on projections as recently published by the ISER (ISER, 2013). The ISER publication was developed for the Alaska Energy Authority (AEA) for the purpose of estimating the potential benefits and costs of renewable energy projects. The report document explains the ISER methodology used the develop the projections and is included herein as **Appendix E1**. A companion Excel workbook contains detailed low, medium, high case fuel price projections for incremental diesel delivered to a PCE community utility tank, which can be downloaded from the AEA with the link below.

http://www.iser.uaa.alaska.edu/Publications/2013_06-Fuel_price_projection_2013-2035.xlsx

The results in 2012 dollars for the Bethel Utilities Corp and Nushagak Electric Cooperative, which serve the communities of Bethel and Dillingham respectively, are included herein as **Appendix E2**. The projections, weighted in relation to the contributing generation for each utility is summarized in **Appendix E3** for the years 2013 through 2035. Values for the remaining years within the 50-year horizon through 2063 are calculated and shown for each scenario on the basis of the respective inflation rates for each case as shown in **Table 6.1**.

Table 6.1 Cost Benefit Analysis, Data Input

	Base Case	Lower Limit	Upper Limit	Source / Comments
FINANCIAL				
Bond rate	AEA	NCERB	Rural Utility Service	
	5.00%	**3.75%**	**7.00%**	
Bond period	**30**	**30**	**50**	AEA
Horizon	**50**	**50**	**100**	AEA
Inflation / discount rate	**2.4%**	**1.9%**	**3.1%**	mean CPI rates for 2001-11
CHIKUMINUK LAKE HYDRO PROJECT - TOTAL CAPITAL REQUIREMENTS (1/13) ($1,000,000)				
Basis	**Base**	**-15%**	**25%**	
Probable Total Construction Cost	**$569.000**	**$494.783**	**$711.250**	Hatch Cost Model
Grant Funding	**($7.000)**	**($23.000)**	**$0.000**	Nuvista
Subtotal	**$562.000**	**$471.783**	**$711.250**	Hatch Cost Model
Interest During Construction	**$13.668**	**$11.474**	**$17.298**	Hatch Cost Model
Probable Total Investment Cost	**$575.668**	**$483.257**	**$728.548**	Hatch Cost Model
Reserve Fund	**$41.299**	**$34.676**	**$52.255**	Hatch Cost Model
Financing & Legal	**$17.270**	**$14.498**	**$21.856**	Hatch Cost Model
Working Capital	**$0.625**	**$0.625**	**$0.625**	Hatch Cost Model
Probable Total Capital Requirements	**$634.862**	**$533.056**	**$803.284**	Hatch Cost Model
CHIKUMINUK LAKE HYDRO PROJECT ANNUAL COSTS (1/13) ($1,000,000)				
Debt Service	$41.299	$34.676	$52.255	Hatch Cost Model
O&M Cost	$2.500	$2.500	$2.500	Hatch Cost Model
Administrative & General	$1.000	$1.000	$1.000	Hatch Cost Model
Insurance	$0.600	$0.500	$0.700	Hatch Cost Model
Hydro Interest on Reserves	($2.065)	($1.734)	($2.613)	Hatch Cost Model
ENERGY				
Average Energy Potential @ Site	78.1	84.0	72.0	Hatch Hydrology Model
Bethel Line Loss = 1.5% @ 10 MW Average Load				
Dillingham Line Loss = 3% @ 4 MW Average Load				
Net transmission loss		**2.0%**		
Average Energy @ Bethel/Dillingham	**76.5**	**82.3**	**70.6**	
SYSTEM LOADS				
FY2011 base load (GWh/yr) Bethel	54.8	54.8	54.8	FY11 PCE data
FY2011 base load (GWh/yr) Dillingham	21.4	21.4	21.4	FY11 PCE data
Bethel load: rate of change	1.06%	1.60%	0.67%	DOL, Table 3.33; US Census 1990-2000 rate
Dillingham load: rate of change	0.29%	0.98%	-0.10%	DOL, Table 3.33; US Census 1990-2000 rate
Initial base load (GWh/yr) Bethel	**56.0**	**56.6**	**55.6**	Adds 2 years growth
Initial base load (GWh/yr) Dillingham	**21.5**	**21.8**	**21.4**	Adds 2 years growth
DIESEL ENERGY COSTS				
Diesel efficiency (kWh/gal)	**13.86**	**13.56**	**15.09**	FY12 PCE data
Diesel O&M ($/kWh)	Avg All	B grid Avg	Dillingham	
	$0.0425	**$0.02**	**$0.05**	
Diesel standby cost ($/kWh)	KEA	MWH p 14-6	+25% for smaller scale plants	
	$0.025	**$0.023**	**$0.030**	

The capital cost element of the diesel plants is not included as they are assumed to be existing and maintained in place in either case as local system backup to the Project.

6.2.3 Lower Limit, Base and Upper Limit Cost / kWh – Project and Diesel Alternatives

The numerical results for the Lower Limit, Base and Upper Limit cases are summarized in **Appendix E4.1**, **Appendix E4.2** and **Appendix E4.3** respectively for the Project and Diesel alternatives in 2013 dollars. These results were obtained from the data included above in the following manner:

- All costs were normalized to 2013 dollars on the basis of the respective inflation rates for each case.
- For each case and year, the fuel cost in $/kWh for the Diesel alternative is calculated on the basis of:
  - The per gallon cost of Diesel fuel, and
  - Project energy as limited by the lower value of system load and available water.
- The O&M cost for the Diesel alternative is based on the respective value for each case.
- The fixed cost for the Project alterative includes the debt service and the interest on reserves for each of the three cases under consideration.
- The variable costs for the Project alternative include the O&M, Administrative & General and Insurance costs for each case.
- All fixed costs are de-escalated by the discount rate over the 50-year horizon 2013 to 2063 for each case.
- All variable costs remain constant over the 50-year horizon 2013 to 2063 on the basis of equal values for the discount and escalation rates.

6.3 Cost Comparisons – Project vs. Diesel

The comparison of the $/kWh cost of the Project and Diesel alternatives are shown graphically in three ways as follows:

1. The annual $/kWh Project-Base Case and Diesel-Medium Projection values are plotted in **Figure 6.2**.
2. The annual $/kWh Project-Upper and Lower Limit cases and the Diesel-Medium Projection values are plotted in **Figure 6.3**.
3. The annual $/kWh Project-Base Case and Diesel-High and Low Fuel Price values are plotted in **Figure 6.4**.

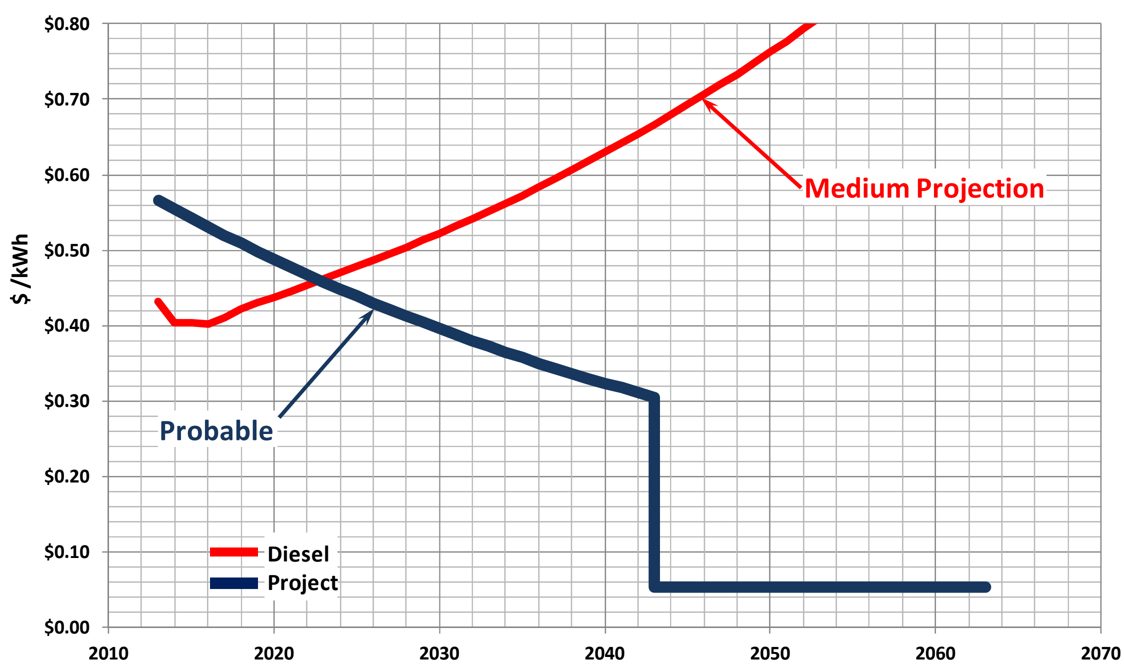

Figure 6.2 Project-Base Case vs. Diesel-Medium Projection (2013 Dollars)

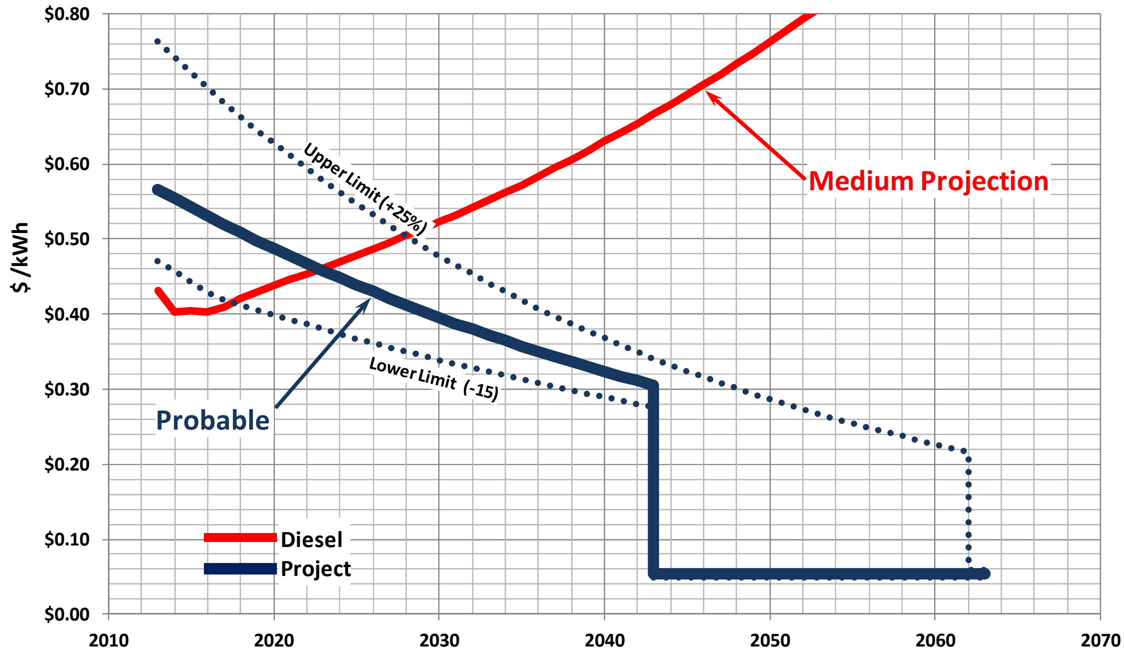

Figure 6.3 Project-Upper and Lower Limits vs. Diesel-Medium Projection (2013 Dollars)

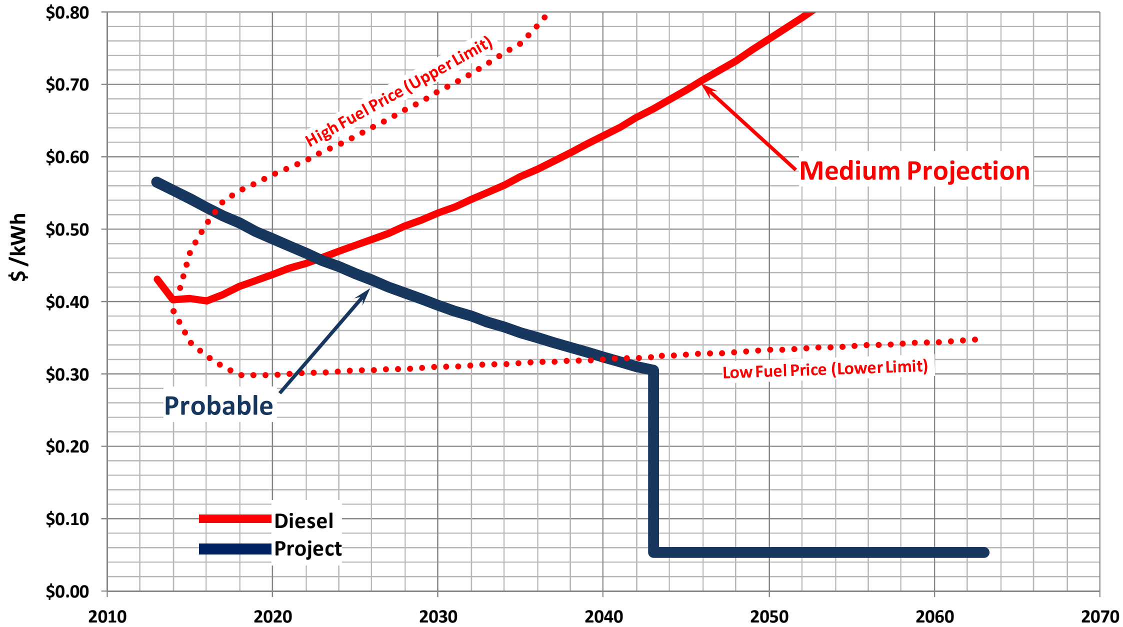

Figure 6.4 Project-Base Case vs. Diesel-High and Low Fuel Prices (2013 Dollars)

7. Conclusions and Recommendations

7.1 Conclusions

- Design and construction of the Project is technically feasible.
- The primary generation features of the Project would consist of:
  - A gravity roller compacted concrete dam providing a normal maximum water surface at El 660,
  - A 900 foot-long power tunnel including a 540 foot-long 13'x19.5' concrete lined horseshoe section and 360 foot-long 16.5' diameter steel lined section,
  - A four unit, 22 MW powerhouse, and
  - A 138 kV - 136 mile and a 69 kV - 119 mile transmission line to the Bethel and Dillingham load centers respectively.
- Completion of the Project would require a minimum of three construction seasons.
- Project construction access is feasible only by air. A landing strip suitable for a Lockheed C-130 cargo airplane would be required.
- The potential average annual energy of the Project is approximately 78 GWh.
- The Project as presented herein demonstrates economic feasibility to a level that supports completion of the technical and environmental studies as would be required for the preparation of a Final Feasibility Report for the Project.

7.2 Recommendations

It is recommended that further review of the feasibility of a hydropower project at Chikuminuk Lake include the following specific studies on the basis of their being critical to the refinement of project features and project operation in support of a final feasibility level opinion of the probable construction cost and an assessment of economic feasibility:

- *Geotechnical*.
  - Geophysical survey in conjunction with a drilling program should be performed within the Y-Pass area and morainal ridges to better define the depth to bedrock and permeability in critical areas.
  - Assessment of the availability of quality on-site aggregate.
  - Subsurface investigations for the tunnel to characterize rock, ground water conditions, and tunnel support requirements and the dam site to assess the foundations conditions at the base and at both abutments.
- *Hydrological*. Continued stream gage data collection on Allen River and NW Passage.
- *Environmental*.
  - A determination of the fish populations along with the availability and usage of the habitat on the lower, middle and upper reaches of the Allen River.
  - An evaluation of the spawning habitat on Lake Chauekuktuli.

8. References

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FIGURES
PREFERRED PROJECT ARRANGEMENT

Plotted: Dec 02, 2013 – 1:14pm
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-1.dwg

HATCH
December 2013

FIGURE 1
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
PROJECT LOCATION

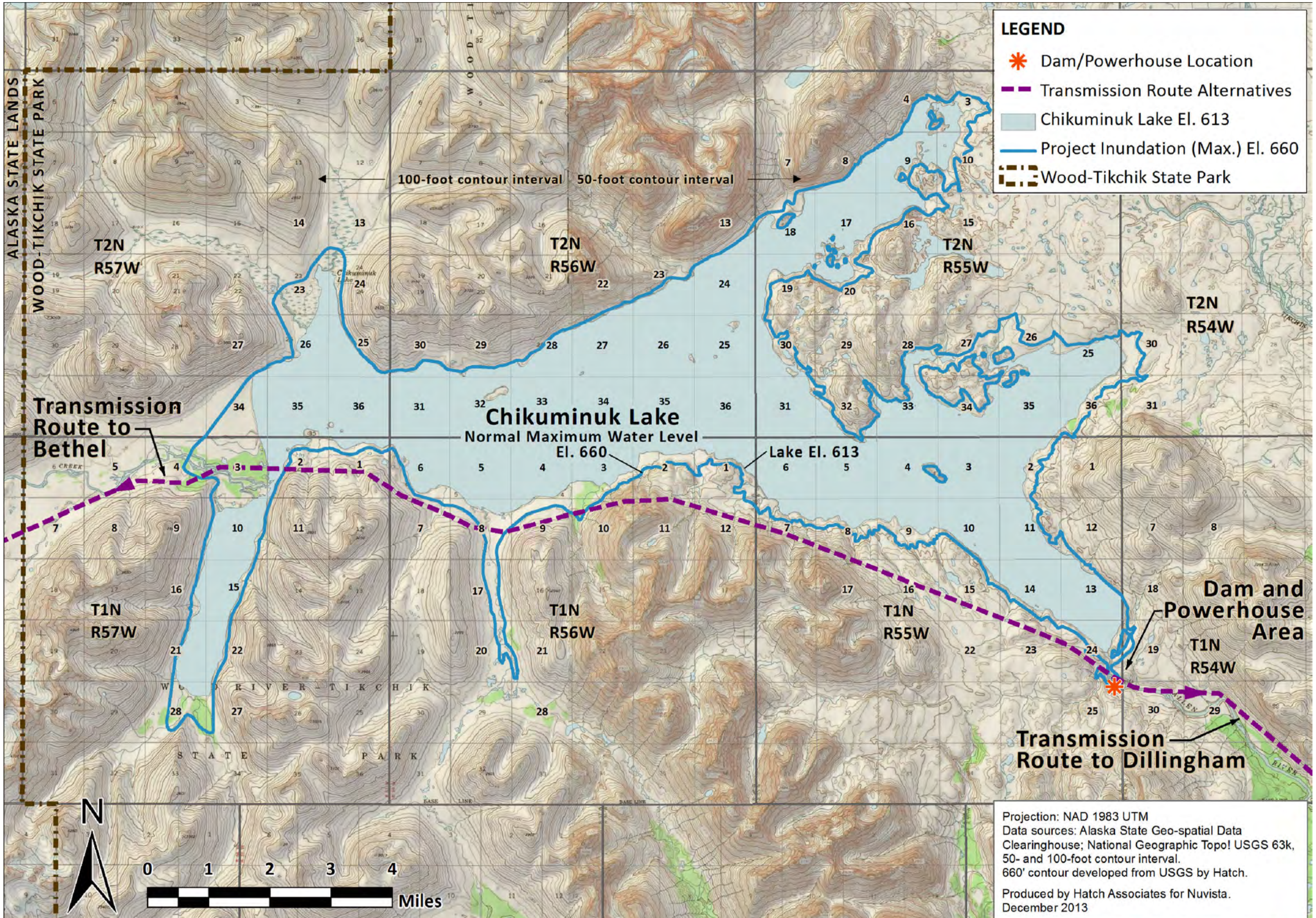
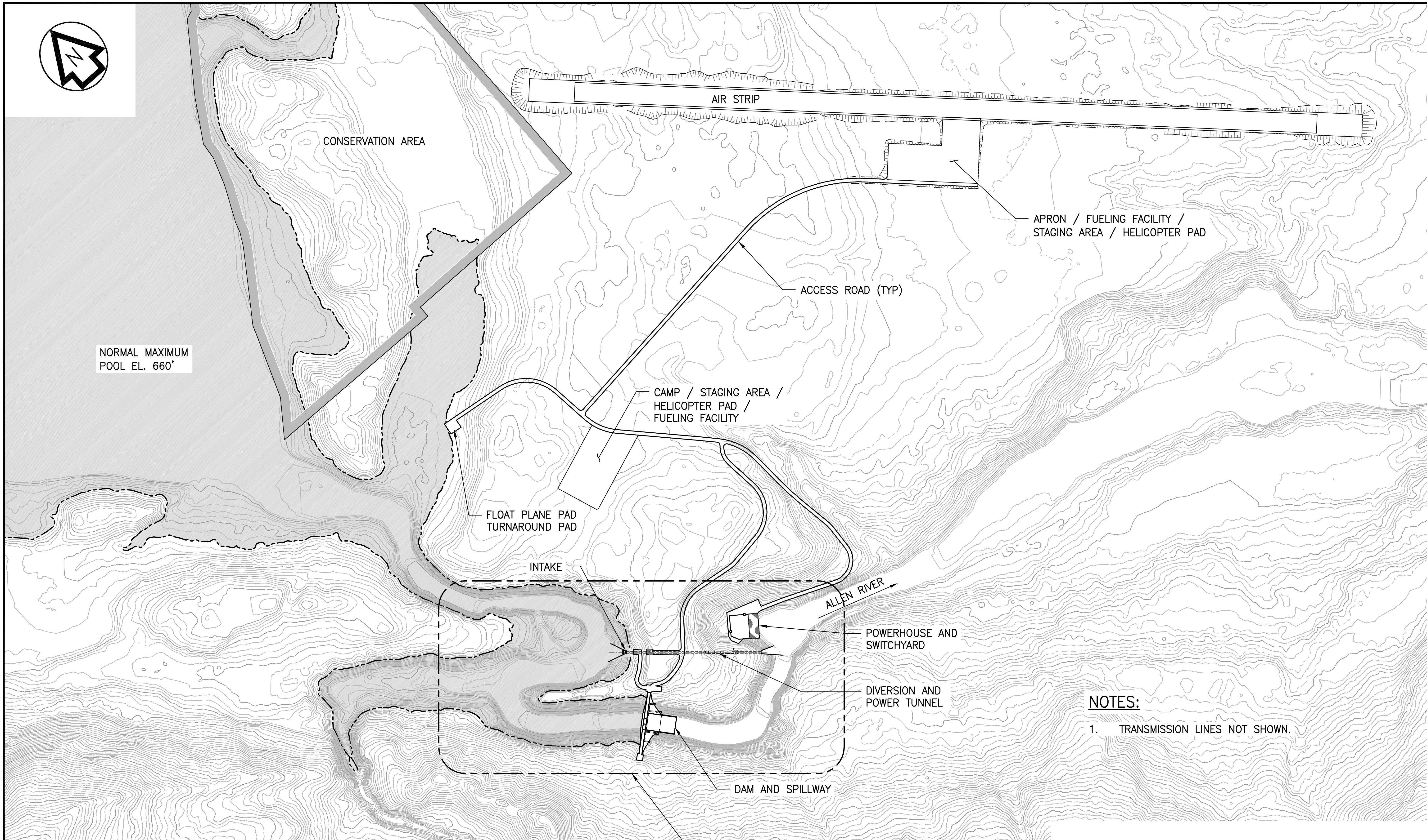


FIGURE 2
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
PROJECT BOUNDARY

HATCH
December 2013

Plotted: Dec 05, 2013 – 10:11am
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-2.dwg



NOTES:

1. TRANSMISSION LINES NOT SHOWN.

Plotted: Dec 03, 2013 – 2:50pm
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-3.dwg

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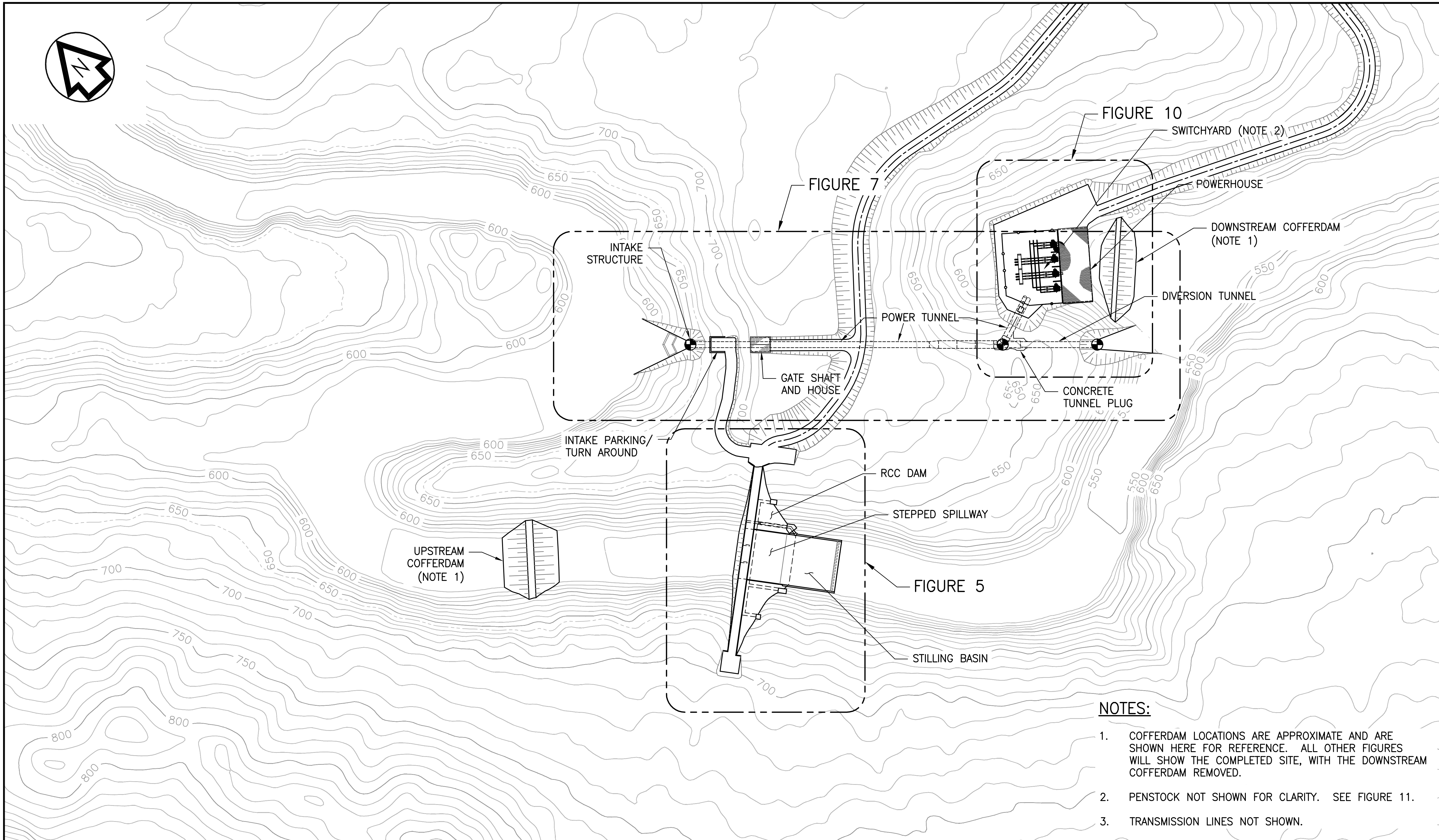
December 2013

FIGURE 3
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
PROJECT FACILITIES - GENERAL ARRANGEMENT



NOTES:

1. COFFERDAM LOCATIONS ARE APPROXIMATE AND ARE SHOWN HERE FOR REFERENCE. ALL OTHER FIGURES WILL SHOW THE COMPLETED SITE, WITH THE DOWNSTREAM COFFERDAM REMOVED.
2. PENSTOCK NOT SHOWN FOR CLARITY. SEE FIGURE 11.
3. TRANSMISSION LINES NOT SHOWN.

Plotted: Dec 04, 2013 – 3:37pm
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-4.dwg

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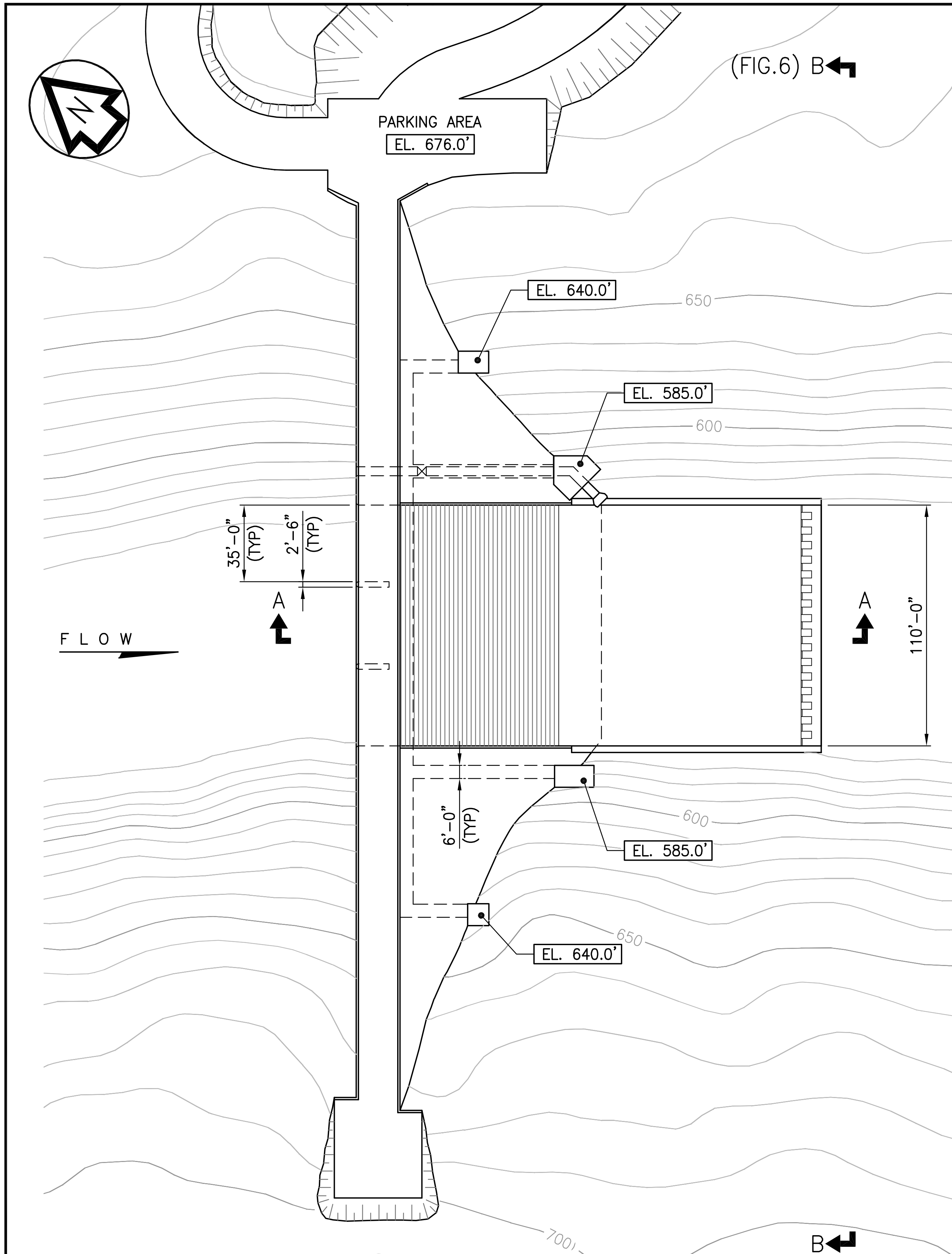
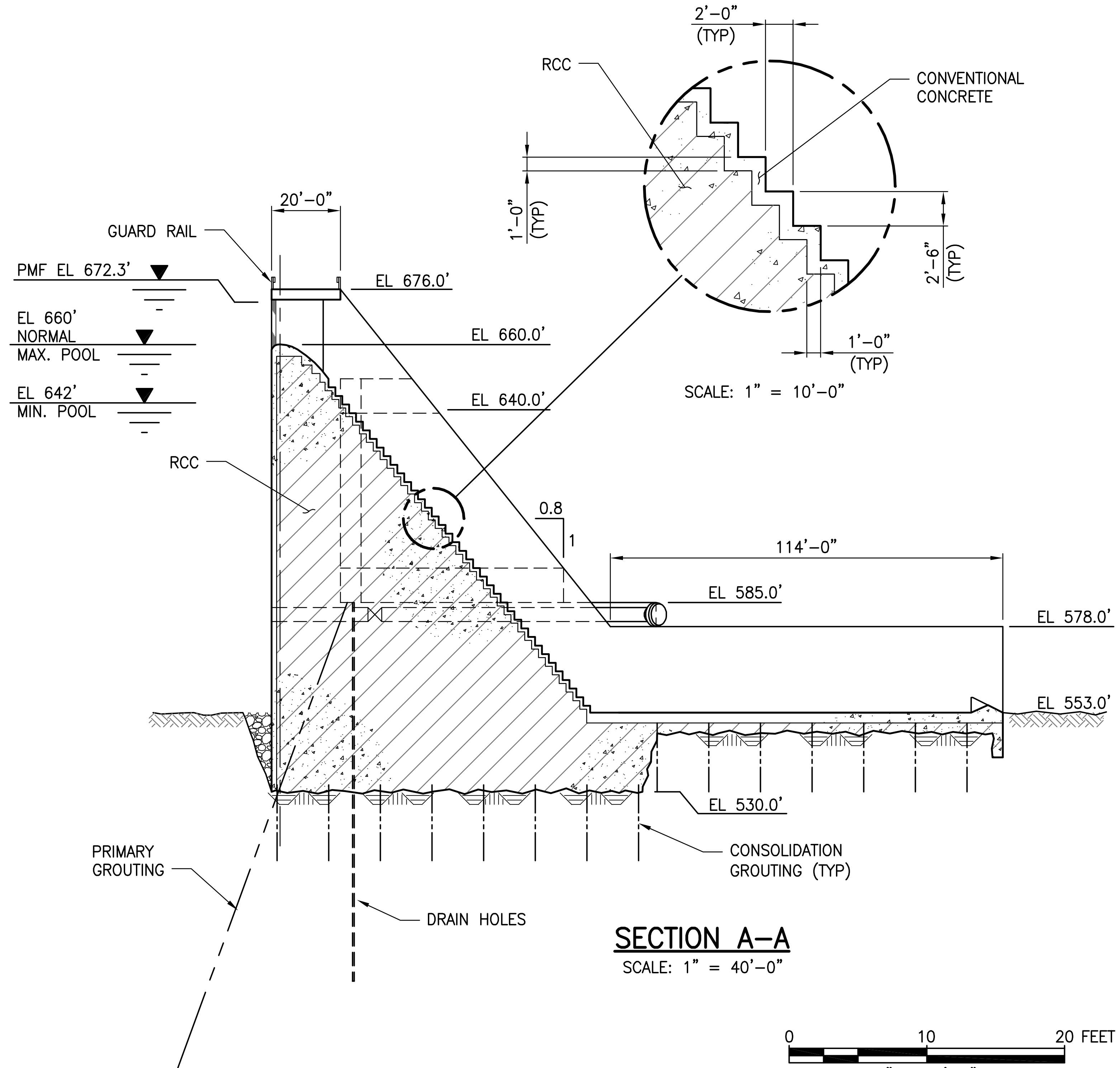
FIGURE 4
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
HYDROELECTRIC FACILITIES - GENERAL ARRANGEMENT - SITE PLAN



PLAN

SCALE: 1" = 60"-0"



SECTION A-A

SCALE: 1" = 40'-0"

0 10 20 FEET
1" = 10'-0"

0 40 80 FEET
1" = 40'-0"

0 60 120 FEET
1" = 60'-0"

Plotted: Dec 05, 2013 - 10:14am
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-5.dwg

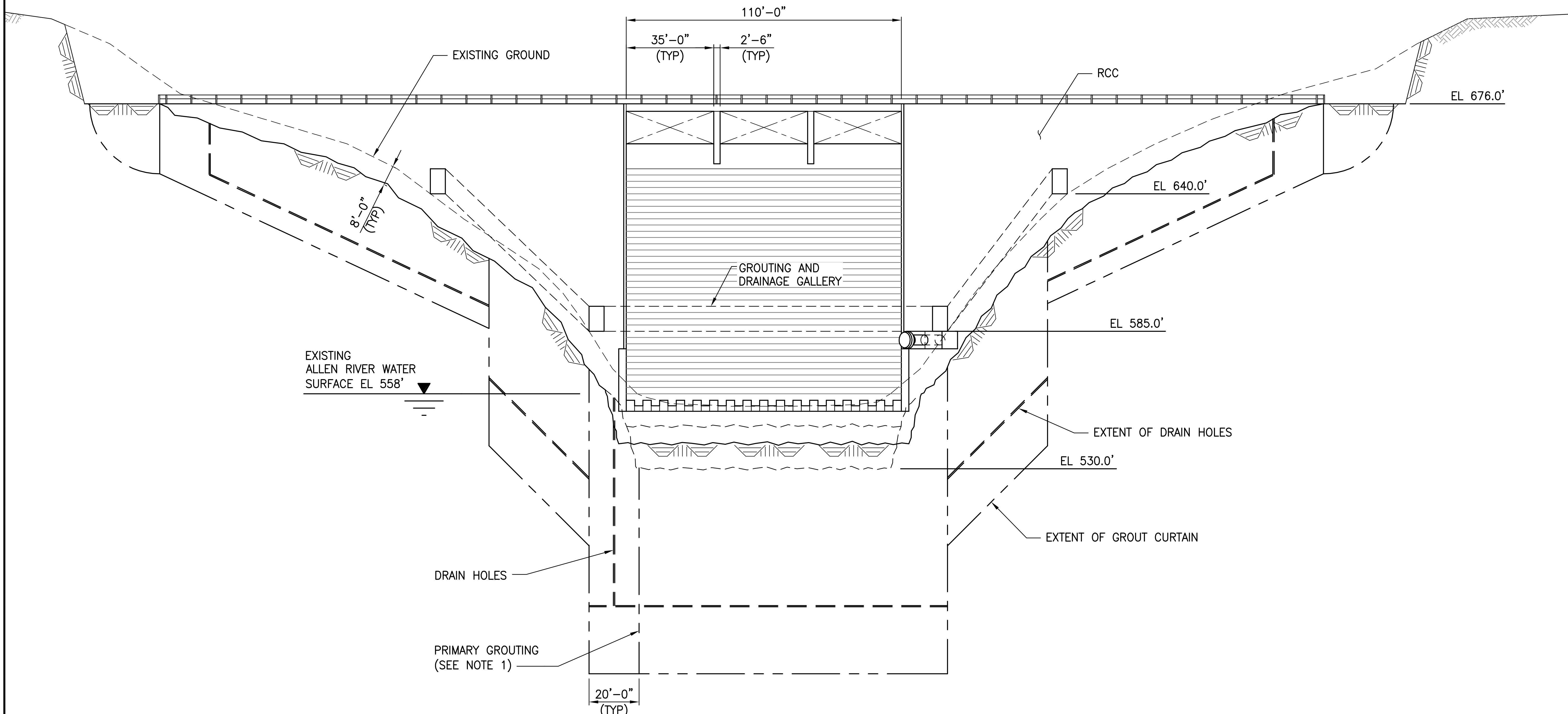
HATCH
December 2013

FIGURE 5

Nuvista Light and Electric Cooperative, Inc.

Chikuminuk Lake Hydroelectric Project

DAM / SPILLWAY - GENERAL ARRANGEMENT



SECTION B–B (FIG. 5)
SCALE: 1" = 40'-0"

NOTES:

1. PRIMARY GROUT HOLES NOT SHOWN FOR CLARITY. SECONDARY AND TERTIARY GROUT HOLES NOT SHOWN.

Plotted: Dec 05, 2013 – 9:10am
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-6.dwg

HATCH
December 2013

0 40 80 FEET
1" = 40'-0"

FIGURE 6
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
DAM - DOWNSTREAM ELEVATION VIEW

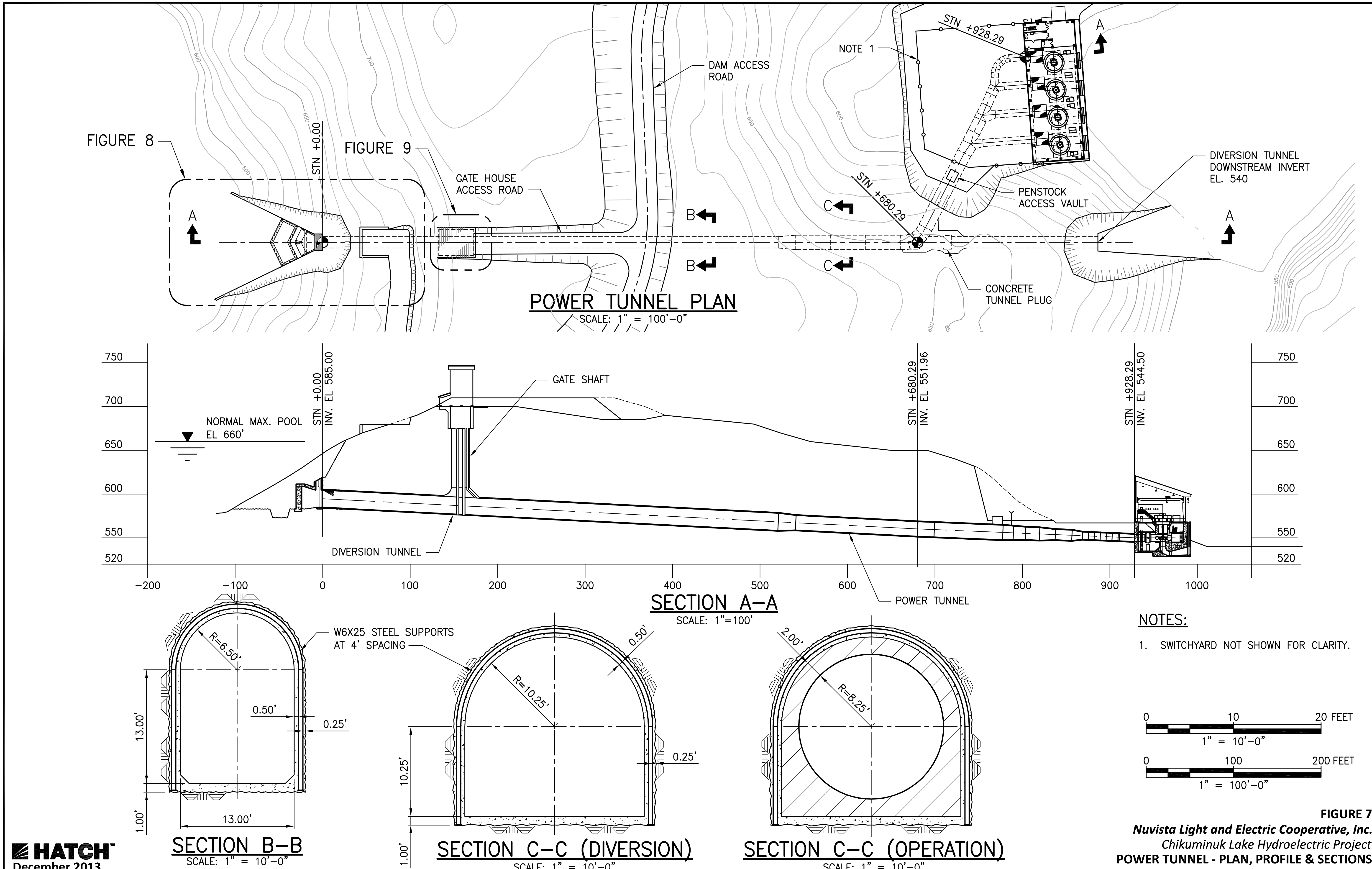


FIGURE 7

Nuvista Light and Electric Cooperative, Inc.

Chikuminuk Lake Hydroelectric Project

POWER TUNNEL - PLAN, PROFILE & SECTIONS

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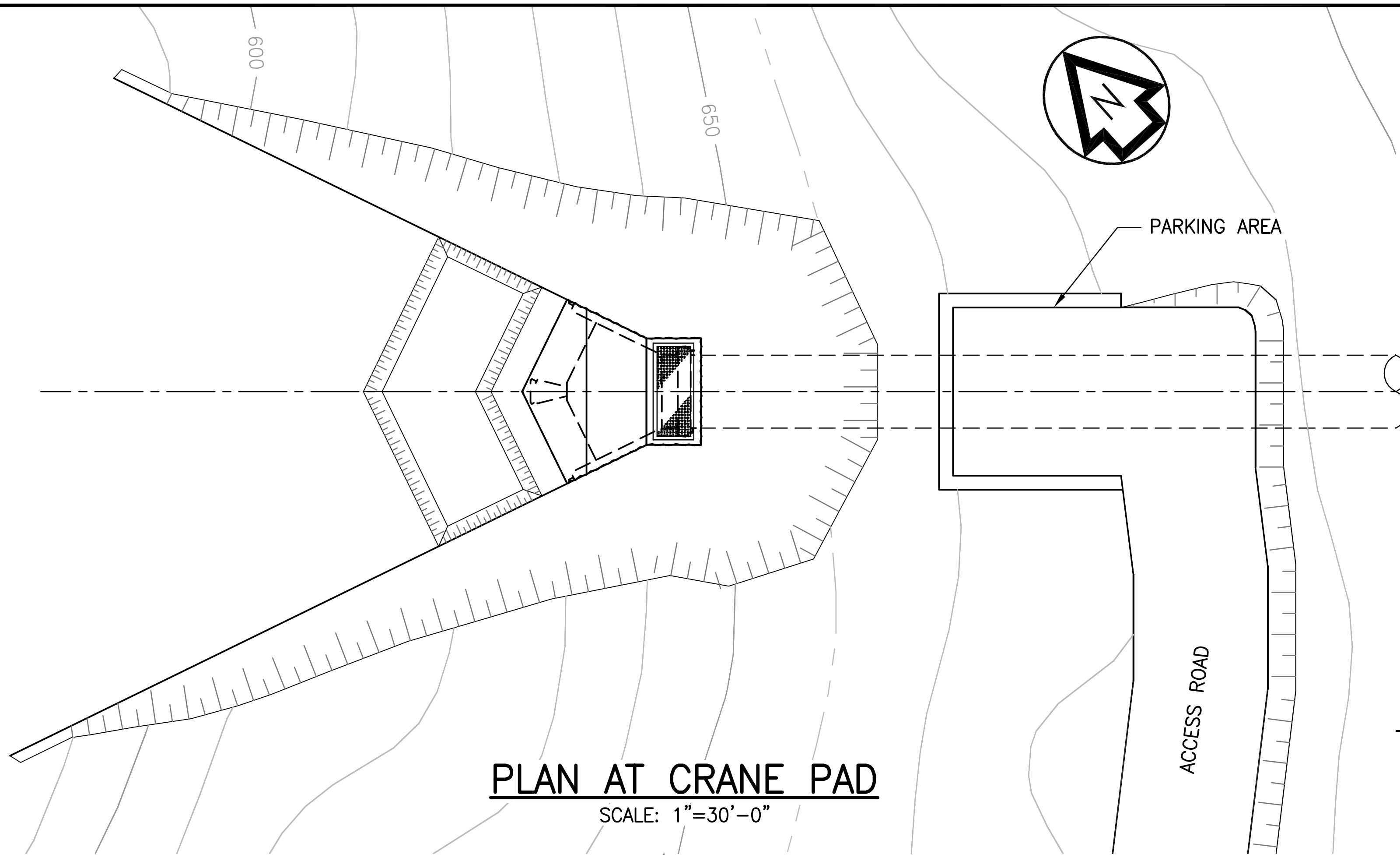
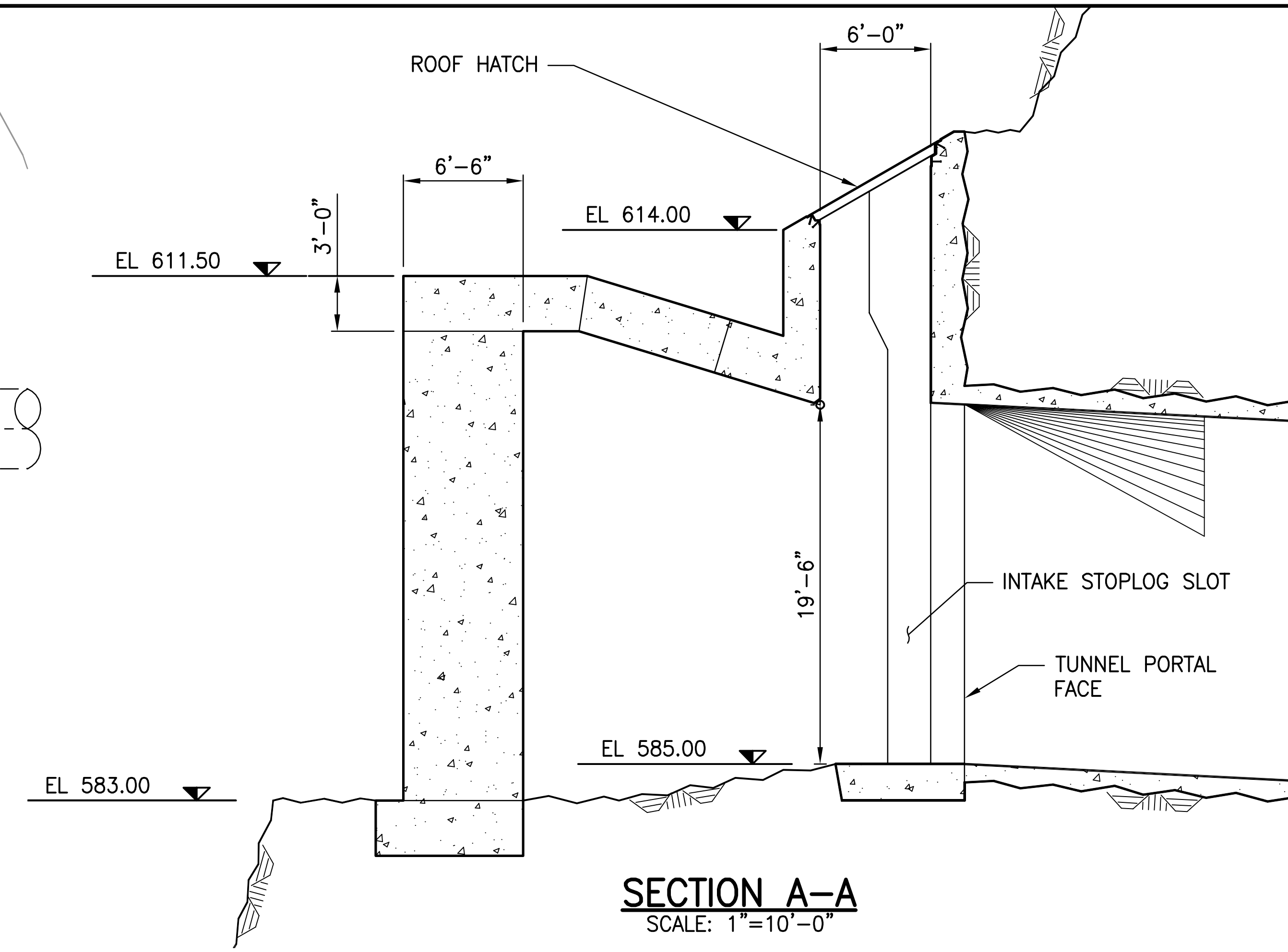
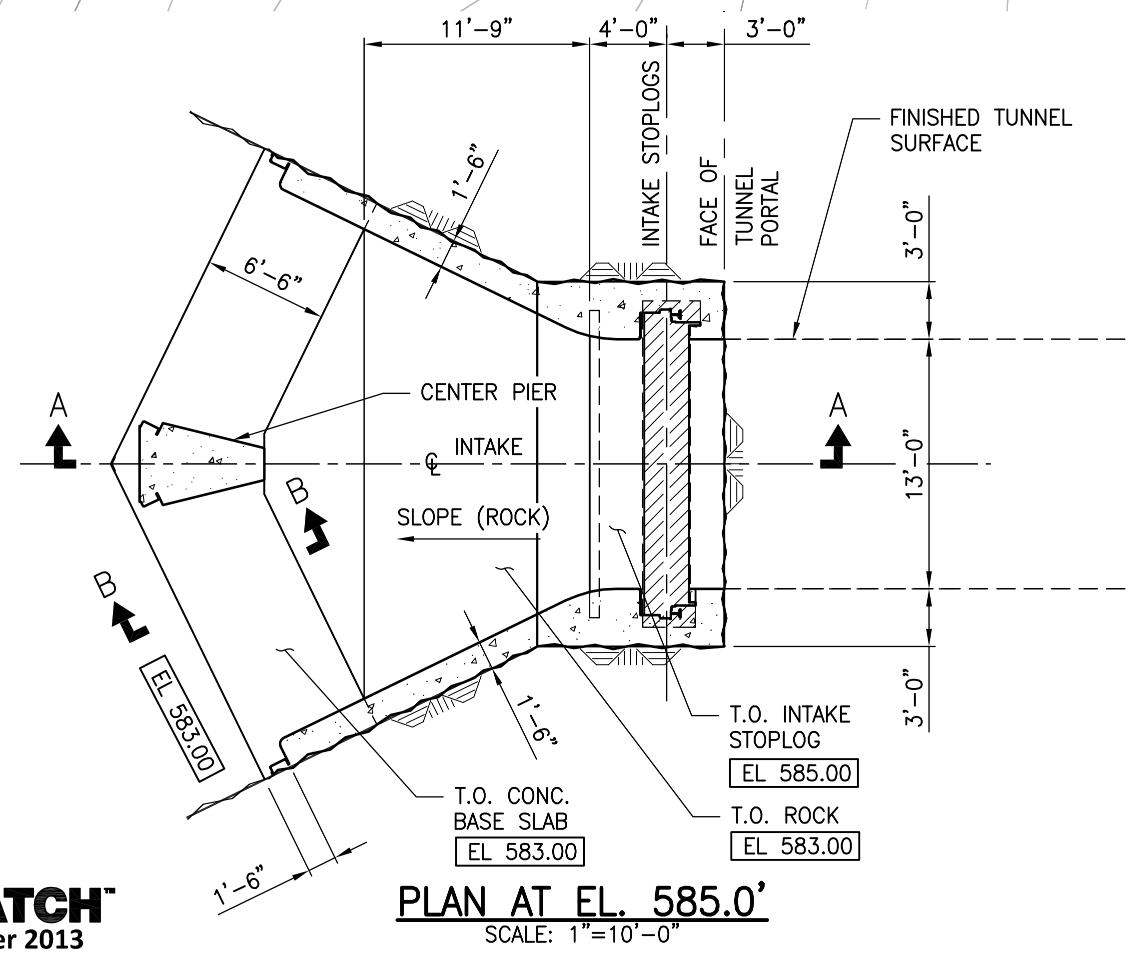
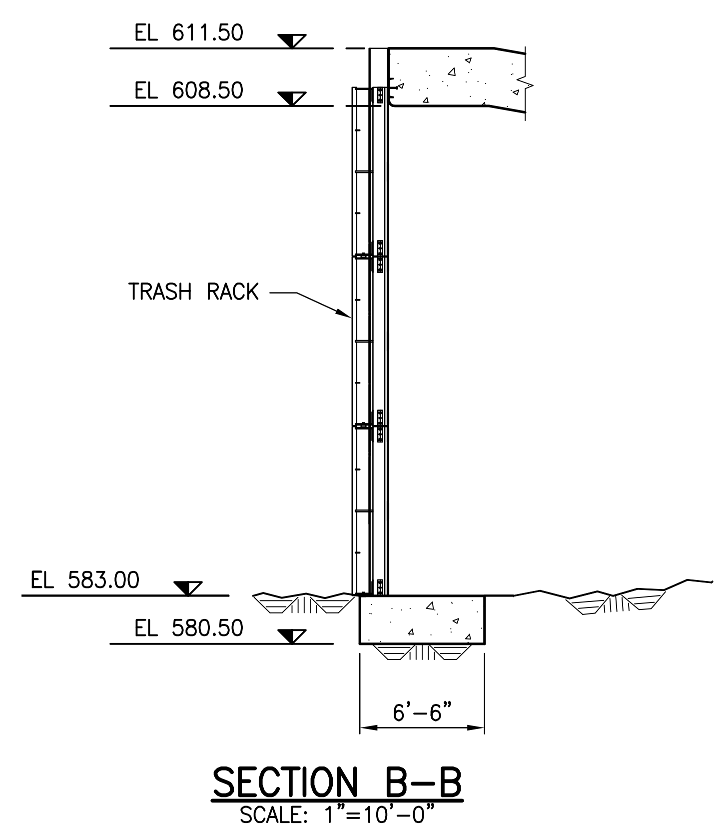
December 2013

Plotted: Dec 02, 2013 – 11:24am
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-7.dwg









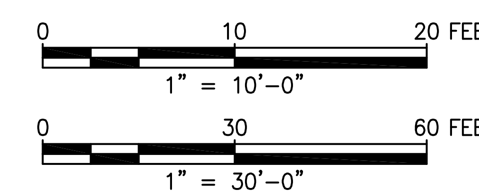


FIGURE 8

Nuvista Light and Electric Cooperative, Inc.

Chikuminuk Lake Hydroelectric Project

INTAKE STRUCTURE - PLAN & SECTIONS

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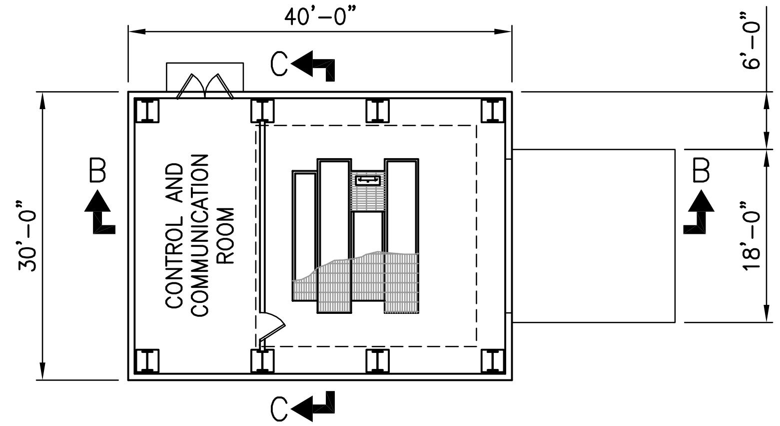
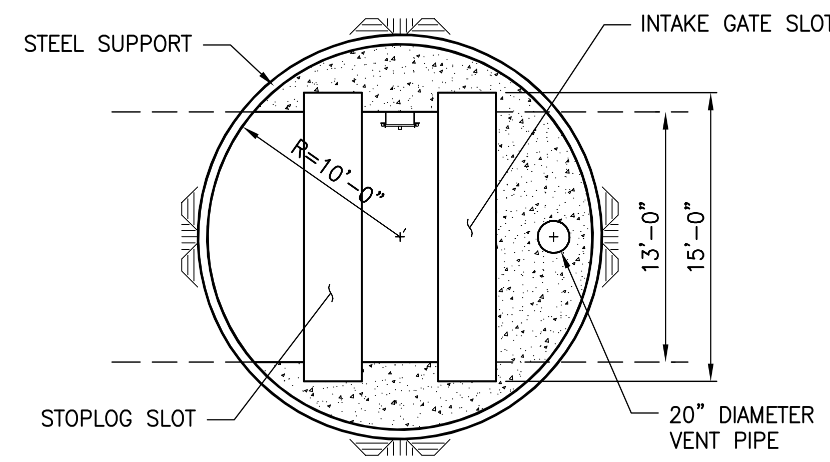
Plotted: Dec 02, 2013 – 11:31am
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-8.dwg



PLAN
SCALE: 1" = 20'-0"



SECTION A–A
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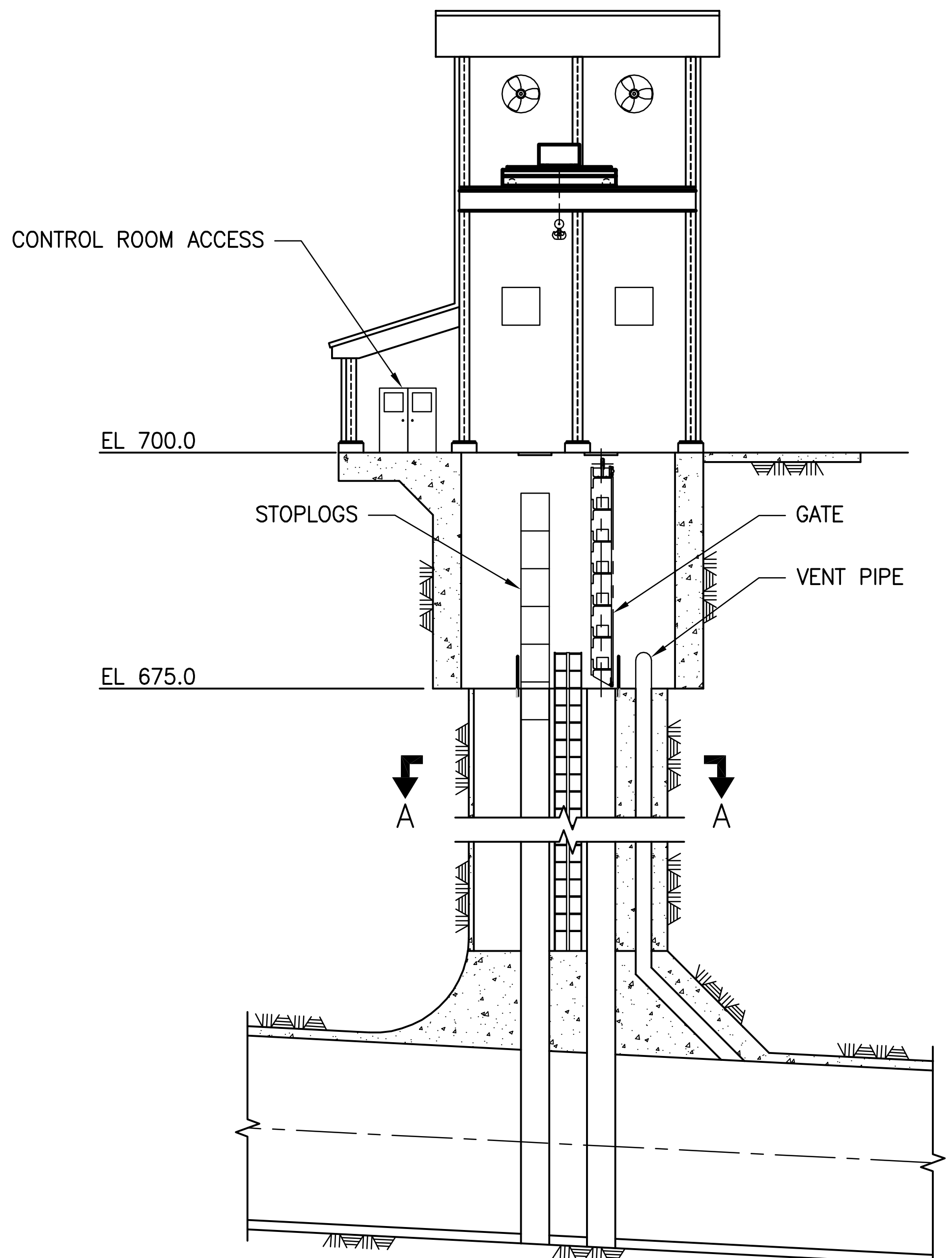
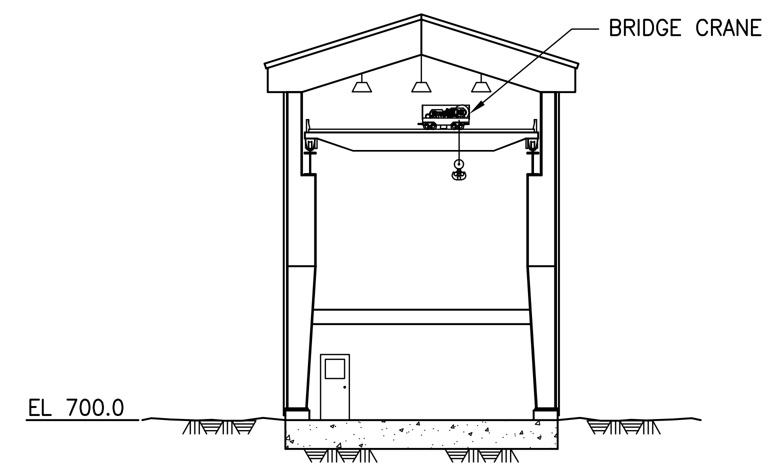


SECTION B–B
SCALE: 1" = 20'-0"



SECTION C–C
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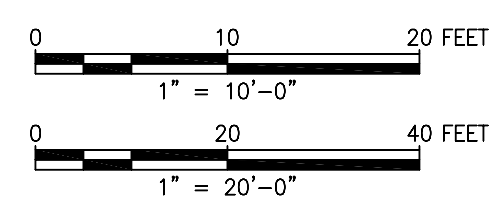

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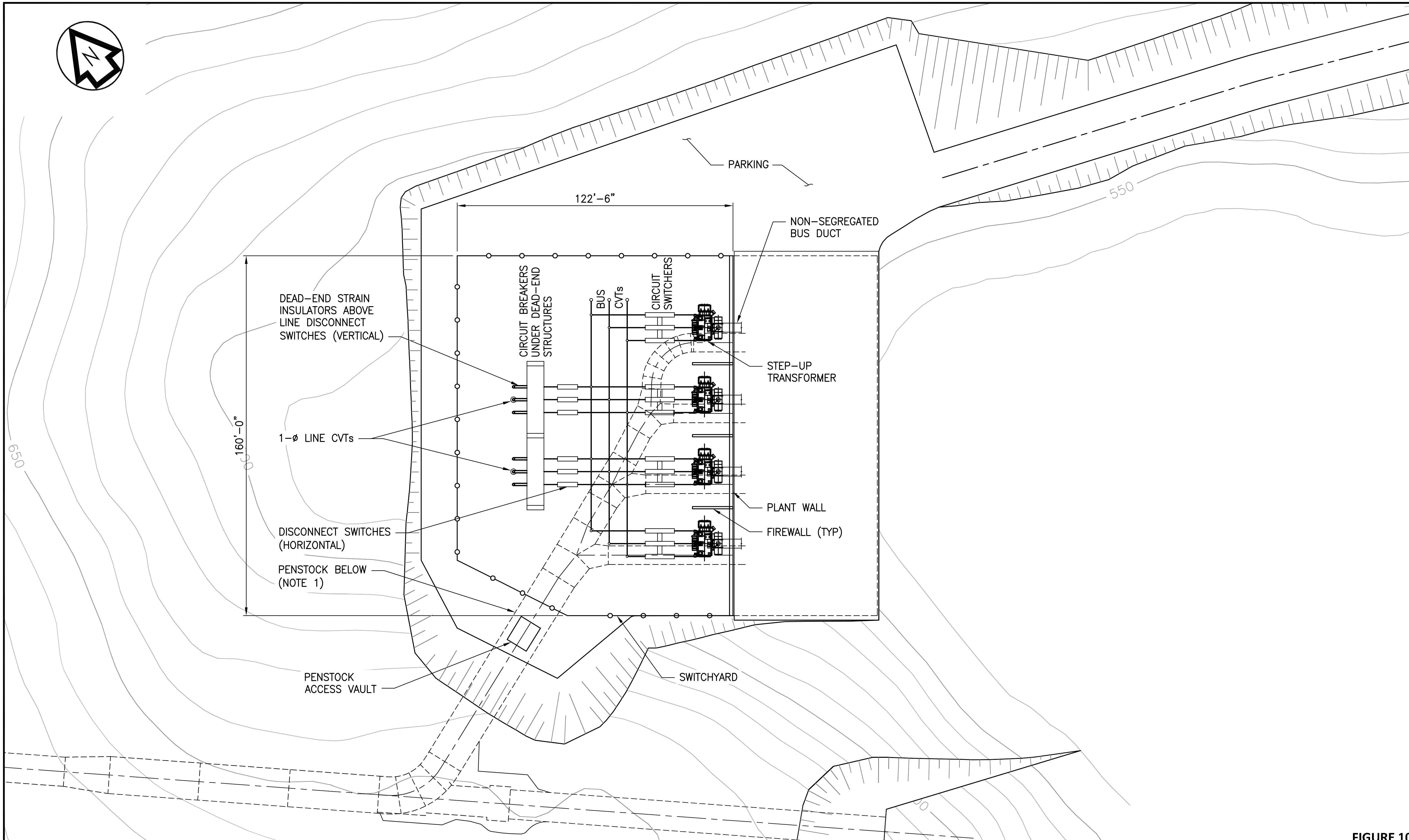
FIGURE 9
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
GATE SHAFT & HOUSE - PLAN & SECTIONS

Plotted: Dec 02, 2013 – 11:35am
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-9.dwg



POWERHOUSE AREA PLAN @ EL. 567.0'

SCALE: 1" = 40'-0"

0 40 80 FEET

1" = 40'-0"

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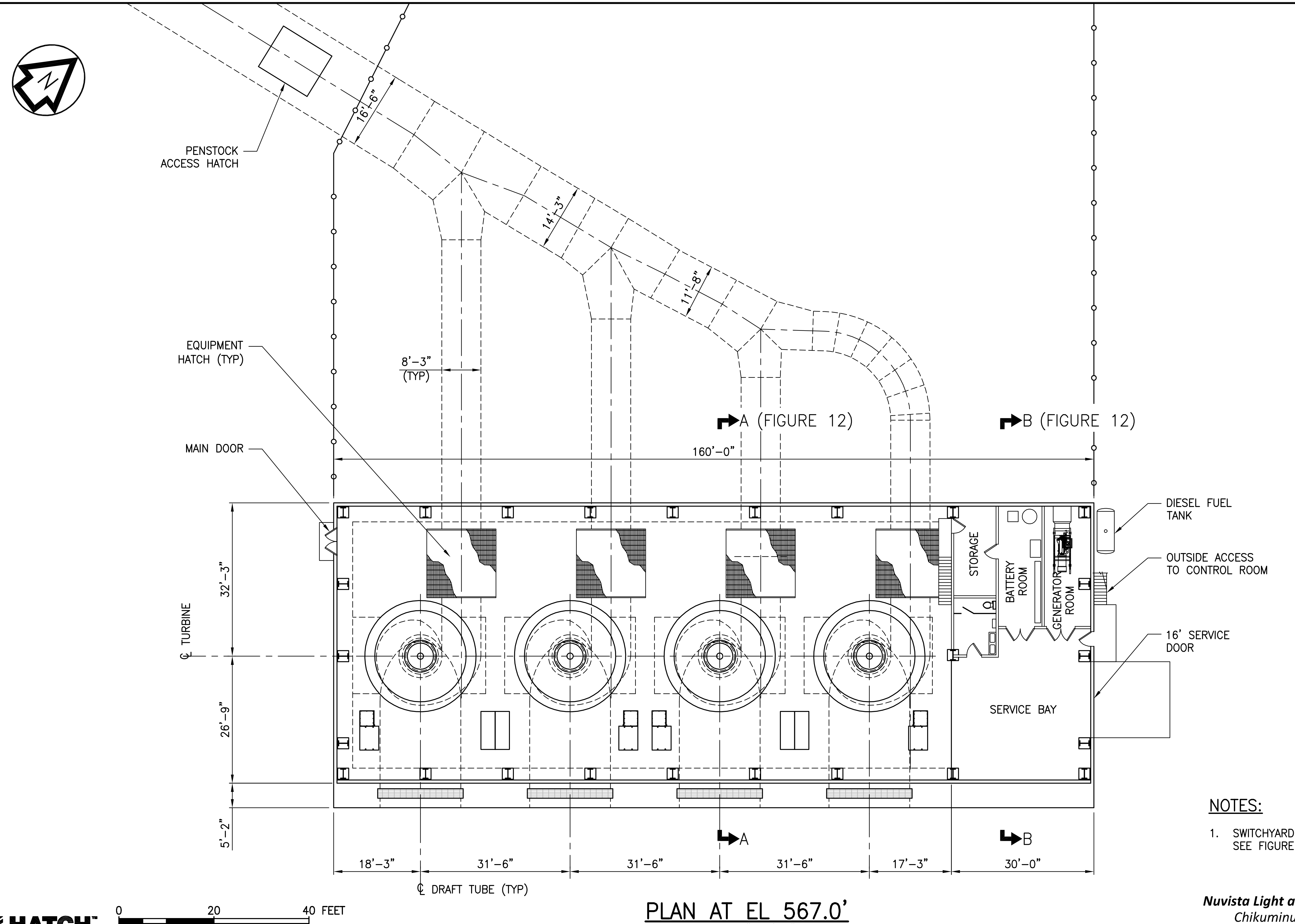
December 2013

Plotted: Dec 02, 2013 – 11:53am
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-10.dwg

FIGURE 10
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
POWERHOUSE - AREA SITE PLAN



PLAN AT EL 567.0'

SCALE: 1"=20'-0"

NOTES:

1. SWITCHYARD NOT SHOWN FOR CLARITY. SEE FIGURE 8.

FIGURE 11

Nuvista Light and Electric Cooperative, Inc.

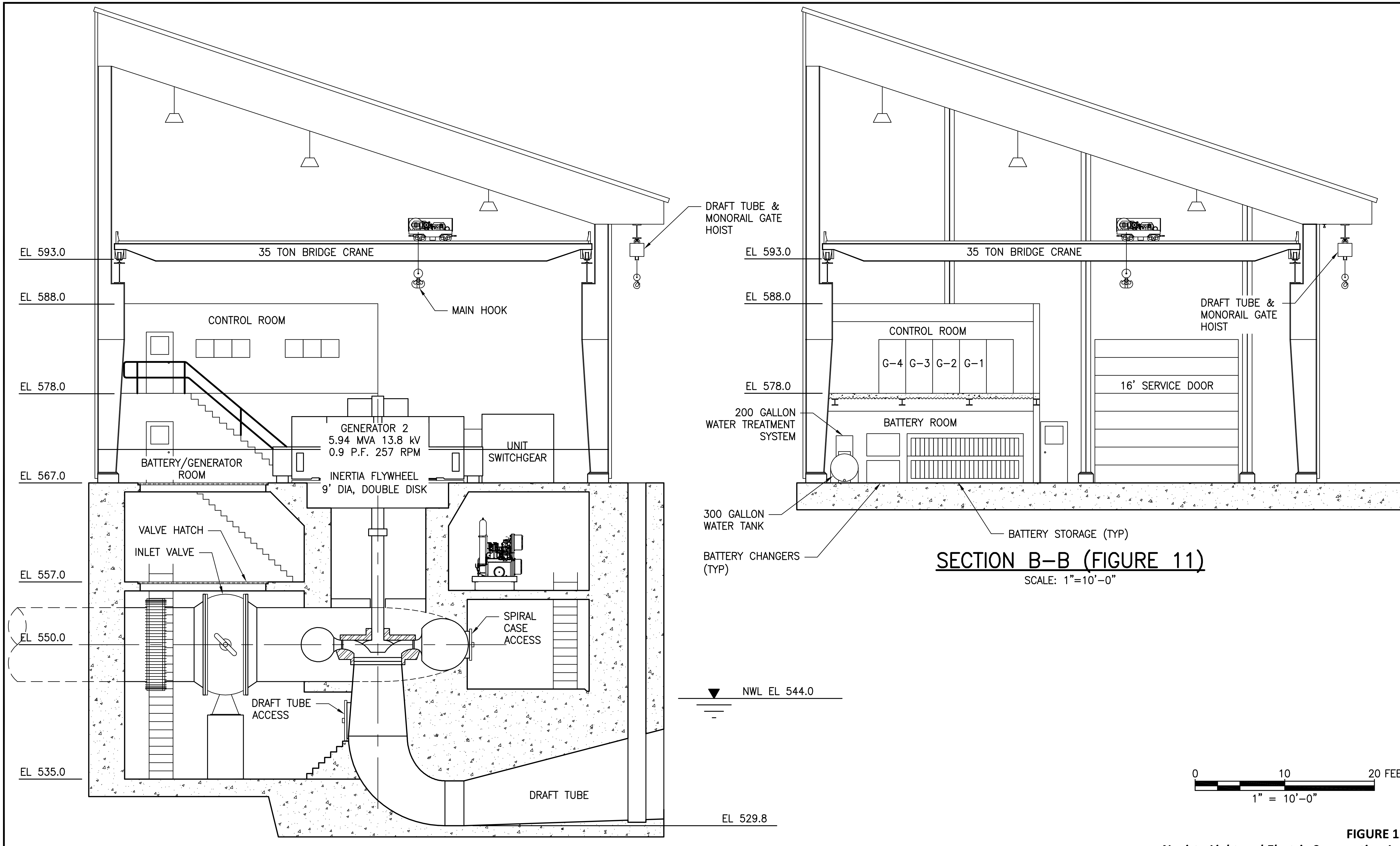
Chikuminuk Lake Hydroelectric Project

POWERHOUSE & PENSTOCK - PLAN

HATCH

December 2013

Plotted: Dec 02, 2013 – 12:42pm
Drawing: P:\NUVISTA\342022\CAD\10\FIGURE-11.dwg



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Drawing: P:\NUVISTA\342022\CAD\10\FIGURE–12.dwg

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December 2013

FIGURE 12
Nuvista Light and Electric Cooperative, Inc.
Chikuminuk Lake Hydroelectric Project
POWERHOUSE - GENERAL ARRANGEMENT - SECTIONS

Chikuminuk Lake Hydroelectric Project
FERC No. 14369

Interim Feasibility Report
Volume I – Technical Studies

Appendix A – Y-Pass Preliminary Geologic Evaluation

DRAFT April, 2014

Prepared By:

HATCH™

R&M CONSULTANTS, INC.
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3504 Industrial Avenue #102 • Fairbanks, AK 99701 • 907.452.5270
9737 Mud Bay Road #301 • Ketchikan, AK 99901 • 907.220.9424

Memorandum

To: Dick Griffith, P.E.

From: Aaron Banks, C.P.G.

Subject: Y-Pass Preliminary Geologic Evaluation

Date: October 28, 2013

Project #: 1806.02

Nuvista Light and Electric Cooperative, Inc. (Nuvista) is currently conducting studies at Chikuminuk Lake for a proposed hydroelectric project. An area referred to as Y-Pass is expected to lie within the inundation zone and is underlain by unknown materials. The area is approximately only 57 to 125 feet higher than the proposed maximum reservoir elevation. Seepage into Lake Chauekuktuli could occur if thick deposits of permeable materials are present. R&M Consultants, Inc. (R&M) was tasked by Hatch Associates Consultants, Inc. (Hatch) to provide a geologic evaluation for the Y-Pass area. This preliminary geologic evaluation will be used for the planning of future field and office studies relating to the potential for seepage through the Y-Pass area from Chikuminuk Lake to Lake Chauekuktuli.

Regional Geology

Chikuminuk Lake lies within the Ahklun Mountains physiographic province (Wahrhaftig, 1965), consisting of rugged steep-walled mountains, having sharp summits 2,000 to 5,000 feet in altitude, separated by broad flat valleys and lowlands. The entire area was covered with glacial ice during advances of late Pleistocene-age (Coulter et al., 1965), as evidenced by the local topography and soil stratigraphy. This region is considered to be underlain by isolated masses of permafrost (Ferrains, 1965).

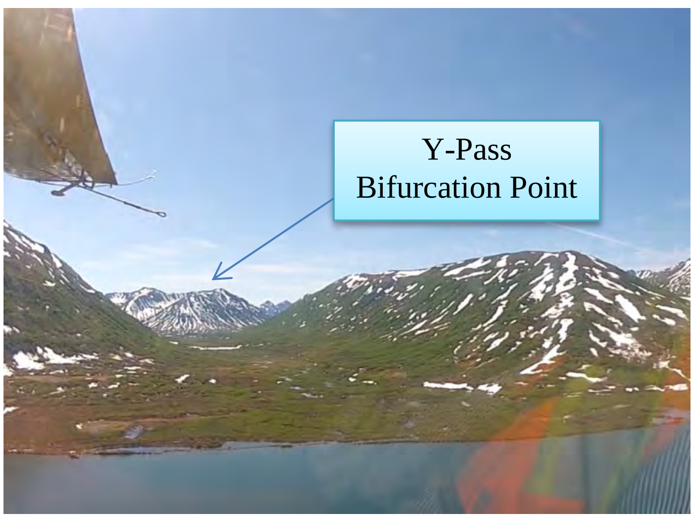
The project area lies within the Tikchik subterrane which occurs in the northern Tikchik Lakes area, southeast of the Togiak-Tikchick fault (Denali-Farewell fault system). The Tikchick subterrane is a structurally complex assemblage (mélange) of clastic rocks, radiolarian chert of Paleozoic and Mesozoic age, Permian limestone and clastic rocks, Permian or Triassic pillow basalt and graywacke, and Upper Triassic clastic and mafic volcanic rocks (Decker et al., 1994)

Little more than what is described above is known about the Tikchik subterrane. The Tikchik subterrane is an apparently chaotic assemblage of blocks, particularly chert, of Ordovician, Triassic, Jurassic and Early Cretaceous age, and of limestone of Permian age. The matrix is mainly graywacke, argillite, tuff and mafic volcanic rock, although blocks of different ages commonly are juxtaposed without intervening matrix. Some of these blocks are quite large (kilometer-scale) and are structurally and stratigraphically coherent. The age(s) of deformation is uncertain, but predates deposition of the unconformably overlying clastic rocks of mid-Cretaceous age (Decker et al., 1994).

Y-Pass Conditions

Y-Pass is a U-shaped glacially carved valley located on the south shore of Chikuminuk Lake approximately 10 miles west of the proposed dam site. The valley is oriented roughly north-south and discharges into Chikuminuk Lake. Approximately 3 miles from the lake shore, the valley bifurcates into a southwest-northeast and southeast-northwest trending valley (Figures 1 and 2).

The main valley is rimmed by bedrock ridges to approximately 2,500 feet in elevation. At the bifurcation point, the valley splits around a headwall of approximately 2,400 feet in elevation. At this point, both valleys continue to gently climb to their passes at an elevation of approximately 800 feet within the west fork and an elevation of 730 feet within the east fork. After topping out at each of their respective passes, the valleys then descend toward the southeast before discharging into Lake Chauekuktuli.



Regional geology, local terrain unit mapping (R&M, 2012) and a review of satellite imagery (GeoEye, 2012) indicate that Y-Pass is underlain by bedrock at varying depths. This bedrock is overlain on moderate slopes and low-lying areas by soil deposits consisting of glacial drift and outwash, alluvial materials, organic deposits and colluvium.

For the purposes of this preliminary evaluation, a reference elevation of 613 feet was established for the existing lake elevation. This elevation was based on the Digital Terrain Model (DTM) created in the fall of 2012 (GeoEye, 2012). A maximum inundation zone of the proposed reservoir was also established by assuming a total of 47 feet would be added to the current lake level, resulting in a maximum inundation elevation of 660 feet. This area of inundation is presented on both Figures 1 and 2.

It should be noted that published USGS topographic quadrangle mapping, current as of 1976, indicates a lake elevation of 598 feet. The discrepancy of 15 feet between the DTM and USGS lake elevations is not surprising given the different timeframes and available technologies.

Although depth to bedrock at both forks of Y-Pass is currently indeterminable, some exposed bedrock has been interpreted within some lower-lying areas of the eastern fork of Y-Pass. This exposed bedrock was identified through satellite imagery interpretation and was only mapped where visible rock was present and landforms indicated bedrock morphology. It should be noted that terrain units were not mapped as that effort fell outside the scope of this preliminary evaluation.

Within the western fork of Y-Pass (Figure 3), no exposed bedrock was identified. The western fork of Y-Pass tops out at a maximum elevation of greater than approximately 798 feet. A more precise elevation could not be determined as the western fork pass lies outside of the DTM boundary.

Although exposed bedrock was not identified in the western fork, it does have the advantage of lying at a higher elevation than the eastern fork. Soil deposits greater than 125 feet thick would need to be present for seepage through soil units to occur. Based on local geo-morphology, bedrock potentially lies at depths shallower than 125 feet deep.

Within the eastern fork of Y-Pass (Figure 4), exposed bedrock was interpreted close to the valley floor at a minimum elevation of approximately 740 feet. Although this exposed bedrock is located on the Chauekuktuli side of the pass and upslope from the main drainage, it indicates that bedrock could potentially underlie the eastern fork of Y-Pass at shallow depth. The maximum elevation of the pass is approximately 57 feet above the proposed maximum reservoir elevation. However, based on currently available data, it appears likely that bedrock occurs in the pass at an elevation above the proposed reservoir.

Conclusion and Recommendations

Preliminary evaluation of both the western and eastern fork of Y-Pass indicates a potential for bedrock to lie at an elevation which could reduce or preclude seepage of the proposed reservoir through permeable soil units.

Prior to the feasibility/design phase of the project, a geotechnical investigation should be performed within the Y-Pass area to better define the depth to bedrock in critical areas. Components of the investigation should include a geophysical survey in conjunction with a drilling program.

References

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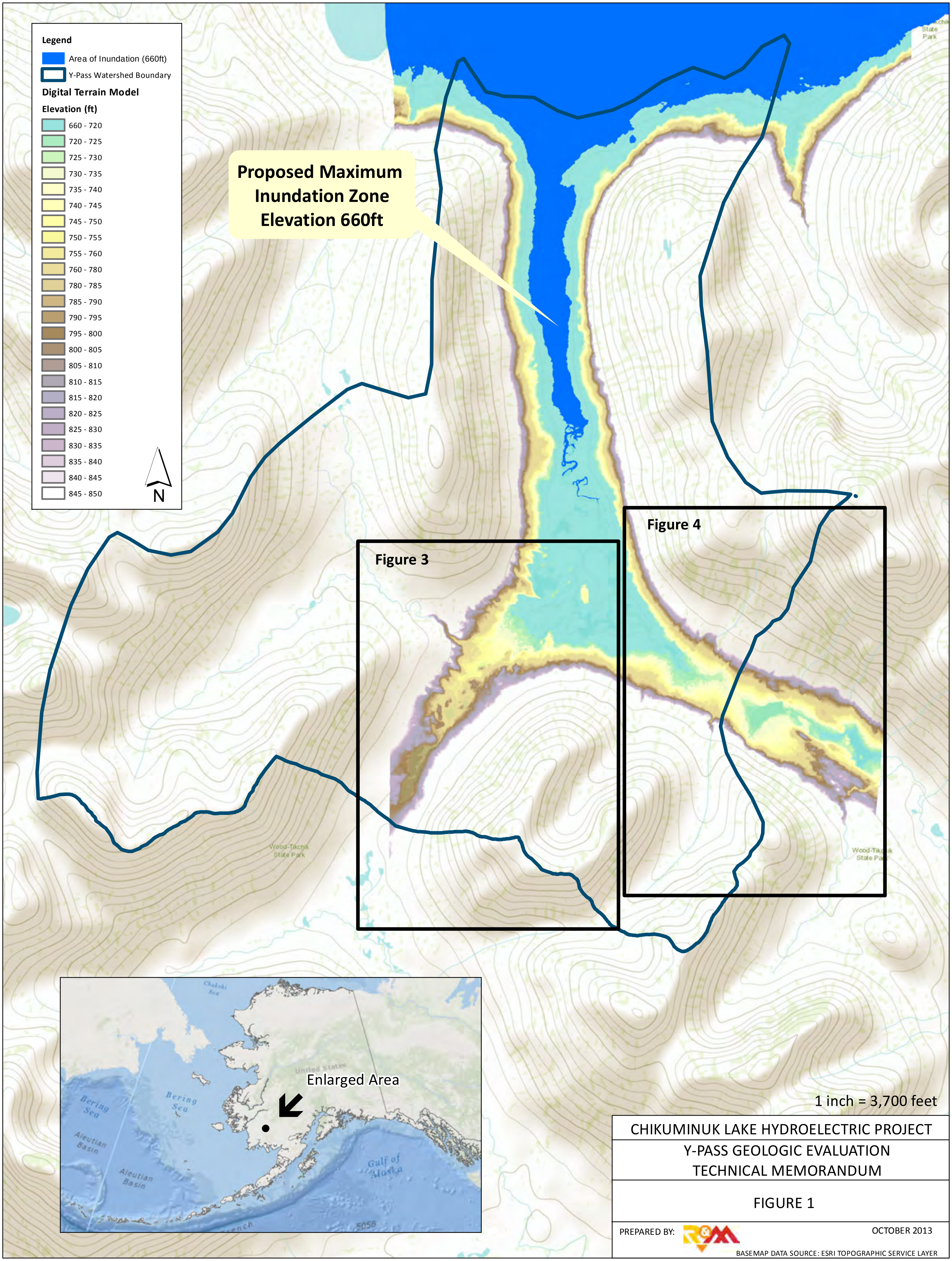


CHIKUMINUK LAKE HYDROELECTRIC PROJECT

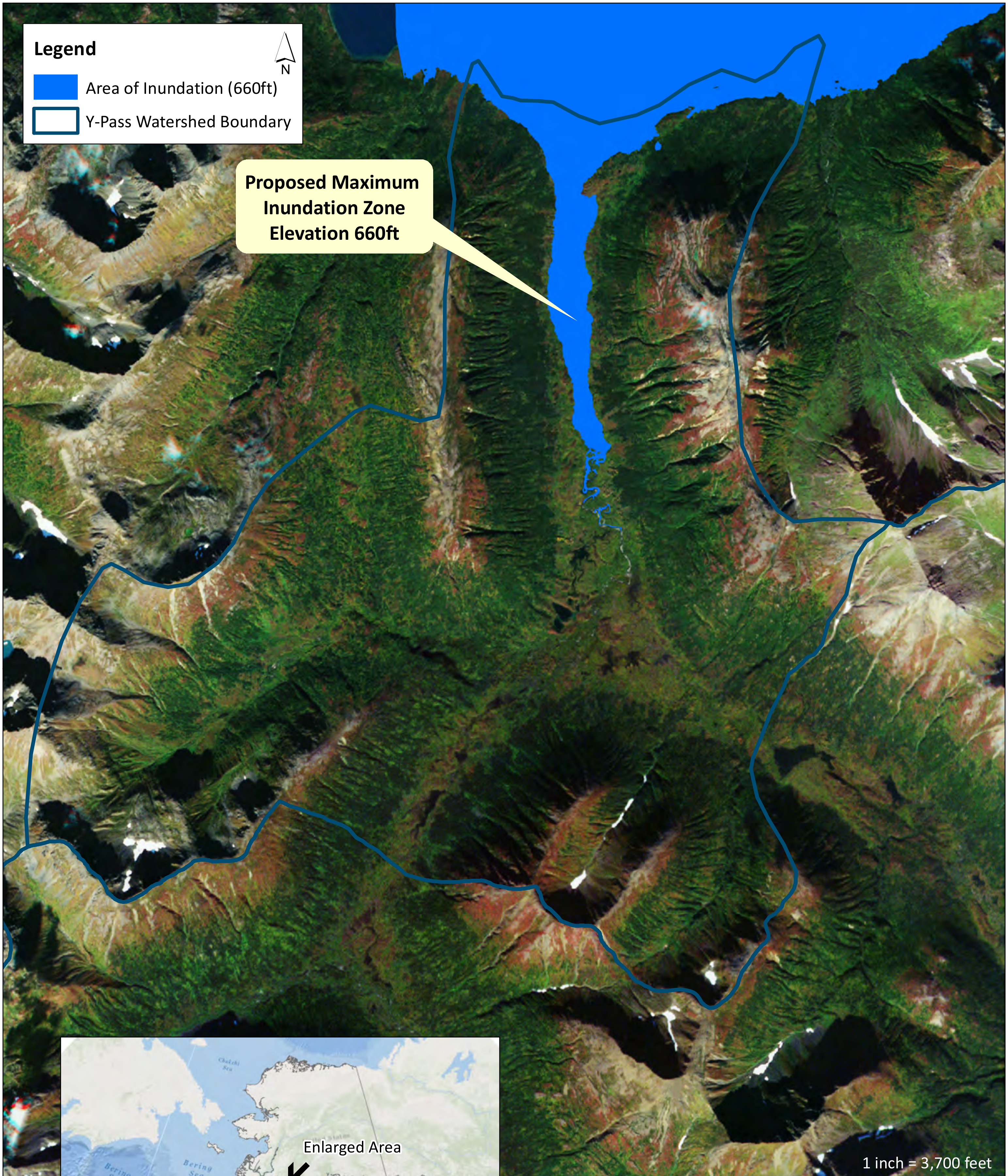
Y-PASS GEOLOGIC EVALUATION
TECHNICAL MEMORANDUM

FIGURE 1

PREPARED BY: R&M

OCTOBER 2013

BASEMAP DATA SOURCE: ESRI TOPOGRAPHIC SERVICE LAYER



CHIKUMINUK LAKE HYDROELECTRIC PROJECT

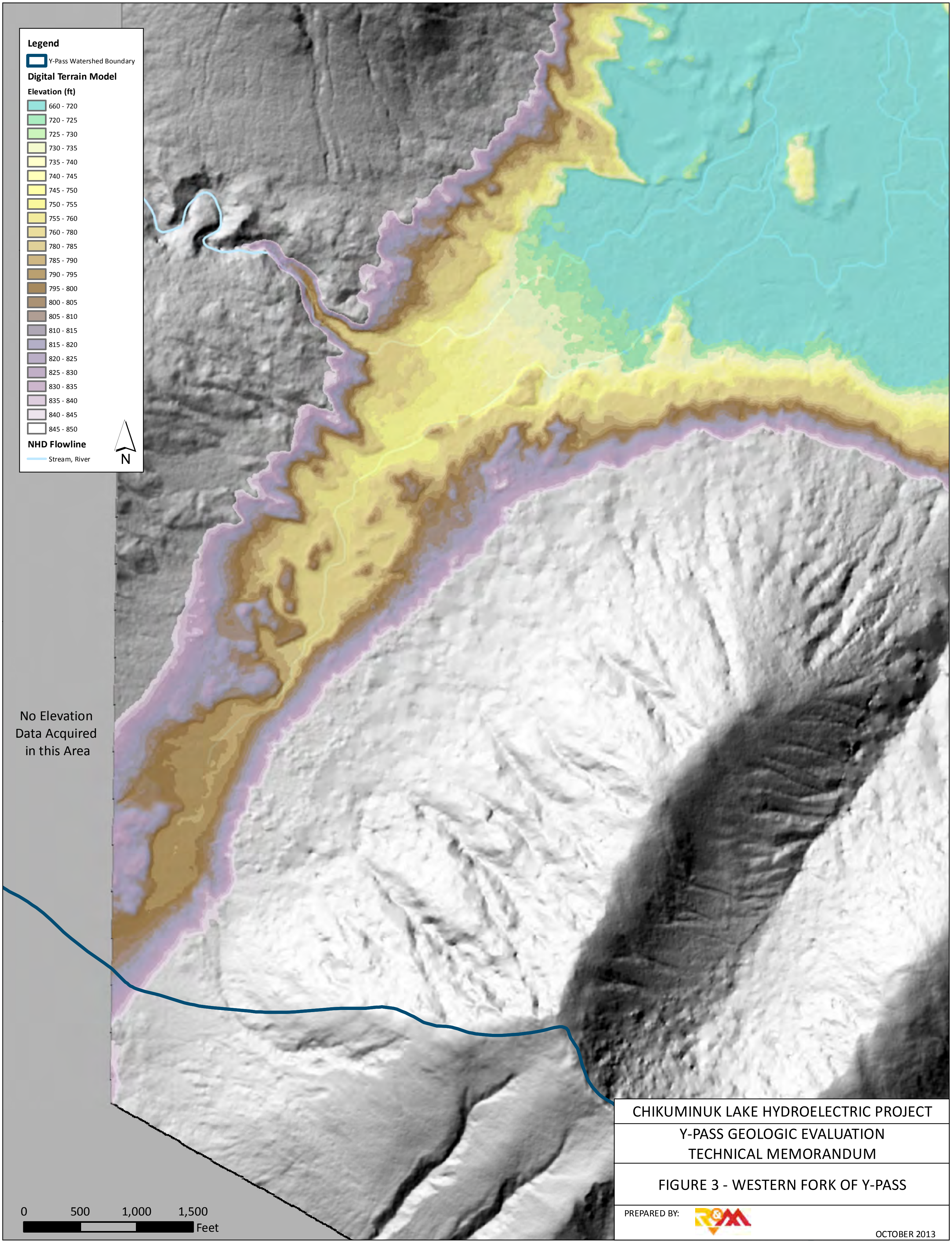
Y-PASS GEOLOGIC EVALUATION
TECHNICAL MEMORANDUM

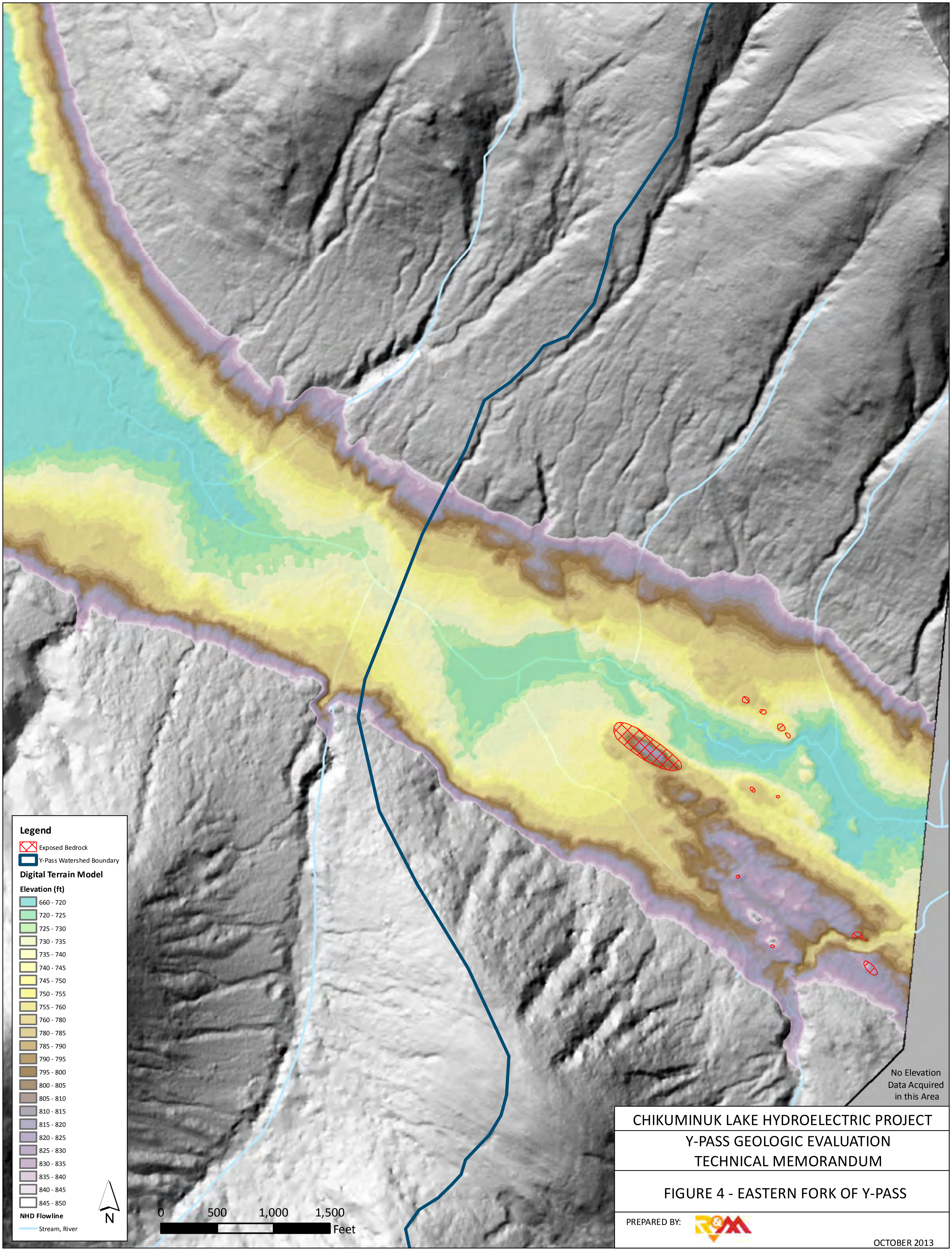
FIGURE 2

PREPARED BY: R&M

OCTOBER 2013

BASEMAP DATA SOURCE: RAPIDEYE IMAGERY ACQUIRED 9/15/2010


Legend
Y-Pass Watershed Boundary
Digital Terrain Model
Elevation (ft)
660 - 720
720 - 725
725 - 730
730 - 735
735 - 740
740 - 745
745 - 750
750 - 755
755 - 760
760 - 780
780 - 785
785 - 790
790 - 795
795 - 800
800 - 805
805 - 810
810 - 815
815 - 820
820 - 825
825 - 830
830 - 835
835 - 840
840 - 845
845 - 850
NHD Flowline
Stream, River
N
No Elevation Data Acquired in this Area
0
500
1,000
1,500
Feet
CHIKUMINUK LAKE HYDROELECTRIC PROJECT
Y-PASS GEOLOGIC EVALUATION
TECHNICAL MEMORANDUM
FIGURE 3 - WESTERN FORK OF Y-PASS
PREPARED BY:
OCTOBER 2013


Legend
Exposed Bedrock
Y-Pass Watershed Boundary
Digital Terrain Model
Elevation (ft)
660 - 720
720 - 725
725 - 730
730 - 735
735 - 740
740 - 745
745 - 750
750 - 755
755 - 760
760 - 780
780 - 785
785 - 790
790 - 795
795 - 800
800 - 805
805 - 810
810 - 815
815 - 820
820 - 825
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835 - 840
840 - 845
845 - 850
NHD Flowline
Stream, River
N
0
500
1,000
1,500
Feet
No Elevation Data Acquired in this Area
CHIKUMINUK LAKE HYDROELECTRIC PROJECT
Y-PASS GEOLOGIC EVALUATION TECHNICAL MEMORANDUM
FIGURE 4 - EASTERN FORK OF Y-PASS
PREPARED BY:
OCTOBER 2013

Chikuminuk Lake Hydroelectric Project
FERC No. 14369

Interim Feasibility Report
Volume I – Technical Studies

Appendix B – Project Layout / Configuration Studies

DRAFT April, 2014
Prepared By:

HATCH™

FINAL TECHNICAL MEMORANDUM

TEMPORARY AND PERMANENT COMPONENTS OF A TRANSPORTATION NETWORK

CHIKUMINUK LAKE HYDROELECTRIC PROJECT FERC No. P-14369

Prepared for:

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November 2013

NOTICE TO USERS

This document reflects the thinking and preliminary design decisions as of September 2013. Changes frequently occur during the evolution of the design process, so persons who may rely on information contained in this document should check with the persons below for the most current information:

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This document is an interim feasibility technical memorandum to select design criteria, identify major project features, identify likely construction phasing and develop rough order of magnitude preliminary construction cost estimates for temporary and permanent components of an integrated transportation network pursuant to the selection of a preferred hydroelectric project arrangement. Many details remain to be addressed through additional field and reconnaissance explorations/investigations, analysis, and studies and numerous variables still exist regarding land status, geotechnical and material characteristics/properties, environmental and permitting challenges and final design details.

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1.0 PROJECT DESCRIPTION

1.1 Introduction

This technical memorandum has been prepared by R&M Consultants, Inc. (R&M) for Hatch Associates Consultants, Inc. (Hatch). The report advances the study of the transportation components described in the Chikuminuk Lake Hydroelectric Project (FERC No. P-14369) Pre-Application Document, Section 2 / Project Location, Facilities, and Operation dated April 12, 2013. A kick-off meeting was held August 19, 2013 in Hatch's Anchorage office.

1.2 Project Location

The proposed Chikuminuk Lake Hydroelectric Project (Project) would be located at the outlet of Chikuminuk Lake, on the Allen River, approximately 118 miles southeast of Bethel, Alaska and 75 miles north of Dillingham, Alaska. Chikuminuk Lake is located within the Wood-Tikchik State Park. (Figure 1-1, Project Location)[1].

The Project facilities and boundary would encompass sections within ranges R54W, R55W, R56W, R57W of townships T1N and T2N of the Seward Meridian of Alaska.

1.3 Proposed Project Facilities

The proposed Project arrangement would potentially consist of the following elements:

- Dam and reservoir
- Spillway
- Penstock (tunnel & piping from intake to powerhouse)
- Powerhouse and related facilities (switch yard),
- Transmission lines
- Tailrace
- Camp facilities for construction, maintenance and operations staff
- Airstrip and access roads to key project related facilities

The dam site is located approximately 2,500 feet downstream of the outlet. (Figures 1-2, Project Location)[2].

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[2] Chikuminuk Lake Hydroelectric Project (FERC No. 14369) Pre-Application Document, Section 2 / Project Location, Facilities, and Operation, April 12, 2013; pg. 2-5.

Figure 1- 1
Project Location

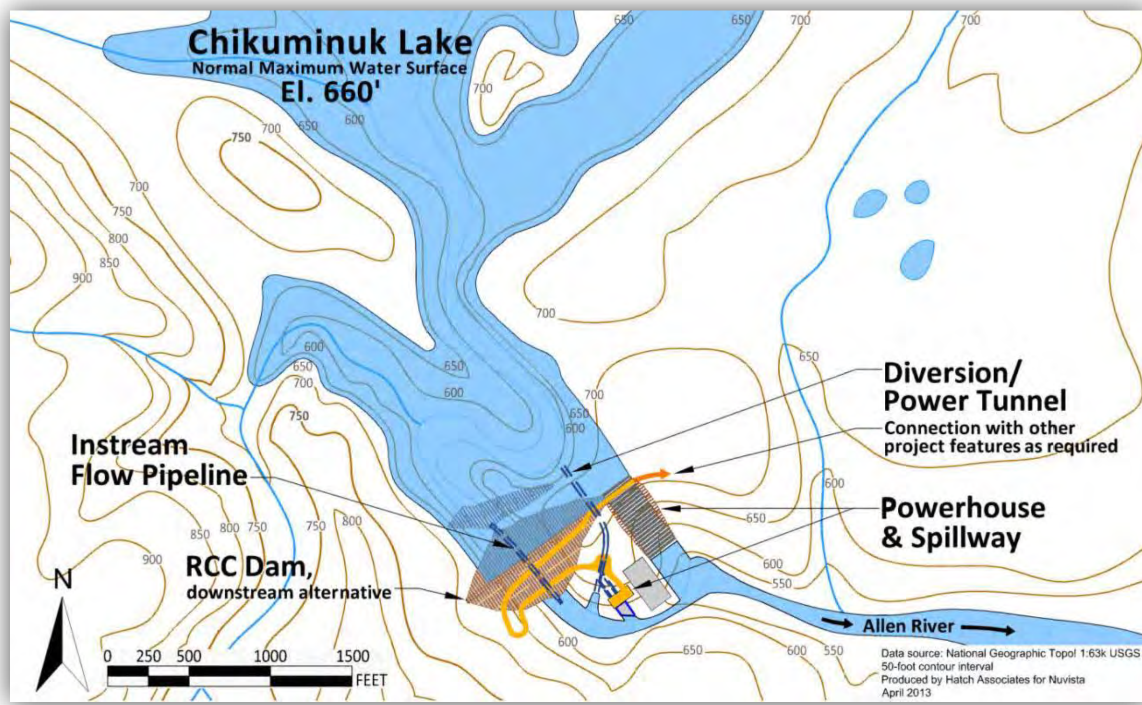


Figure 1- 2
Dam Site Location

1.4 Scope of Work

The objective of this memo is to identify, establish and develop likely access scenarios for temporary and permanent components of an integrated transportation network in support of the hydroelectric project. To that end, the scope of study included:

1. Site Access
    a. Overland Road
    b. Barge with Overland Road and or Barge with Ice/Winter Road
    c. Airstrip
    d. Ice/Winter Road Access
2. Establish Design Criteria
    a. Design Aircraft and Runway
    b. Design Helicopter and Touchdown/Lift-Off Area
    c. Roadway
    d. Camp
3. Downstream Alternative
    a. Prepare preliminary plans, profiles, and typical sections for roads accessing runway, camp and dam related facilities
    b. Calculate preliminary quantities
4. Construction Phasing
5. Preliminary Construction Cost Estimates.

2.0 EXISTING CONDITIONS

Access to the Project site is limited to floatplane or helicopter. There are no permanent roads connecting Chikuminuk Lake to Bethel or Dillingham.

The Project site is generally located between two physiographic areas. To the west lie the rugged Wood River Mountains, ranging in elevation from 2000 feet to 5000 feet. Further west lays the Yukon Delta National Wildlife Refuge and the community of Bethel, Alaska. East of the Project site lay the Nushagak and Bristol Bay lowlands, ranging between 50 and 500 feet above sea level. The lakes in Wood-Tikchik State Park are glacial in origin and are long and deep. The area has been extensively glaciated.

The natural environment varies greatly from wet tundra and marshlands at the lowest elevations to bare rock, heath tundra and alpine meadows at the highest. In between are coniferous forests comprised of white spruce and mixed spruce-birch, muskeg, and willow-alder thickets.

3.0 SITE ACCESS

Construction and operation of the Project would require establishing temporary and permanent elements of an integrated transportation network. A key element of the infrastructure network is access to the Project site. For the purpose of this technical memorandum, construction of four site access options was studied: 1) an overland road; 2) barge with overland road and or barge with ice/winter road; 3) airstrip; 4) ice/winter road.

3.1 Overland Road

Construction of an all season, overland route from either Dillingham or Bethel to the Project site would present engineering, environmental, permitting, social/cultural and cost challenges. In addition, permanent road construction would be through the Yukon Delta National Wildlife Refuge and/or the Wood-Tikchik State Park and may be prohibitive to permit. If permittable, such a road would be over 120 miles in length depending on its origin. It would be today's equivalent of the Dalton Highway or haul road from Livengood to Coldfoot, constructed in the mid-1970s to the oil fields of the North Slope.

Likely engineering challenges would include multiple stream and river crossings requiring permanent culvert and/or bridge installation; construction over tundra, discontinuous and continuous permafrost, muskeg, soft soils, and the rugged Wood River Mountains (from Bethel).

Environmental and permitting challenges would be linked to new construction through a national wildlife refuge and state park. Conventional wilderness management practices restrict or prohibit the use of motorized activities. Additional challenges include crossing extensive wetlands and numerous anadromous waters (streams, rivers, and lakes important to anadromous fish species), namely the Nushagak, Wood, Nuyakuk, and Tikchik Rivers and their tributaries.

Likely social/cultural challenges would be tied to increased access, affecting the practice of the subsistence lifestyle, increasing access to fish and game resources, and affecting the remote, wilderness context, with the area receiving little visitation and offering limited man-made comforts.

Table 3- 1
ADVANTAGES and DISADVANTAGES of an Overland Road

ADVANTAGES	DISADVANTAGES
Reliable, all season access to the Project site	High capital construction costs
Ability to transport materials and equipment without restrictions	Yearly maintenance and operations costs
Lower transport costs	Environmental, permitting, and social/cultural impacts
	Management practices restrict or prohibit the use of motorized activities in State Park

It is difficult to estimate the total cost to construct an overland route at this time. There are a number of factors that are unknown and additional study is required. For example, routes have not been thoroughly developed with alignment, profile, and typical section inputs from which excavation and embankment quantities are calculated, the number of stream crossings and types (culvert or bridge), and allowances for roadway construction over the varied terrain types likely to be encountered (muskeg, permafrost, gravel, rock). A range of costs for a rural resource road classification in Alaska would be $400,000 to $1,000,000 per mile.

3.2 Barge with Overland Road and or Barge with Ice/Winter Road

In an effort to reduce the constructed length of an overland or winter road, an alternative access option would involve barging equipment, materials and supplies up the Nushagak River to the village of Koliganek. From the village, it is approximately 80 miles to the Project Site. While this alternative reduces the amount of impacts by reducing the total length of an overland or winter road, it does not completely eliminate the impacts and challenges. The advantages and disadvantages with this alternative are similar and the major challenge of permitting a route through the State Park remains.

The challenges of constructing an ice or winter road from the village to the Project site are similar and are discussed in Section 3.4.

3.3 Airstrip

Access to the Project site could be accomplished by air via construction of a 4,900-foot airstrip, with 300-foot runway safety areas (RSA) on each end. The runway would be 125 feet in width, or 150 feet, including the RSA widths. The 125-foot width would accommodate the design aircraft being able to turn around for either a back taxi to the apron area or for takeoff, eliminating the need for turnaround areas on each end. The runway profile grade would be 1.5 percent. Figure 3-1 shows a feasible runway typical section.

The runway would be considered restricted to operate under Visual Flight Rules (VFR).

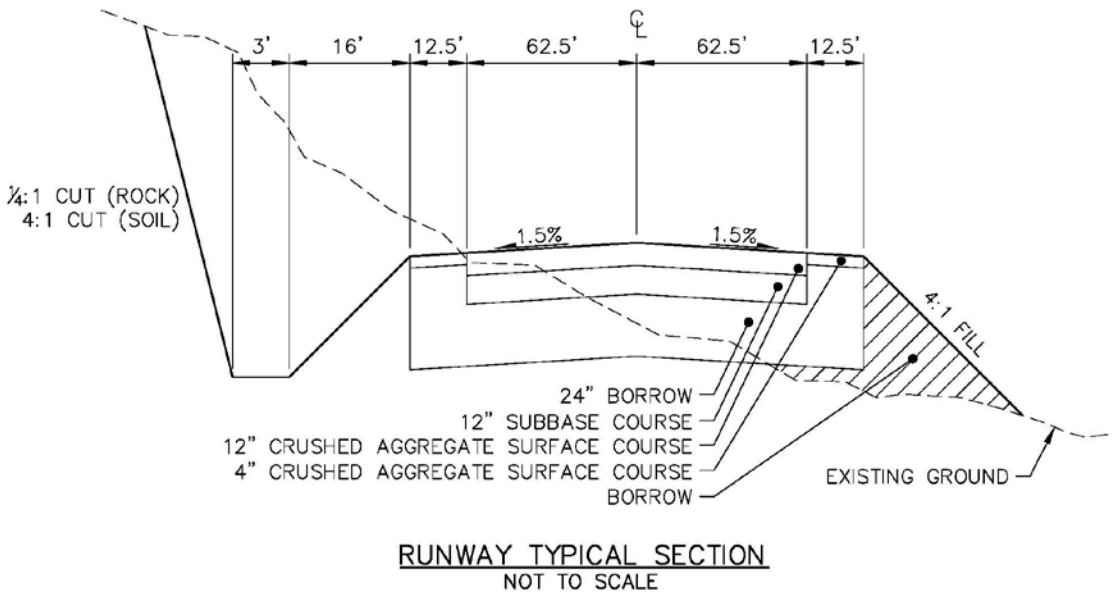


Figure 3- 1
Runway Typical Section

The airstrip could be located within a mile of the dam site, positioned in a southeast to northwest orientation that mirrors the general valley layout, accommodates the prevailing winds and avoids the steep mountains on each side. The challenges facing the other site access options are greatly reduced and impacts limited to the immediate Project vicinity. In addition, access could be controlled. A preliminary runway layout is provided in Appendix A.

Table 3- 2
ADVANTAGES and DISADVANTAGES of an Airstrip

ADVANTAGES	DISADVANTAGES
Lower capital costs / proven option for rural Alaskan access	Access, including emergency / rescue access is weather dependent
Lower maintenance and operations cost	Payload limited to maximum carrying capacity and opening dimensions of design aircraft. May drive the selection and sizing of other Project elements (ie. Transformer, turbines, etc.)
Improved control of access to the site	Higher transportation costs for re-supplying and maintaining site and camp operations, including crew change outs.
Fewer engineering, environmental and permitting challenges	Increased noise, particularly during construction, as equipment and materials are brought to the Project site

3.4 Ice/Winter Roads

This alternative attempts to reduce the impacts associated with a permanent, overland access road constructed from a soil embankment by constructing a temporary “winter” road using snow and/or ice. The winter road would begin from either Dillingham (120-mile length) or Koliganek (82-mile length) and extend to the Project site. The model for this type of access is the ice and winter roads constructed on the North Slope to access remote on and off shore oil reserves.

Design criteria for key roadway elements can be found in Table 5-3.

This alternative assumes that the snow or ice embankments are founded on soil and that the construction and maintenance activities can be accomplished using equipment common to traditional earthwork projects. Crossing of large rivers or streams would be via construction of ice bridges. The primary performance objectives for a winter road are: 1) to provide the minimum structural section (snow and/or ice) to support the planned loads and protect the underlying vegetation; 2) to provide an alignment, geometrics, and cross section that provides for safe and efficient vehicle movements; and 3) to evaluate project costs when comparing the design, construction and maintenance costs for a winter road to that of a similar road constructed of a soil embankment.

3.4.1 Factors Affecting Ice/Winter Roads

The constructability and performance of a winter road are a function of the local climate, vehicle loads, the strength of constructed snow or ice embankment and the length of the operating season. The operating season can be characterized as the period during which the daily average air temperatures are below about 25°F. A partial list of climate factors affecting the operating period include: the average start of freezing period, average date of first snowfall, snow fall distribution and total snowfall, air temperature, and the average start of the thawing period. The time at which construction of a winter road can begin is typically limited by the bearing capacity of the natural ground upon which the snow or ice embankment is constructed or the minimum natural snow cover required to protect the underlying vegetation, which may be an agency-mandated minimum depth (10” to 14”) or a specific calendar day. Generally, the depth of frost in most soil subgrades should be sufficient to support the winter road construction equipment once the cumulative freezing degree days has reached more than about 300 °F-Days. A record of reliable climate data (air temperature, precipitation, etc.) is unavailable for the Project site. The nearest station according to the Western Regional Climate Center records is the Dillingham Airport. Table 3-1 shows the mean of the monthly average air temperatures for the period of 1951 to 2005.

Table 3- 3
Mean of the Monthly Average Air Temperatures at Dillingham

MONTH	°F	Freezing Degree Days
October (30 days)	33.1	N/A
November (30 days)	22.7	279
December (31 days)	14.4	545
January (31 days)	16.1	492
February (28 days)	16.4	437
March (31 days)	22.1	306
April (30 days)	31.4	N/A
Average Air Temperature	18.3	

Recognizing the variability in the local climate and the potential for warm or "Chinook" events, the operating period is generally mid-December through mid-March. Additional climate data and further analysis is needed before proceeding with preliminary winter road design.

3.4.2 Snow and Ice Embankment Depths

Snow and ice embankment thicknesses vary depending on the type of foundation material (ground or water), the planned design loads and construction methods (discussed below).

Winter roads constructed with snow embankments typically range from 10 to 36 inches. Roads subjected to heavy or repeated loads usually require an additional treatment for improved performance (durability, safety, lower maintenance). A common treatment is spraying water to provide a frozen cap, typically on the order of 2 to 4 inches thick.

The depths of ice embankments founded over soil (grounded) typically range from 10 to 24 inches while depths over water (floating) range from 10 to 60 inches.

3.4.3 Alignment

Winter road construction and maintenance costs can generally be reduced by selecting alignments to:

- Minimize overall length;
- Minimize profile grades;
- Favor terrain with minimum micro-relief;
- Follow existing pre-cleared trails, seismic lines, fire breaks;
- Avoid natural snow catchments (i.e., narrow valleys, and the lee of tree/shrubs) as drifting snow is a maintenance and safety concern;
- Follow along the tops of ridges or valley bottoms;

- Avoid following a contour across a slope where the embankment may pond or otherwise alter established surface drainage during spring thaw;
- Avoid crossing areas with natural springs and very wet ground;
- Avoid south facing slopes or be shaded to minimize exposure to direct sunlight; and,
- Optimize distances between the winter road and source areas to supply snow and water.

Crossing streams and rivers via temporary ice bridges are fundamentally different than snow or ice embankments founded over soil. Additional ice bridge considerations include:

- Minimizing ice bridge length;
- Locating ice bridges so that the thickened ice does not obstruct the natural flow of water in the stream and/or river, thus:
    - Adversely affecting wintertime aquatic life;
    - Increasing flow velocities, possible increasing erosion in the stream or river bed;
    - Increasing the upstream hydraulic forces and reducing the longitudinal stability of the bridge, and
    - Increasing upstream water levels resulting in overflows or surface icing buildup.
- Potential for river flow to physically and or thermally erode the underside of the ice bridge;
- Locating ice bridges with gentle sloping banks to minimize erosion and provide reasonable vehicle operation/control; and,
- Align ice bridges parallel with the prevailing wind or as far from the shore as possible to minimize snow drifting. Added dead load and insulating effects of snow cover are detrimental to the allowable bearing capacity of the ice bridge.

For planning purposes, a conceptual winter road route from Koliganek to the Project site is provided in Appendix A.

3.4.4 Winter Road Construction Sequence

Prior to full scale winter road construction, the route surface must be prepared. Preparation activities include clearing of trees, either by hand (chain saw) or mechanical (hydro-axe) and an initial leveling, grading and compacting of the snow cover to the rough subgrade widths.

The strength of snow is comprised of cohesive and frictional components, both functions of the particle grading, contacts and bonding. The bonding in snow is in turn a function of temperature and time. As such, snow embankments should be constructed in stages in order to achieve the high strengths to support the design loadings. The recommended construction sequencing is as follows:

1. Process the snow using tillers and/or blowers to maximize the particle grading;
2. Place the snow in graded and compacted lifts to maximize inter-granular contacts and density; and,
3. Allow the embankment to set for a period to “sinter” (a natural, irreversible time and temperature dependent hardening of the snow)

Overland solid ice embankments require a great deal of water (approximately 1 - 1.5 million gallons for a one mile road, 40 feet wide and 6 inches thick), but can provide the hardest and thinnest embankment section. An initial lift is usually made by pulling a drag behind an all-terrain vehicle to prepare the surface and provide, after an initial hardening, a minimal ice surface to support wheeled construction equipment. Water is then sprayed on the surface in thin lifts using tank trucks until the desired structural section is built up (surface or layer flooding). Build up rates vary by physical location and local climate conditions.

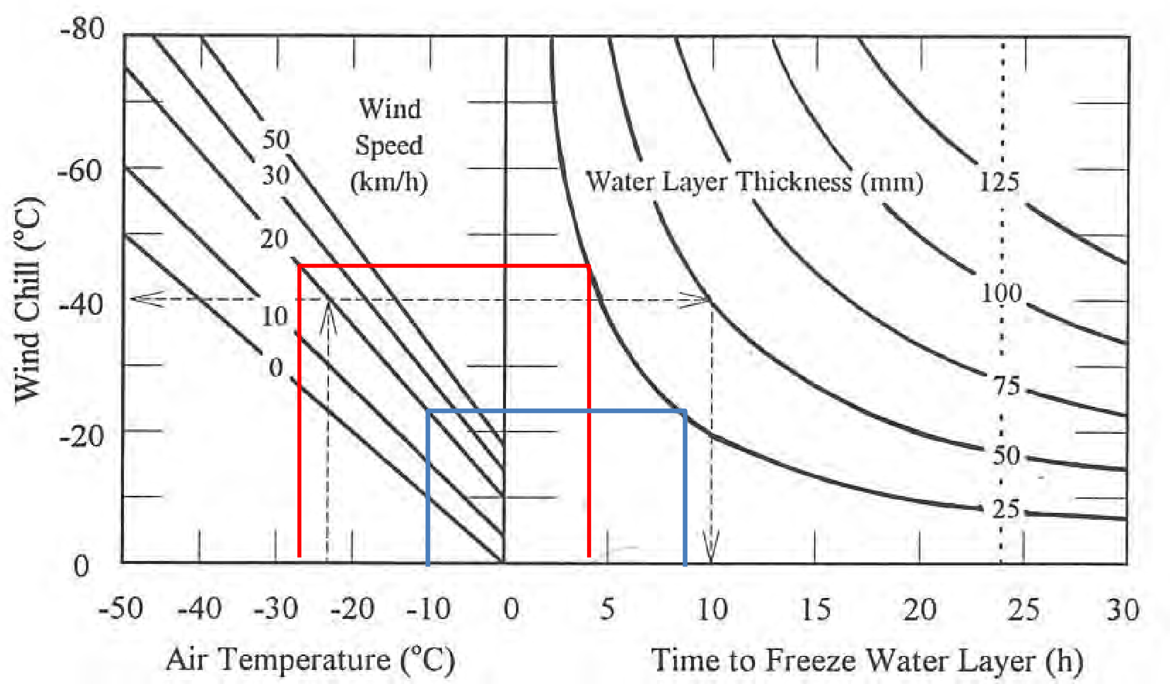


Figure 3- 2
Theoretical Optimum Ice Growth Rate Versus Flooded (Pumped) Water Thickness (after Duthweiler and Utt, 1985)

Figure 3-2 compares the theoretical ice growth rates for the Project Site (blue) and Alaska’s North Slope (red) assuming constant typical mean air temperatures and an average wind speed.

Table 3- 4
Time, in Hours, to Freeze a 1" Thick Water Layer

Location	Air Temp (°F) / (°C)	Wind Speed (miles/hr) / (km/hr)	Time to Freeze 25 mm / 1" Thick Water Layer (Hr)
North Slope	-20 / -28.8	12 / 20	4.5
Project Site	14* / -10.0 *From Table 3-3	12 / 20	8.5

Assuming nonstop buildup or flooding operations over a 24 hour period and each flooded layer well frozen before the next layer is added, the predicted theoretical buildup rate for the North Slope and Project Site would be approximately 5.3 inches/day (24/4.5) and 2.8 inches/day respectively.

Average ice growth rates reported from actual North Slope projects have been on the order of one-half the optimum predicted theoretical ice growth or approximately 1.5 to 2.5 inches/day. It would be reasonable to expect a similar reduction at the Project site (0.75 to 1.4 inches/day) and considering the need to haul water, a further reduction in the average ice buildup rate would not be unexpected (0.25 to 0.5 inches/day). Considering the overall length of an ice/winter road (82 to 120 miles), the low ice buildup rates, the topographical, environmental, and construction challenges, and uncertainties associated with a maritime climate, the construction of an ice/winter road is not feasible.

An option to the traditional technique of "built-up" ice road construction is ice harvesting. Ice is harvested from a source, such as a frozen lake, using a piece of equipment that "shaves" off the ice (similar to pavement rotomilling). The ice is then hauled to the road and placed as an "ice aggregate". Equipment and haul costs can render this option not feasible when the route is located significant distances from the ice source.

3.4.5 Additional Construction Considerations

The use of a winter road to access the Project site presents the following additional challenges:

- The overall length may require multiple construction crews, strategically located along the route, all working towards one another to construct the entire length;
- If the use of multiple construction teams is not possible or feasible, it may be that only a portion of the overall winter road length is constructed during a single operating season; thus the transport of equipment, material and supplies only advances as far as the winter road construction, resulting in multiple years to reach the Project site. The high risk of stockpiling equipment, materials and supplies mid route and having favorable weather to continue on during the next operating season would be reflected in the construction costs.

- Increased exposure to direct sunlight and air temperatures associated with spring would likely reduce the operating season and or increase maintenance activities. It would be reasonable to expect the hauling or transport operations to occur at night, with maintenance activities performed during the day, readying the road for that night's heavy traffic.

3.4.6 Winter Road Maintenance Considerations

Winter roads require maintenance just like their earthen counterpart. Maintenance efforts can be categorized into preventative and routine. Preventative activities include clearing, grading, and dragging to keep the top of the embankment surface smooth and hard. Bumps which develop due to traffic or frost heave, or some other action tend to grow rapidly and affect speed, safety and increase maintenance costs if not treated early. Periodic compaction, (if no frozen cap) can improve useful life.

Routine maintenance activities include repairing cracks, ruts, potholes and surface treatments (frozen cap) to improve vehicle control and traction on curves and grades. Cracks, ruts and potholes can typically be repaired by filling with compacted slush or an ice chip and water slurry.

Removing snow berms and drifting snow are often significant portions of maintenance costs. In addition to safety concerns associated with winter road travel, snow berms and drifting snow can reduce the performance of winter roads, particularly ice embankments and bridges over water (floating), where their weight effectively reduces the net allowable load capacity and may lead to overflow on top of the surface.

3.4.7 Winter Road Construction Costs

It is difficult to estimate the total cost to construct a temporary winter road at this time. There are a number of factors that are unknown requiring further study. For example, detailed research, collection and analysis of climate data may be necessary to refine the operating seasons, identification of available water sources, development of route alternatives with alignment, profile, typical sections and identification of feasible river/stream crossings and estimated winter road production rates (miles/day). Cost estimates for constructing winter roads in Prudhoe Bay are approximately $100,000 per mile, where the projects are connected and supported by the existing road system. For the Project location, it is not unreasonable for the estimated construction costs to be 2 to 4 times the cost per mile.

4.0 PROJECT SITE

4.1 Network Roads

The road network to access and serve the dam related facilities (camp, powerhouse, airstrip, float plane dock, helipad, spillway etc.) will be designed and built to the standards for new construction for a rural resource recovery road functional classification. Design criteria for key roadway elements can be found in Table 5-4.
For purposes of this study, the network roads are identified as:

- Roadway #1 – from the runway to the camp intersection
- Roadway #2 – from the camp intersection to the float plane dock/ boat ramp
- Roadway #3 – from the camp intersection to the power house
- Roadway #4 – from Roadway #3 to the dam, including the penstock gate valve.

Preliminary plan and profile sheets for each roadway are provided in Appendix A.

Figure 4-1 depicts the typical cross section for all roadways, comprised of two 10-foot lanes and two 2-foot outside shoulders for an overall width of 24 feet. The 24-foot top width will facilitate two way traffic, the transport of the larger pieces of equipment and truck tracking. The 3% roadway cross slope or crown improves surface runoff from the road, preserving the well graded gravel running surface and reducing maintenance costs.

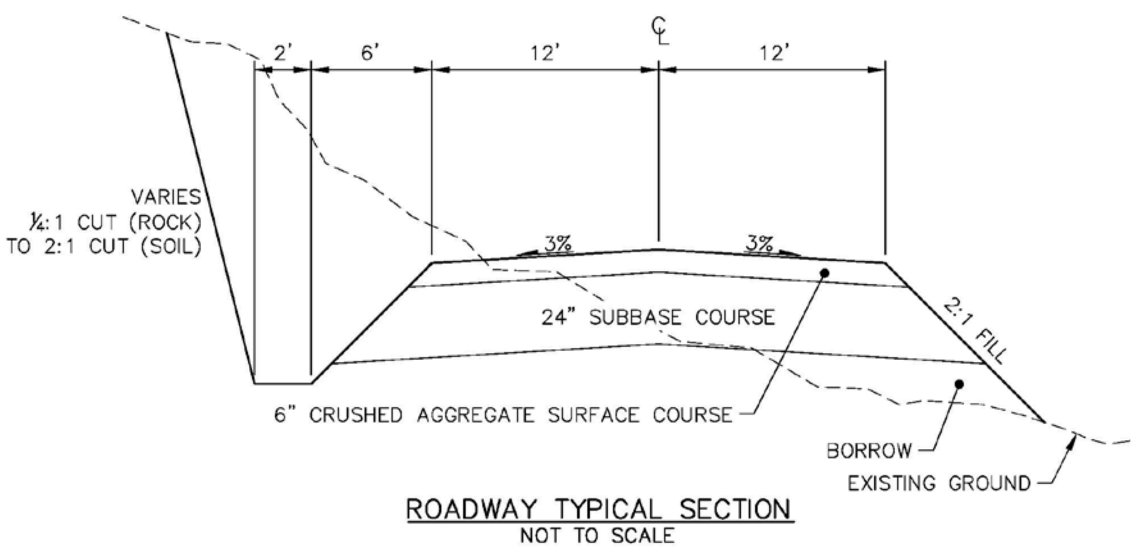


Figure 4- 1
Road Typical Section

A feasible embankment section (from top to bottom) is composed of 6-inches of crushed aggregate base course (grading D-1) and 24-inches Borrow Type A over a prepared subgrade. Final, individual structural section depths will be based upon the recommendations as a result of geotechnical field investigations and lab analysis.

Many of the design criteria values reflect the acceptable minimums in an effort to minimize the impacts to the surrounding natural environment by minimizing the improvement footprint. Cut slopes are 2H:1V in soil and 1/4H:1V in rock. Fill slopes are 2H:1V. It is assumed that the soil overburden stripped from project excavations will be used as topsoil on the engineered slopes and will be seeded. Rock cut slopes will be left in their post construction state.

To avoid a temporary degradation of water quality and to meet Alaska Pollutant Discharge Elimination System (APDES) permit requirements, Best Management Practices (BMP) will be implemented. An Erosion and Sediment Control Plan (ESCP) will be developed based upon construction sequencing, available and existing materials, and other relevant factors during the design process. The ESCP will contain information regarding the construction site that may be used by the contractor in developing and implementing a Storm Water Pollution Prevention Plan (SWPPP).

4.2 Permanent Camp

For planning purposes, the permanent camp site is centrally located for short vehicle trips or walking access to all other related facilities. The permanent camp site area is approximately 4 acres in size and is located to minimize the earthwork to construct. The site can be expanded as needed.

Likely elements of the camp include sleeping, meal/recreation, supply and utilities (power, water, etc.) buildings, equipment and maintenance shop and storage/staging yard, fueling station (vehicles and equipment) and a helipad located at one of the furthest corners of the camp pad.

4.3 Apron

The apron is located mid-point along the runway and is approximately 5.5 acres in size and can be expanded as needed. The layout would allow for the design aircraft (C130) to taxi over to the apron and load/unload without affecting runway operations. The apron would also serve as a staging area to store incoming or outgoing cargo. The apron could support aircraft refueling operations. The apron could also serve as a helipad and temporary camp location while the runway is being constructed.

4.4 Lake Based Operations

The conceptual site layout includes access to the lake to accommodate water based operations such as floatplane access, dock and boat ramp. From a usability perspective, the final location for these elements should be located to protect the water based operations from the fetch.

4.5 Fuel Storage

It is anticipated that onsite fuel storage would be in double walled, self-contained tanks mounted on skids.

5.0 DESIGN CRITERIA

5.1 Airstrip

The preliminary runway design criteria based on the design aircraft characteristics are presented in Table 5-1.

Table 5- 1
Runway Design Criteria

ELEMENT	VALUE	SOURCE
Design Aircraft	Lockheed 100-C130 Hercules (C130)	Based on the transport of the largest & heaviest anticipated piece of equipment/ material which is likely to be the transformer equipment –(approx.. 54,000 lbs).
Aircraft Characteristics Approach Speed: 138 knots Runway Design Code: C-IV Wind Span: 132.60 ft Tail Height: 39.20 ft	• 125 ft Runway Width • No turn around areas required • Maximum longitudinal grade 1.5%	
C-130 Maximum Landing Wt: 135,000 lbs C-130 Maximum Takeoff Wt: 130,000lbs.	• 4,900 ft (most critical) • 4,800 ft (uphill) • 4,000 ft (downhill)	Lynden Air Cargo C-130 FAA Approved Airplane Flight Manual
Runway Protection Parameters for Design Aircraft: B-II	• 300 ft Runway Safety Area beyond runway ends, • 150 ft Runway Safety Area Width, • 500 ft Object Free Area Width	AC 150/5300-13A Appendix 7 Table A7-3

5.2 Helicopter and Touchdown/Lift-off Area

Preliminary touchdown and lift-off areas based on the design helicopter characteristics are presented in Table 5-2.

Table 5- 2
Touchdown and Lift-Off Area Design Criteria

ELEMENT	VALUE	SOURCE
Design Aircraft	Bell 212	
Aircraft Characteristics Length: 57.14 ft Rotor Diameter: 48 ft Height: 12.57 ft Maximum takeoff wt: 11,200 lbs	• 48 ft x 48 ft Touchdown & Lift-off Area • 85.5 ft x 85.5 ft Final Approach and Takeoff Area • 115.5 ft x 115.5 ft Safety Area	AC 150/5390-2B Figure 2-2.

5.3 Winter Road

Preliminary winter roadway design criteria are presented in Table 5-3.

Table 5- 3
Winter Road Design Criteria

ELEMENT	VALUE	SOURCE
Functional Classification	Rural Resource Recovery	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001.
Average Daily Traffic	≤ 400	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001.
Terrain	Rolling/Mountainous	AASHTO 2001, Pg. 274
Design Speed (mph)	35 mph	Roads and Airfields in Cold Regions, ASCE Technical Council on Cold Regions Engineering Monograph. Pg. 103.
Design Vehicle	WB-50	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001.
Total Roadway Width Overland Grounded Ice Floating Ice	20 - 30 ft 50 – 200 ft 100 – 150 ft	Roads and Airfields in Cold Regions, ASCE Technical Council on Cold Regions Engineering Monograph. Pg. 103.
Maximum Grade Snow surface Ice Surface	< 8 – 10% (12 – 15% with traction treatment) < 5%	Roads and Airfields in Cold Regions, ASCE Technical Council on Cold Regions Engineering Monograph. Pg. 103.
Cross Slope (Snow surface)	< 2 - 3%	Roads and Airfields in Cold Regions, ASCE Technical Council on Cold Regions Engineering Monograph. Pg. 103.
Stopping Sight Distance	650 ft	Roads and Airfields in Cold Regions, ASCE Technical Council on Cold Regions Engineering Monograph. Pg. 102
Minimum Radius of Curvature	950 feet	Roads and Airfields in Cold Regions, ASCE Technical Council on Cold Regions Engineering Monograph. Pg. 103.
Minimum K-Value for Vertical Curves	Crest: 7 Sag: 17	AASHTO 2001, pg. 274, Exhibit 3-76 AASHTO 2001, pg. 280, Exhibit 3-79
Side Slopes	4:1 (h:v)	

5.4 Roadway

Preliminary roadway design criteria are presented in Table 5-4.

Table 5- 4
Roadway Design Criteria— Rural Resource Recovery

ELEMENT	VALUE	SOURCE
Functional Classification	Rural Resource Recovery	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001.
Average Daily Traffic	≤ 400	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001.
Terrain	Rolling/Mountainous	AASHTO 2001, Pg. 231
Design Speed (mph)	35 mph (Site Access Road) 35 mph (Between Runway/Float plane ramp & Camp) 20 mph (Camp & Powerhouse) 15 mph (Powerhouse & Dam Site)	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001. Exhibit 1.
Design Vehicle	WB-50	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001.
Total Roadway Width (both lane + shoulders)	24 ft	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001. Exhibit 1.
Cross Slope	Minimum 3% for gravel roads	
Stopping Sight Distance	170 ft	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001. Exhibit 12.
Maximum Grade Minimum Grade	6% desirable (10% maximum) 1.0 % minimum	AASHTO 2001, Exhibit 5-15 Pg. 409
Minimum Radius of Curvature	35 mph – 275 ft 20 mph – 115 ft 15 mph – 65 ft	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001. Exhibit 7.
Superelevation	e = 6%	6-inch crushed aggregate surface course C-1 or D-1.
Minimum K-Value for Vertical Curves	Crest: 14 Sag: 49	AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) 2001. Exhibit 12.
Roadway surfacing (lanes & shoulders)	6" Crushed Aggregate Base Course, C-1 or D-1 24" Borrow, Type A	To be confirmed through a formal geotechnical investigation & recommendation phases.
Side Slopes	Soil: Cut and Fill 2:1 (h:v) Rock: Cut varies 1/4:1 to 1:1	To be confirmed through a formal geotechnical investigation & recommendation phases.

Final decisions regarding alignment, typical section widths and proposed improvements will be decided during subsequent phases of the design process.

6.0 PREFERRED ACCESS OPTION AND CONSTRUCTION SEQUENCING

The previous sections discussed the four basic options to access the Project site:

- Overland Road
- Barge with Overland Road and/or Winter Road
- Airstrip
- Winter Road

There are combinations of these options that may be feasible and worthy of additional consideration. For example, construct a winter road to only bring in the equipment to construct a runway. Ultimately, the final decision will be based on cost, constructability, and the ability to secure construction related environmental permits.

6.1 Preferred Access Option

Access by air is a viable and proven approach for constructing large infrastructure projects in remote, interior Alaska. Because of a lack of a connection with a navigable waterway or established overland route (permanent or winter), the initial construction push must also be accomplished by air. The likely scenario would use heavy lift helicopters, with load capacities in excess of 20,000 lbs, to sling load equipment, materials, and supplies from Dillingham into the Project site. Initially, a remote camp and small pioneer workpad would be constructed with small earthwork equipment (operating weight < 40,000 lbs). Once the pioneer workpad and roads are completed, a temporary construction camp and medium sized earthwork equipment (operating weight up to 55,000 lbs.) can be brought in pieces and reassembled. Both the 234 Chinook and Erickson S-64F Aircrane can meet the payload requirements.

The larger pieces of equipment (operating weights up to 55,000 lbs) will increase production rates in order to complete the runway and associated roadway construction in two construction seasons. A single construction season is defined as May 1 through October 31. Depending on equipment model and manufacturer, most medium sized earthwork equipment can be air lifted in 2 to 4 trips. A likely equipment fleet mix and operating weights are shown in Table 6-1. This mix represents the minimum fleet required and does not include backup equipment to replace equipment taken out of service due to scheduled maintenance, mechanical breakdown or outright failure.

A temporary construction camp for approximately 30 individuals from the construction, engineering, materials, inspection and owner representative groups is necessary to support the construction of the runway and site access/circulation roads. The camp would be needed for approximately 1.5 construction seasons. The camp would be capable of providing a basic level of living conditions (room and board, and limited recreation). Primary power and backup power would be available. The camp would be re-supplied via helicopter and float plane initially and then wheeled aircraft as the runway embankment is built up. It is estimated that a camp staff of three persons (cook, housekeeping, and maintenance) would be necessary for camp operations.

Preliminary quantity estimates support the position that the runway and roadway can be completed in two construction seasons. A likely construction scenario would be to complete the runway excavations and embankment to the bottom of the structural section by the end of the first year. This would allow the runway embankment to consolidate over the winter. The second season would repair any settlement areas and place the runway structural under a grading operation, freeing the majority of the equipment for roadway construction. All roadways would be completed by the end of the second year.

Table 6- 1
Equipment Fleet

EQUIPMENT	OPERATING WEIGHT (lbs.)	QUANTITY
Small Equipment		
CAT Dozer D4	19,000	1
CAT Excavator 316	38,000	1
Medium Equipment		
CAT Dozer D6	46,150	2
CAT Excavator 320	55,000	2
CAT 725 Articulated Truck	50,000	2
CAT Loader 950	44,000	1
CAT 54B Compactor	24,000	1
CAT 160M2 Motor Grader	45,500	1
Total Weight of Fleet to be Air Lifted	**472,800**	

This approach was successfully used to construct the access road to Quartz Hills Mine near Ketchikan Alaska. An Erickson Air-Crane moved over 1,100 tons in four days.

Based on a carrying capacity of 20,000 lbs. and the need to move approximately 600,000 lbs. of equipment, materials, and supplies (475,000 + 125,000), approximately 30 trips will be required. Assuming 2.5 hours per round trip (75 trip flight hours), 16 contingency flight hours, and 8 weather hours, approximately 100 total flight hours are estimated.

For estimating purposes, a breakdown of airlift costs is shown below:

Table 6- 2
Estimated Air Lift Costs to Project Site

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	AMOUNT
Mobilization / Demobilization to/from Dillingham Alaska	1	LS	$400,000	$400,000.
Lift work	100	Hrs	$15,000	$1,500,000.
Fuel (400 gal/hr)	40,000	Gal	$12	$480,000.
Lodging, Per Diem for crew of 10 for 10 days	100	Each	$294	$29,400.
Subtotal				$2,409,400.

7.0 CONSTRUCTION COST ESTIMATE SUMMARY

Estimated total construction cost for the Project airstrip and site access/circulation roads:

Component	Amount
Runway & Apron	$33,760,000.
Site Roads & Pads	$12,100,000.
Total	$45,860,000.

Detailed estimated access costs, preliminary quantities and estimated site construction costs are provided in Appendix B.

8.0 ASSUMPTIONS

The following assumptions were made in preparing this pre-feasibility study and developing estimated construction costs.

- Estimated costs and unit prices are in 2013 dollars. It would not be unreasonable to expect a 10-15% cost escalation going forward;
- These are unit price estimates and do not break out equipment purchase and depreciation, risk, profit, etc. as a contractor would when preparing a bid for competitive selection;
- Access roads and layouts for related facilities are based on the preliminary dam location alternatives developed by Hatch and distributed during the August 19, 2013 meeting. All existing ground and proposed finished grade elevations are based on 10' contour interval mapping generated from aerial imagery collected the summer of 2012;
- There are no provisions for temporary or construction access roads to the dam site or dam related facilities, (portals for penstock, coffer dam, and material sites, etc.)
- Excavations in the moraine areas above the Allen River can be accomplished without blasting and the material is usable for meeting road and runway embankment, surfacing and other material requirements. Opportunities to reduce the overall earthwork quantities would be accomplished during design level surveys and final design activities. Without specific geotechnical information, soil overburden, limits of rock excavation, material sites and access and the usability of the excavated material to meet material requirements will potentially impact construction costs;
- The proposed equipment fleet from Table 6-1 represents the minimum. It would be reasonable to expect backup equipment on site to cover mechanical breakdowns and/or to increase construction production. The equipment mobilized to construct the runway would be available to construct other related facilities (dam, spillway, powerhouse, tunnel/penstock, etc.),
- Additional specialty construct equipment and materials (cement, flyash, pozzolan, reinforcing steel) to construct dam and related facilities would be brought in via air after the runway is completed;
- Dam and power generation related equipment and materials will be delivered via air;

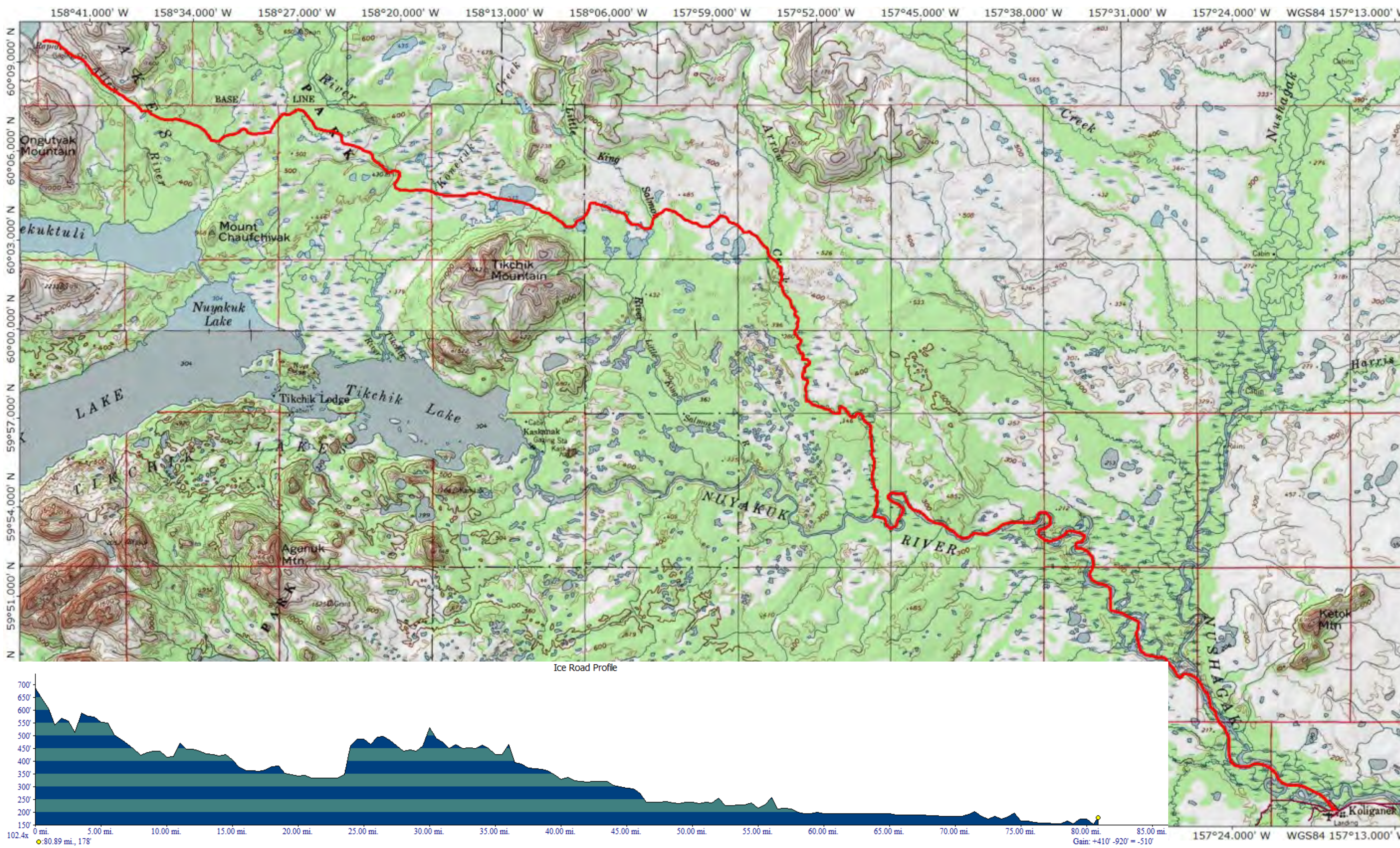
9.0 REFERENCES

Scher, Robert L (1996) Temporary Snow and Ice Pavement Structures. Roads and Airfields in Cold Regions. *American Society of Civil Engineers Technical Council on Cold Regions Engineering Monograph.*

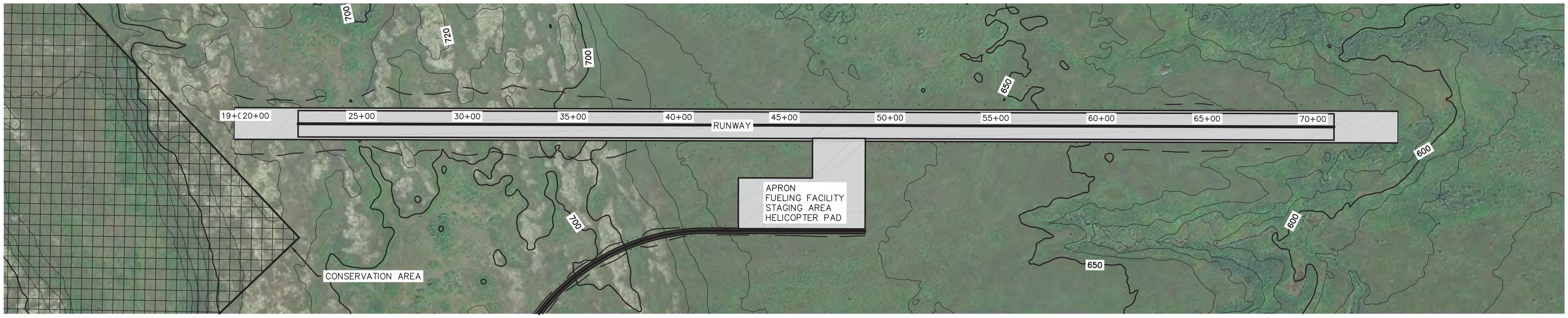
Appendix A

Plan Sheets

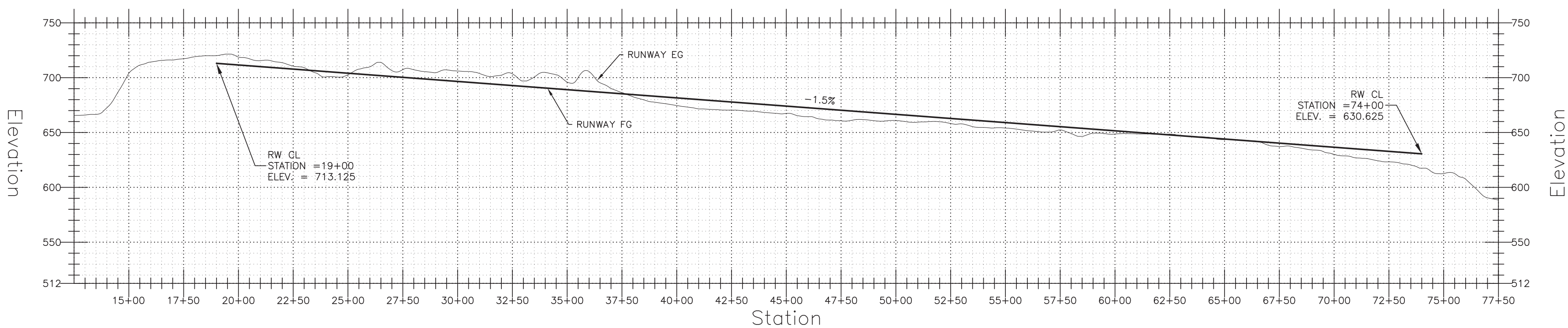
Ice Road Plan and Profile



STATE	YEAR	SHEET NO.	TOTAL SHEETS
ALASKA	2013		



Profile View of Runway

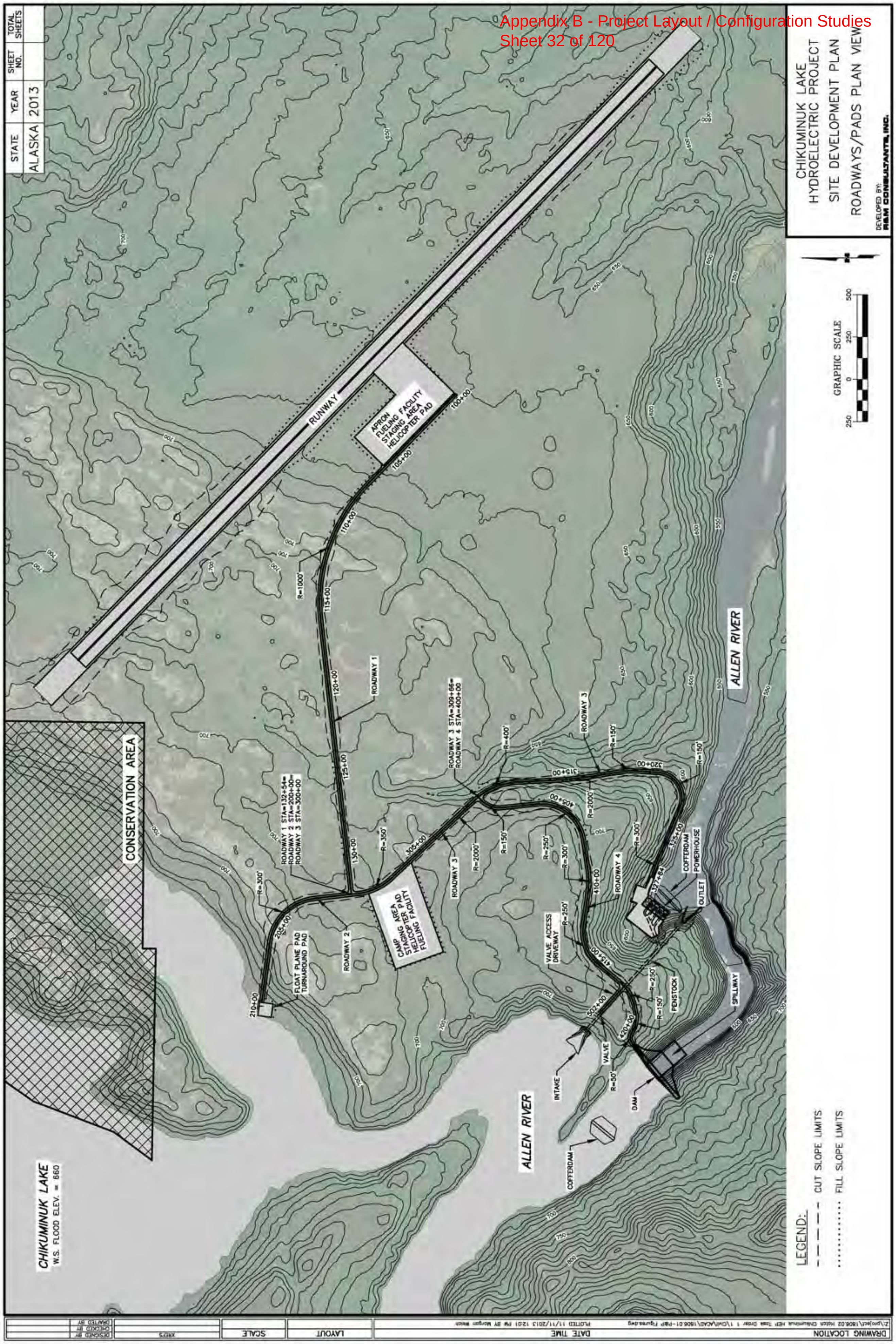


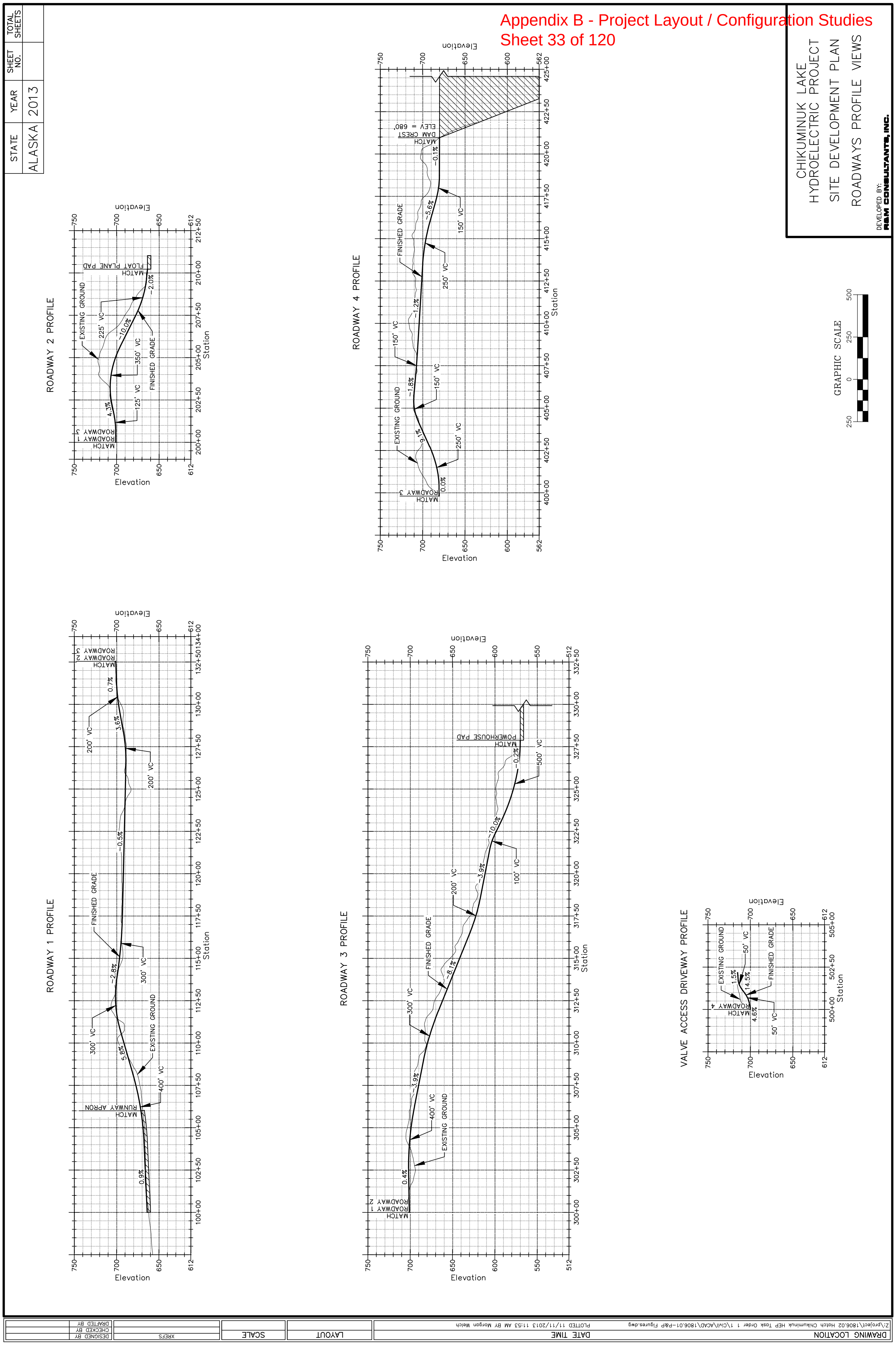
GRAPHIC SCALE
250 0 250 500

CHIKUMINUK LAKE
HYDROELECTRIC PROJECT
RUNWAY
PLAN AND PROFILE

DEVELOPED BY:
R&M CONSULTANTS, INC.

DRAWING LOCATION	DATE TIME	LAYOUT	SCALE	XREFS	DESIGNED BY / CHECKED BY / DRAFTED BY
Z:\project\1806.02 Hatch Chikuminuk HEP Task Order 1 1\Civil\ACAD\Chikuminuk Prelim Design.dwg	PLOTTED 9/27/2013 9:58 AM BY Nicholas Straka				


STATE ALASKA
YEAR 2013
SHEET NO.
TOTAL SHEETS
CHIKUMINUK LAKE HYDROELECTRIC PROJECT
SITE DEVELOPMENT PLAN
ROADWAYS/PADS PLAN VIEW
DEVELOPED BY: R&M CONSULTANTS, INC.
GRAPHIC SCALE
RUNWAY
APRON FUELING FACILITY STAGING AREA HELICOPTER PAD
ROADWAY 1
ROADWAY 2
ROADWAY 3
ROADWAY 4
ROADWAY 1 STA=132+54= ROADWAY 2 STA=200+00= ROADWAY 3 STA=300+00
ROADWAY 3 STA=309+66= ROADWAY 4 STA=400+00
CAMP STAGING AREA HELICOPTER PAD FUELING FACILITY
FLOAT PLANE PAD TURNAROUND PAD
CONSERVATION AREA
CHIKUMINUK LAKE
W.S. FLOOD ELEV. = 660
ALLEN RIVER
ALLEN RIVER
VALVE ACCESS DRIVEWAY
VALVE
INTAKE
PENSTOCK
DAM
SPILLWAY
OUTLET
POWERHOUSE
COFFERDAM
COFFERDAM
LEGEND:
CUT SLOPE LIMITS
FILL SLOPE LIMITS
DRAWING LOCATION
DATE TIME
LAYOUT
SCALE


STATE
ALASKA
YEAR
2013
SHEET NO.
TOTAL SHEETS
CHIKUMINUK LAKE
HYDROELECTRIC PROJECT
SITE DEVELOPMENT PLAN
ROADWAYS PROFILE VIEWS
DEVELOPED BY:
R&M CONSULTANTS, INC.
GRAPHIC SCALE
ROADWAY 1 PROFILE
ROADWAY 2 PROFILE
ROADWAY 3 PROFILE
ROADWAY 4 PROFILE
VALVE ACCESS DRIVEWAY PROFILE
MATCH FLOAT PLANE PAD
MATCH RUNWAY APRON
MATCH POWERHOUSE PAD
MATCH DAM CREST ELEV = 680'
EXISTING GROUND
FINISHED GRADE
Elevation
Station
DRAWING LOCATION
DATE TIME
LAYOUT
SCALE
XREFS
DESIGNED BY
CHECKED BY
DRAFTED BY
PLOTTED 11/11/2013 11:53 AM BY Morgan Welch

Appendix B

Estimated Costs and Quantities

Estimated Construction Costs by Access Alternative

Line	Access Option / Item Description	Unit	Quantity	Unit Price	Amount	Notes
1	**Airstrip Construction**					
	Heavy Lift Copter Operations					
a	Heavy Lift Copter Mobe / Demobe to Dillingham	Lump Sum	1	$ 400,000	$ 400,000	
b	Lift Work	Hr	100	$ 15,000	$ 1,500,000	
c	Fuel	Gal	40,000	$ 12	$ 480,000	
d	Lodging, Per Diem for crew of 10 for 10 days in Dillingham	Each	100	$ 294	$ 29,400	
e	Subtotal Heavy Lift Copter				$ 2,409,400	Lines a-d
f	Heavy Lift Copter Contingency @ 20%				$ 481,880	Line e
g	**Total Heavy Lift Copter Operations**				**$ 2,891,280**	Line e+f
	Runway & Apron Construction					
h	Mobe / Demobe Dillingham	Lump Sum	1	$ 2,460,000	$ 2,460,000	
i	Clear and Grub	Acre	29	$ 10,000	$ 290,000	
j	Unclassified Excavation	Cu. Yd	200,000	$ 22	$ 4,400,000	
k	Runway Structural Section	Cu. Yd	120,000	$ 55	$ 6,600,000	
l	Borrow	Cu. Yd	3,000	$ 35	$ 105,000	
m	Drainage Items @ 5%	Lump Sum	1	$ 570,000	$ 570,000	
n	30-Person Camp, Lodging, Meals	Lump Sum	1	$ 4,381,000	$ 4,381,000	
o	Temporary Erosion Control Measures @ 3%	Lump Sum	1	$ 360,000	$ 360,000.00	
p	Subtotal Runway & Apron Construction				$ 19,166,000	Lines h-o
q	Contingency Runway & Apron Construction @ 40%				$ 7,666,400	Line p
r	Construction Engineering @ 15%				$ 4,030,000	Lines p+q
s	**Total Runway & Apron Construction incl. Heavy Lift Copter**				**$ 33,760,000**	Lines g,p,q,r
2	**Overland Access Road Construction**					
a	From Dillingham					
	Access Road	Mile	120	$ 700,000	$ 84,000,000	
	Contingency Roadway Construction @ 50%				$ 42,000,000	
	Construction Engineering @15%				$ 18,900,000	
	Total Overland Road Construction from Dillingham				**$ 144,900,000**	
b	From Bethel					
	Access Road	Mile	170	$ 700,000	$ 119,000,000	
	Contingency Roadway Construction @ 50%				$ 59,500,000	
	Construction Engineering @15%				$ 26,775,000	
	Total Overland Road Construction from Bethel				**$ 205,275,000**	
c	Barge to Koliganek/Overland Road to Project Site					
	Access Road	Mile	82	$ 700,000	$ 57,400,000	
	Contingency Roadway Construction @ 50%				$ 28,700,000	
	Construction Engineering @15%				$ 12,915,000	
	Total Barge & Road Construction from Koliganek				**$ 99,015,000**	

Estimated Construction Costs by Access Alternative

Line	Access Option / Item Description	Unit	Quantity	Unit Price	Amount	Notes
3	**Winter Road Construction**					
a	From Dillingham					
	Winter Road	Mile	120	$ 400,000	$ 48,000,000	
	Contingency Winter Roadway Construction @ 50%				$ 24,000,000	
	Construction Engineering @15%				$ 10,800,000	
	Total Winter Road Construction from Dillingham				**$ 82,800,000**	
b	Barge to Koliganek/Winter Road to Project Site					
	Access Road	Mile	82	$ 400,000	$ 32,800,000	
	Contingency Roadway Construction @ 50%				$ 16,400,000	
	Construction Engineering @15%				$ 7,380,000	
	Total Barge & Winter Road Construction from Koliganek				**$ 56,580,000**	

ASSUMPTIONS

1. Construction Cost Estimates are Unit Price Estimates in 2013 Dollars. There are no cost adjustments to anticipated construction year.
2. Construction Cost Estimates do not include Owner's costs for oversight and administration of the construction contract.
3. Construction Cost Estimates based on relevant past projects:
   a. Rural Airport Construction: Takotna, Akutan, Tuntutuliak, Manokotak, Nunapitchuk
   b. Rural Road & Bridge Construction: Aleknagik-Wood River Bridge, Dalton Highway, Allison Creek, Battle Creek, Akutan
   c. Winter Road Construction: Various North Slope Projects
4. Regarding the Airstrip Construction Option, the following assumptions have been made in preparing the cost estimate:
   a. All the excavated material would be useable for constructing other project elements, embankment, subbase, surface courses, etc. The structural section unit price reflects the fact that not all material quantity requirements can be satisfied with project excavations and the development of a dedicated material source is likely. It is assumed that such a source would need to be developed regardless in order to construct other Project related elements, dam, coffer dam, aggregates, etc. and would be available for construction of the runway and various site access/circulation roads.
   b. The runway operates under restricted use and Visual Flight Rules (VFR) conditions, meaning installation of minimal lighting and navigational aids.
   c. Construction for the runway, apron, and associated site access/circulation roads would take two seasons. The runway could be constructed to the bottom of the runway structural section at the end of year one and the embankment left to settle/consolidate over the winter. Year two would repair any settled areas and put down the material for the structural section. The partially completed runway would be open to aircraft operation, depending on load restrictions. Construction of the site access/circulation roads would be concurrent in year two. With the runway open to aircraft, additional equipment and personnel could be brought in to complete remaining construction activities.
   d. The 30 person construction camp is temporary, intended to support staff necessary for the construction of the runway, apron and site access/circulation roads. Permanent housing and camp facilities would be constructed at the permanent camp pad. Camp costs reflect housing, power, equipment, food and supplies for 30 persons for 1.5 construction seasons. After that, construction staff would stay in the permanent camp. Power includes primary and backup generators and fuel. Camp Costs include 3 support staff (cook, housekeeping and maintenance).
   e. Two seasons for runway and site access/circulation road construction based on the provided construction equipment mix. This mix represents the minimum. Actual equipment fleet would be decided by the Contractor. More equipment could reduce construction time but increase mobe/demob costs.
5. Regarding the Overland Access Road Construction Options, the provided costs per mile reflect construction efficiencies associated with the project scale.

Estimated Construction Costs for Network Roads and Supporting Elements

Line	Item Description	Unit	Quantity	Unit Price	Amount
1	**Roadway 1 Construction (Runway to Camp Intersection (Intx))**				
	Clear and Grub	Acre	13	$ 10,000	$ 129,262
	Unclassified Excavation	Cu. Yd	19,000	$ 22	$ 418,000
	Borrow	Cu. Yd	0	$ 35	$ -
	Roadway Structural Section	Cu. Yd	9,000	$ 55	$ 495,000
	Subtotal Roadway 1 Construction				**$ 1,042,262**
2	**Roadway 2 Construction (Camp Intx to Float Plane & Boat Ramp Pad)**				
	Clear and Grub	Acre	4	$ 10,000	$ 35,196
	Unclassified Excavation	Cu. Yd	25,000	$ 22	$ 550,000
	Borrow	Cu. Yd	0	$ 35	$ -
	Roadway Structural Section	Cu. Yd	3,000	$ 55	$ 165,000
	Subtotal Roadway 2 Construction				**$ 750,196**
3	**Roadway 3 Construction (Camp Intx to Powerhouse Site)**				
	Clear and Grub	Acre	9	$ 10,000	$ 94,495
	Unclassified Excavation	Cu. Yd	51,000	$ 22	$ 1,122,000
	Borrow	Cu. Yd	2,000	$ 35	$ 70,000
	Roadway Structural Section	Cu. Yd	8,000	$ 55	$ 440,000
	Subtotal Roadway 3 Construction				**$ 1,726,495**
4	**Roadway 4 Construction (Intx with Roadway 3 to Dam*)** *(Includes driveway to valve)				
	Clear and Grub	Acre	6	$ 10,000	$ 59,858
	Unclassified Excavation	Cu. Yd	67,000	$ 22	$ 1,474,000
	Borrow	Cu. Yd	1,000	$ 35	$ 35,000
	Roadway Structural Section	Cu. Yd	6,000	$ 55	$ 330,000
	Subtotal Roadway 4 Construction				**$ 1,898,858**

Estimated Construction Costs for Network Roads and Supporting Elements

Line	Item Description	Unit	Quantity	Unit Price	Amount
5	**Camp Pad (Permanent)**				
	Clear and Grub	Acre	5	$ 10,000	$ 45,839
	Unclassified Excavation	Cu. Yd	6,000	$ 22	$ 132,000
	Borrow	Cu. Yd	8,000	$ 35	$ 280,000
	Roadway Structural Section	Cu. Yd	14,000	$ 55	$ 770,000
	Subtotal Camp Pad Construction				**$ 1,227,839**
6	**Float Plane & Boat Ramp Pad (Permanent)**				
	Clear and Grub	Acre	5	$ 10,000	$ 45,839
	Unclassified Excavation	Cu. Yd	3,000	$ 22	$ 66,000
	Borrow	Cu. Yd	0	$ 35	$ -
	Roadway Structural Section	Cu. Yd	1,000	$ 55	$ 55,000
	Dock, Ramp, Misc Items	Lump Sum	1	$ 100,000	$ 100,000
	Subtotal Float Plane & Boat Ramp Pad Construction				**$ 266,839**
	Subtotal Project Site Development/Access Roads				$ 6,912,489
	Contingency Project Site Development Construction @ 40%				$ 2,764,996
	Drainage Items @ 5%				$ 483,874
	Temporary Erosion Control Measures @ 3%				$ 304,841
	Subtotal Project Site Development/Access Roads				**$ 10,466,200**
	Construction Engineeering @ 15%				$ 1,569,930
	Total Project Site Development Construction Costs				**$ 12,036,130**
	Total Project Site Development Construction Costs (Rounded)				**$ 12,100,000**

ASSUMPTIONS

1. Construction Cost Estimates are Unit Price Estimates in 2013 Dollars. There are no cost adjustments to anticipated construction year.
2. Construction Cost Estimates do not include Owner's costs for oversight and administration of the construction contract.
3. Roadway Structural Section unit cost reflects the assumption that the specific material layers can be derived from on-site project excavations or material site with select screening and minimal processing.

Estimated Temporary Construction Camp Costs and Staffing

Estimate Duration (days)* 360

*Based on 180 days/construction season.
Construction season is from May 1 thru October 31.

Cost Item	Unit	Quantity	Unit Price	Amount
Camp Mobe/Demobe to Dillingham	Each	1	$ 250,000	$ 250,000
30-Person Camp	Per Person-Day	8,100	$ 400	$ 3,240,000
Power	Per Person-Day	8,100	$ 50	$ 405,000
30-Person Camp Support staff of 3	Per Person-Day	8,100	$ 60	$ 486,000
Subtotal Camp Development				**$ 4,381,000**

Estimated Project Construction Staffing

Contractor	
Equipment Operators	10
On-Site Mechanic	1
Oiler	1
Project Super	1
Foreman	1
Project Engineer	1
Grade Check/Surveyor	1
Laborers (general)	4
Camp Staff (cook, housekeep, maintenance, staff)	3
Owners Reps	
Project Engineer	1
Inspector/Material	3
Others	3
Total	**30**

ASSUMPTIONS

1. Temporary Construction Camp Cost Estimate is in 2013 Dollars. There are no cost adjustments to anticipated construction year.
2. The 30 person construction camp is temporary, intended to support staff necessary for the construction of the runway, apron and site access/circulation roads. Permanent housing and camp facilities would be constructed at the permanent camp pad. Camp costs reflect housing, power, equipment, food and supplies for 30 persons for 1.5 construction seasons. After that, construction staff would stay in the permanent camp. Power includes primary and backup generators and fuel. Camp Costs include 3 support staff (cook, housekeeping and maintenance).
3. Number of equipment operators based on the Estimated Construction Equipment Mix.

Estimated Construction Equipment Mix

EQUIPMENT	OPERATING WEIGHT (lbs.)	QUANTITY	Total
Small Equipment			
CAT Dozer D4	19,000	1	19,000
CAT Excavator 316	38,000	1	38,000
Medium Equipment			
CAT Dozer D6	46,150	2	92,300
CAT Excavator 320	55,000	2	110,000
CAT Loader 950	44,000	1	44,000
CAT 725 Articulated Truck	50,000	2	100,000
C AT 54B Compactor	24,000	1	24,000
CAT 160M2 Motor Grader	45,500	1	45,500
Total Weight to be Lifted (lbs)			472,800
Total Weight to be Lifted (tons)			236

ASSUMPTIONS

1. This estimated equipment mix represents the minimum pieces of equipment necessary to complete runway and site access roads in two construction season.
2. This equipment mix has limited redundancy in case of mechanical breakdowns or scheduled maintenance.
4. Additional equipment considerations may include additional trucks (2-CAT 725) and a second compactor/roller (CAT 54B)
5. This equipment would be available for dam and related facility construction.
6. Equipment unique to dam and related facility construction would be delivered via plane using the newly constructed runway.

Estimated Heavy Lift Copter Operations and Costs

DESCRIPTION	Quantity	Unit	Unit Price	Amount
Mobilization / Demobilization	1	LS	$400,000	$400,000
Airlift Work	100	hrs	$15,000	$1,500,000
Fuel	40,000	gal	$12	$480,000
Lodging & Per Diem for crew of 10 for 10 days	100	each	$294	$29,400
Subtotal				$2,409,400

ASSUMPTIONS

1. Heavy lift Copter cost estimate is in 2013 Dollars. There are no cost adjustments to anticipated construction year
2. Heavy lift operations, including equipment staging and loading operations will be out of Dillingham
3. Estimate 90 air miles from Dillingham to Chikuminuk Lake Project Site for a total of 2.5 flight hours for round trip
4. Estimate 9 actual days of flying and 2 weather days for total of 10 days (90 hrs + 8hrs
5. Weather days are charged at a minimum of 4hrs/day or 8hrs for two days.
6. Estimate the need to move 600,000 lbs (475,000 lbs of equipment and another 125,000 lbs of misc. other supplies, equipment, fuel, etc.
7. Estimate moving 20,000 lbs per trip:

# of trips =	30	(600,000/20,000)
# of flight hours =	75	(30 x 2.5)
cont. hrs =	16	
weather hrs =	8	
Subtotal hrs	99	
Use	100	

8. Estimated fuel consumption 400 gal per hour

Internal Project Memo

H342022

Nov 1, 2013

To: Dick Griffith

From: Ray Trudgeon

cc: Carl Mannheim
Joe Earsley
Eli Sanders

Nuvista
Chikuminuk Hydroelectric Project

Selection of Preferred Site and Dam Alternative

1. Introduction

Hatch is currently preparing the Interim Feasibility Report (Task 6.7) for the proposed Chikuminuk Lake Hydropower Project (Project), FERC No. P-14369. This objective of this report is provide an economic analyses and feasibility assessment of a hydropower development at Chikuminuk Lake and will identify the preferred project configuration such as site access, hydropower features, and transmission line routing. An intermediate step is to select a preferred dam site and dam configuration. This memorandum summarizes the decision process and ultimate selection of the preferred alternative. The dam site and configuration review included an upstream and downstream site with the review of a concrete-faced rockfill dam (CFRD) and roller compacted concrete (RCC) dam configuration at each site, for a total of four dam alternatives. Further review and refinement to the selected alternative will be performed as part of the Interim Feasibility Report.

The project would be located on the Allen River which is the outlet to Chikuminuk Lake. Existing normal pool elevation of the lake is 598 ft with a surface area of about 24,640 acres, while the project would raise the lake elevation to a normal maximum pool elevation of 660 ft. The outlet of the lake is at the southeast end and is formed by the Allen River. A recessional moraine over shallow rock is located at the southeast arm of the lake and the Allen River cuts through this moraine as an approximately 60 to 80 ft deep and 100 to 150 wide U-shaped canyon.

Previous feasibility studies have been performed by Harza (Harza 1984) and MWH (MWH 2011). The Harza 1984 study analyzed both CFRD and RCC dam configurations at the upstream site and selected the RCC alternative as the preferred alternative. The MWH 2011 study analyzed a CFRD configuration near the downstream site. The results of these studies were reviewed as part of the current study.

As part of this study, R&M Consultants (R&M) performed additional survey of the project site and developed a Digital Terrain Model (DTM) which has 10-ft contour intervals. The DTM and survey information has allowed for a more detailed review and layout of the major hydropower features and access.

Layouts of the dam, spillway, diversion tunnel and cofferdams, power tunnel and powerhouse were prepared for each of the four dam alternatives. These major project features are the major items that will vary between the alternatives and help to distinguish the pros and cons of each site. Additional major project features such as site access and transmission routes were not included in this phase of the project, as they are common for each of the alternatives.

Preliminary cost estimates on a unit cost basis of major project features were prepared for each alternative. These preliminary cost estimates were compared as well as additional items such as environmental concerns, aesthetics, visual impact, and hydrological considerations. Based on a comparison of these criteria the RCC Downstream alternative was selected as the preferred alternative. The methodology and basis for this selection is described below.

2. Descriptions of Alternatives

2.1 General

The upstream and downstream sites are approximately 1,500 ft and 4,500 ft downstream by river of the existing lake outlet respectively. In order to maintain the same operating head between the four alternatives, the powerhouse is located in same area for each alternative, thus the diversion tunnel and power tunnel lengths are significantly different for the upstream and downstream locations.

2.2 Geology

Due to permitting constraints no geologic assessment from the surface was allowed. Site geology was inferred from helicopter flyovers and photographs. From this assessment it was determined that the beds are standing on end (near vertical) and roughly parallel to the line of the tunnel as evidenced by the long stretches of the lake outlet in the legs of the "S" curves.

2.3 Tunnel

The site geology requires that the tunnels should be fully supported w/ steel sets and lagging. The diversion and power tunnels have been designed as horseshoe shaped with steel sets at a 4 ft spacing. Due to the anticipated highly jointed nature and joint orientation of the bedrock for the tunnels, the power tunnel has been designed to be fully concrete lined. This type of support for the final lining will provide a decreased surface roughness, thus less friction head loss, and a more positive rock protection than an open rock surface. The diversion tunnel has been designed without concrete lining.

The diameter of the diversion tunnels were designed to maintain normal depth flow for the given tunnel length and gradient. The design diversion flows for the RCC alternatives were lower than the CFRD alternatives, since the damage consequences of cofferdam overtopping for the CFRD alternatives is significantly greater. A diversion dam failure for the CFRD alternatives would likely result in the destruction of the dam under construction and create a significant construction delay. The RCC alternatives can tolerate overtopping and construction delays due to concrete cleaning and preparation would be minimized. Also, a low level outlet pipe would be installed at the base of the RCC alternatives and could serve as a secondary dewatering measure.

The power tunnels for the four dam alternatives were designed such that the head losses were relatively the same for each alternative. Steel tunnel liners have been assumed at the power tunnel outlet for each alternative, but since they were similar for each alternative the cost comparison was not included in this study. As the selected alternative is further reviewed as part of the Interim Feasibility Report, the tunnel support and lining will be reviewed.

2.4 CFRD Dam and Spillway Characteristics

In a CFRD configuration the dam is composed primarily of large diameter rockfill with layers of a coarse transition material and bedding material at the upstream face to support an impervious facing of reinforced concrete. The upstream and downstream faces were designed at 1.7H:1V and 1.5H:1V respectively. A separate spillway channel through an abutment is required for the CFRD alternatives and requires a significant volume of excavation. The excavated material from the spillway would be the primarily source of fill for the dam, thus source material would be readily available and haul distances would be relatively short.

The CFRD spillway is comprised of an unlined approach channel with a reinforced concrete ogee spillway and stilling basin. A Type II Stilling Basin was selected based on the design head and flow using The United States Bureau of Reclamation Engineering Monograph No. 25 – Hydraulic Design of Stilling Basins and Energy Dissipators. The dam and spillway for the CFRD alternatives were sized to pass the Probable Maximum Flood (PMF) flow while maintaining 5 ft of freeboard at the dam.

2.5 RCC Dam and Spillway Characteristics

RCC mixes are composed of less cement and fly ash than structural concrete. Since the RCC mixes are typically designed for a significantly lower compressive strength than structural concrete, RCC dams are designed to resist overturning by gravity of the dam mass. RCC dams are constructed primarily of RCC with structural concrete being utilized at the upstream face, spillway and stilling basin. The RCC mix would be delivered to the dam and concrete trucks via conveyor belts from a batch plant located at the left abutment. The RCC mix is placed and compacted using traditional earthwork construction equipment such as bulldozers and rollers, thus it doesn’t require specialty equipment or labor. Another typical benefit of RCC construction is that it can be placed with relatively high efficiency.

The RCC dam alternatives were designed with a vertical upstream face and a downstream face sloping at 0.8H:1V. With an RCC dam the spillway and stilling basin are integrated into the dam. A Type II Stilling Basin was also selected for the RCC alternatives. Due to the more robust structure of an RCC dam, the design freeboard while passing the PMF flow was selected as 2 ft.

2.6 RCC Dam Upstream Alternative

The RCC dam at the upstream site would have a dam crest elevation of 676 ft for a dam height of approximately 86 ft. A 90 ft wide ogee spillway would be located on the dam with a crest elevation of 660 ft. The overall volume of RCC and structural concrete is approximately 19,000 CY and 6,000 CY respectively.

The diversion and power tunnels are located in the left abutment with approximate lengths of 500 ft and 2,100 ft respectively. An approximately 250 ft length of the upstream end of the permanent power tunnel will be utilized during flow diversion for dam construction. The slope of the diversion and power tunnels will be approximately 2.5%. See Appendix A for the layout of the RCC Dam Upstream Site Plan.

Pros:

- Reduced dam footprint and volume compared to CFRD Upstream alternative and CFRD and RCC Downstream alternative.
- Shorter overall diversion tunnel length than downstream sites.
- Integrated spillway so no separate spillway excavation.
- Lower cost than CFRD Upstream and Downstream alternatives.

Cons:

- Longer power tunnel than downstream alternatives.
- Approximate 4,200 length of stream dewatered between dam and powerhouse.
- Dam and intake are visible from Chikuminuk Lake.
- Dam site is upstream of an unnamed tributary to the Allen River, thus reducing reservoir inflow compared to downstream alternatives.
- Higher cost than RCC Downstream alternative.

2.7 CFRD Upstream Alternative

The CFRD dam at the upstream site would have a dam crest elevation of 676 ft for a dam height of approximately 86 ft. The overall volume of fill materials is approximately 56,000 CY, while the combined structural concrete volume of the dam and spillways is approximately 10,300 CY. The ogee spillway would be located on the right abutment with a crest elevation of 660 ft and crest width of 150 ft. Excavation for the spillway will be significant and as cuts are as deep as 75 ft, and the overall excavation volume is approximately 260,000 CY. Separate mobilization to the right abutment would be required in order for the spillway excavation to begin and generate the required fill for the dam.

The diversion and power tunnel arrangement is the same for CFRD Upstream alternative as the RCC Upstream alternative. Cofferdam heights for the CFRD Upstream alternative would be higher than the RCC Upstream alternative since it will be designed for a higher flow recurrence interval. See Appendix A for the layout of the CFRD Upstream Site Plan.

Pros:

- Lower volume than CFRD Downstream alternative.
- Shorter overall diversion tunnel length than downstream sites.

Cons:

- Highest cost alternative.

- Longer power tunnel than downstream alternatives.
- Approximate 4,200 length of stream dewatered between dam and powerhouse.
- Dam, spillway and intake are visible from Chikuminuk Lake.
- Dam site is upstream of an unnamed tributary to the Allen River, thus reducing reservoir inflow compared to downstream alternatives.

2.8 RCC Dam Downstream Alternative

At the downstream site the RCC Dam alternative would have a dam crest elevation of 676 ft for a dam height of approximately 124 ft. A 110 ft wide ogee spillway would be located on the dam with a crest elevation of 660 ft. The overall volume of RCC and structural concrete is approximately 35,000 CY and 8,300 CY respectively.

The diversion and power tunnels are located in the left abutment with approximate lengths of 400 ft and 800 ft respectively. An approximately 750 ft length of the upstream end of the permanent power tunnel will be utilized during flow diversion for dam construction. The slope of the diversion and power tunnels will be approximately 4.0%. See Appendix A for the layout of the RCC Dam Downstream Site Plan typical dam, and tunnel sections.

Pros:

- Lowest cost alternative.
- Reduced dam footprint and volume compared to CFRD alternatives.
- Shortest overall tunnel length of any alternative.
- Integrated spillway so no separate spillway excavation.
- Approximate 1,300 length of stream dewatered between dam and powerhouse is much less than upstream alternatives.
- Major hydropower features not visible from Chikuminuk Lake.
- Gain inflows from unnamed tributary to the Allen River that may be used for generation.

Cons:

- Greater RCC and structural concrete volume than RCC Upstream alternative.
- Steepest tunnel gradient required for construction.

2.9 CFRD Downstream Alternative

The CFRD dam at the downstream site would have a dam crest elevation of 676 ft for a dam height of approximately 124 ft. The overall volume of fill materials is approximately 152,000 CY, while the combined structural concrete volume of the dam and spillways is approximately 16,100 CY. The ogee spillway would be located on the left abutment with a crest elevation of 660 ft and crest width of 150 ft. Excavation for the spillway will be significant and as cuts are as deep as 80 ft, and the overall excavation volume is approximately 210,000 CY.

Due to the location of the spillway in the left abutment, the powerhouse would be located east of the spillway and further downstream than the RCC Dam Downstream alternative. This shift in powerhouse location increases the tunnel lengths, and the diversion and power tunnels lengths are approximately 600 ft and 1,100 ft respectively. An approximately 800 ft length of the upstream end of the permanent power tunnel will be utilized during flow diversion for dam construction. The slope of the diversion and power tunnels will be approximately 3.5%. Cofferdam heights for the CFRD Downstream alternative would be higher than the RCC Downstream alternative since it will be designed for a higher flow recurrence interval. See Appendix A for the layout of the CFRD Downstream Site Plan.

Pros:

- Lower cost than CFRD Upstream alternative.
- Shorter overall tunnel length than upstream alternatives.
- Approximate 1,300 length of stream dewatered between dam and powerhouse is much less than upstream alternatives.
- Major hydropower features not visible from Chikuminuk Lake.
- Gain inflows from unnamed tributary to the Allen River that may be used for generation.

Cons:

- Higher cost than RCC Dam alternatives.
- Greatest footprint and volume of any dam alternative.
- Spillway is a significant excavation that is highly visible from air.

3. Cost Estimates

3.1 Unit Cost Approach and Assumptions

As part of the evaluation process for the four dam alternatives, preliminary cost estimates for each alternative were prepared on a unit cost basis. The preliminary cost estimates focused only on the major hydropower items that differ significantly between the four alternatives including the dam, spillway, and diversion and power tunnel features. Preliminary quantity takeoffs were performed for these project features. Dam quantities and unit costs were developed for the excavation, concrete (Structural and RCC), and fill material. Excavation and concrete quantities and unit costs were developed for the spillways. Tunnel unit costs included excavation and concrete lining.

These items are the major cost items that are likely to differ significantly between the alternatives and help to distinguish the costs. For this phase of the study and cost estimate, it was assumed that site access is by airstrip. The Lockheed C-130 (Hercules) with a payload of 48,000 lb was used as the assumed plane for air freight delivery. The overall weight of imported items was estimated for the preliminary cost items in order to determine the total number of air freight deliveries. A delivery cost of $30,000 per flight was assumed for the preliminary cost estimate based on previous experience. Air freight delivery costs will be reviewed further during the detailed cost estimate and will involve discussion with vendors.

Sample mixes for the structural concrete and RCC were developed to estimate the total weight of cement, fly ash and aggregate required. Preliminary geological assessment of the rock at the site indicate that aggregate produced on-site may have the potential of creating the damaging Alkali-Aggregate Reaction (AAR), which is also known as Alkali-Silica Reaction (ASR), when used in concrete. Previously the importation of concrete aggregate had been discussed to avoid the AAR potential. However based on review of the quantity of aggregate required and costs for air freight delivery, the importation of concrete aggregate would make all alternatives cost prohibitive. AAR is a widely recognized problem and the sample mixes were designed to counteract this problem.

3.2 Structural Concrete and RCC Unit Costs

Sample structural concrete and RCC mixes were determined based on previous project experience for sites of similar climate. In order to counteract the potentially reactive aggregate, the fly ash content for both mixes was kept high. The total weight cement and fly ash, which is the total cementitious materials, was determined for both concrete mixes in order to determine the number of required flights and the air freight delivery costs. The delivery cost was then added cost of cementitious materials purchased in Anchorage, which was based on previous estimates.

Previous project experience was used to estimate cost of aggregate production, and concrete placement costs on a CY basis, as well as the cost of the batch plant. When the batch plant is cost is included in the concrete unit cost, the mobilization costs and operation costs spread across the volume and a slight scale of economy is realized.

Reinforcement costs were included in the structural concrete unit costs and total weight of reinforcement and air freight delivery costs were estimated similar to the cementitious materials. Approximate weight of steel was estimated per CY of structural concrete. It was assumed that the amount of reinforcing steel per CY of structural concrete was slightly less for the RCC alternatives than for structural concrete used in the CFRD alternatives. This assumption was made since more CFRD features were cantilever, where structural concrete bears against the RCC dam. Also the upstream structural concrete facing of the RCC alternatives, which is a significant volume, would be minimally reinforced.

The unit cost for the structural concrete lining of the tunnels was simply increased $100/CY above the cost of the structural concrete for the dam and spillway for each alternative. This assumption was based on the fact that costs for concrete in tunnels are typically greater due to increased formwork and working space and access restrictions.

3.3 Excavation and Fill Unit Costs

The excavation volumes for the dam and spillways were determined using AutoCAD and checked by hand calculations. The total volume of each dam alternative was also calculated using AutoCAD and checked by hand calculations. The unit costs for excavation were based on previous project experience. Unit costs for dam excavation were estimated higher than for spillway excavation due to the steep topography at the dam site and more difficult site access. Also the spillway excavation could proceed with larger production blasting operations than at the dam due to the topography and significantly greater volume of excavation. Similarly the fill material unit costs for the CFRD alternatives were based on previous project experience.

3.4 Tunnel Unit Costs

Unit costs were developed for the excavation, which includes steel support, and concrete lining for the diversion and power tunnels. The diameter of the finished modified (straight leg) horseshoe diversion tunnel was sized for each alternative in order to maintain normal depth for the design diversion flow. The diversion tunnel diameter varies for each design alternative from 14.0’ to 16.5’.

A reinforced concrete liner was assumed for the power tunnels. An overbreak of 0.5 ft is assumed for the tunnels. The reinforced concrete liner for the power tunnels is estimated to extend 0.5 ft to the interior of each side of the steel sets and will encapsulate the steel sets

The preliminary estimated cost of tunnel excavation was $600/CY. This estimate was based upon a previous 18-foot horseshoe tunnel for a recent bid on in Central British Columbia, and is of comparable size to the excavation required for both the diversion and power tunnels. This cost includes using type V tunnel supports (steel sets) which would be fabricated from W6x25’s and installed at a 4 ft spacing for all diversion and power tunnels. Front-end loaders have been assumed for all spoils removal. An additional cost of approximately $1,000,000 would be required for mobilization of the equipment to the site, while the cost of demobilization would be slightly less. The mobilization/demobilization costs are approximately the same for all design alternatives, and were not considered in the selection process.

3.5 Preliminary Cost Estimate

The development of the aforementioned unit costs allowed for the cost comparison of the four alternatives through the preliminary cost estimates. The preliminary cost estimate of the CFRD Upstream and Downstream alternatives is approximately $61 million and $56 million respectively, while the Upstream and Downstream RCC alternatives are approximately $48 million and $35 million respectively. In general the cost comparison indicates that the RCC alternatives are less costly than the CFRD alternatives significantly due to the high cost of the separate spillway, which is approximately $20 million, for the CFRD alternatives. Also, the cost comparison indicates that the increased tunnel lengths required for the upstream alternatives significantly increase the costs above the downstream alternatives. The total tunnel costs CFRD and RCC Upstream alternatives are approximately $13 million and $19 million greater than the downstream alternatives respectively. **Table 1** in below provides a cost comparison summary of the four alternatives.

Table 1: Cost Comparison Summary

		Upstream Dam Location						Downstream Dam Location					
		Concrete Faced Rockfill			Roller Compacted Concrete			Concrete Faced Rockfill			Roller Compacted Concrete		
Item	Units	Quantity	Unit Cost	Cost	Quantity	Unit Cost	Cost	Quantity	Unit Cost	Cost	Quantity	Unit Cost	Cost
Dam													
Excavation	CY	10,200	$55	$561,000	6,100	$55	$335,500	20,400	$55	$1,122,000	11,000	$55	$605,000
Structural Concrete	CY	4,400	$1,500	$6,600,000	6,000	$1,350	$8,100,000	6,500	$1,350	$8,775,000	8,300	$1,250	$10,375,000
RCC Concrete	CY			$0	19,000	$475	$9,025,000			$0	35,000	$375	$13,125,000
Rock Fill	CY	43,200	$40	$1,728,000			$0	126,000	$40	$5,040,000			$0
Bedding Fill	CY	3,000	$50	$150,000			$0	6,000	$50	$300,000			$0
Transition Material Fill	CY	9,600	$45	$432,000			$0	20,000	$45	$900,000			$0
Dam Subtotal				$9,471,000			$17,460,500			$16,137,000			$24,105,000
Spillway													
Excavation	CY	260,000	$40	$10,400,000			$0	210,000	$40	$8,400,000			$0
Structrual Concrete	CY	5,900	$1,500	$8,850,000			$0	9,600	$1,350	$12,960,000			$0
Spillway Subtotal				$19,250,000			$0			$21,360,000			$0
Diversion Tunnel													
Excavation and Support	CY	8,732	$600	$5,239,200	8,732	$600	$5,239,200	9,917	$600	$5,950,200	3,912	$600	$2,346,959
Diversion Tunnel Subtotal				$5,239,200			$5,239,200			$5,950,200			$2,346,959
Power Tunnel													
Excavation and Support	CY	24,739	$600	$14,843,229	24,739	$600	$14,843,229	12,369	$600	$7,421,400	8,996	$600	$5,397,600
Concrete Liner	CY	7,316	$1,600	$11,705,545	7,316	$1,450	$10,608,150	3,658	$1,450	$5,304,100	2,660	$1,350	$3,591,000
Power Tunnel Subtotal				$26,548,774			$25,451,379			$12,725,500			$8,988,600
TOTALS				$60,509,000			$48,151,000			$56,173,000			$35,441,000

4. Selection of Preferred Alternative

4.1 Conclusions

The results of the preliminary cost estimates and alternative reviewed were presented to Nuvista during and internal team meeting on September 25th, 2013, and the RCC Downstream alternative was selected as the preferred alternative. The RCC Downstream alternative emerged as the preferred alternative for several factors including; lowest cost alternative; least visible alternative; shorter dewatered reach when compared to upstream alternatives; and the downstream location has increased reservoir inflow.

Following the September 25th meeting, a peer review of the preliminary estimate of costs for the four alternatives was conducted. A memorandum summarizing the peer, unit cost review is included in Appendix B. The review suggested certain revisions to the unit costs. These revisions are reflected in Table 1. As the unit cost revisions were minor, the cost comparison rankings did not change.

4.2 Recommendations and Next Actions

Although the preliminary cost estimates were performed in limited scope, only significant changes to the unit costs would likely changes the cost comparison rankings. Further features of the selected alternative, RCC Downstream, will be developed in more detail.

These detailed drawings will be utilized to develop a detailed cost estimate and schedule. The detailed cost estimate will be prepared in a “Contractor” approach in which unit costs will be estimated based on labor, equipment and materials costs. It will also include all major project features which were not included as part of the alternative review and overhead costs such as the construction camp.

The detailed drawing and cost estimate preparation are currently under development.

:

Appendix A

Dam Alternative Figures

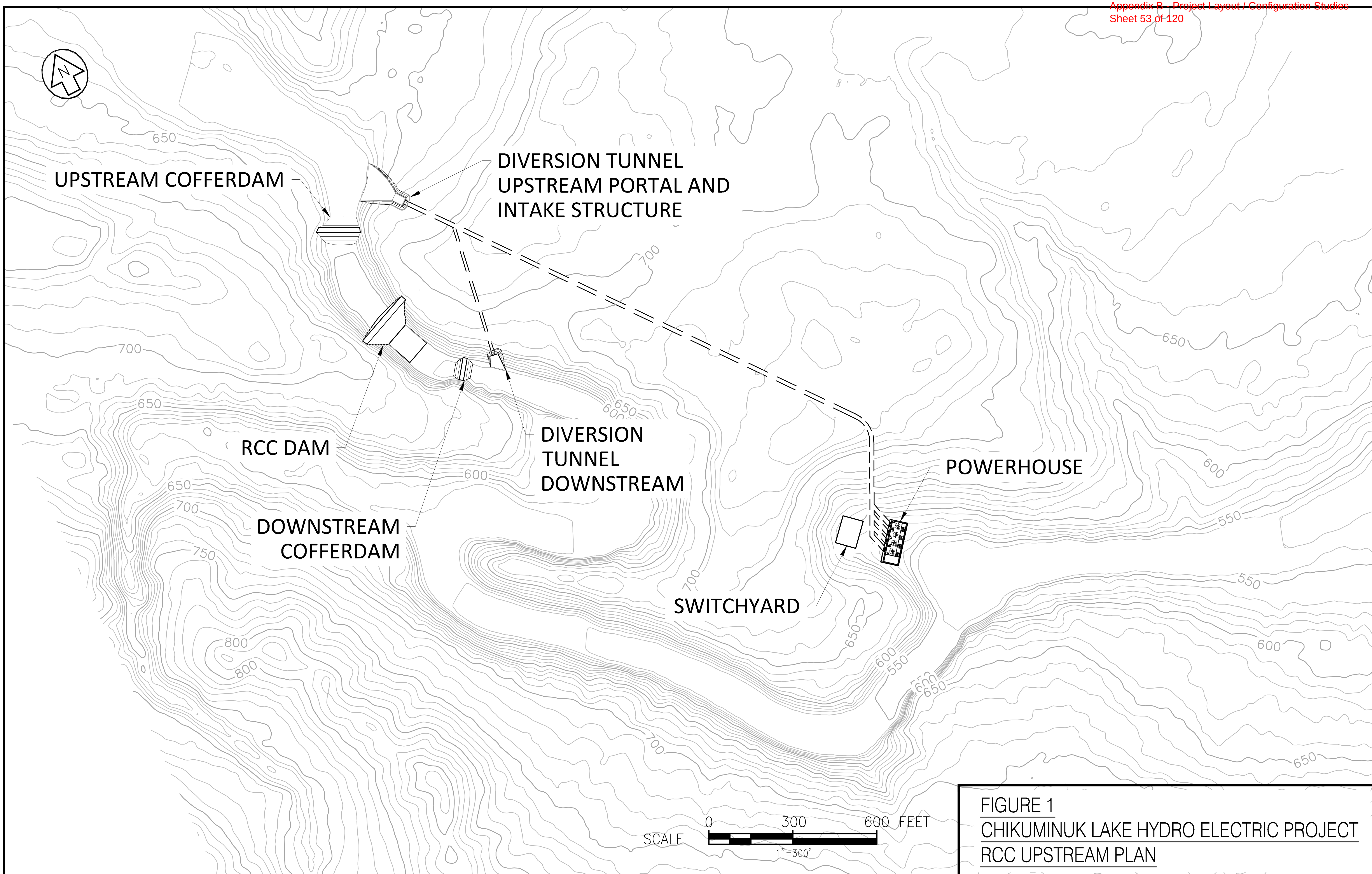


FIGURE 1
CHIKUMINUK LAKE HYDRO ELECTRIC PROJECT
RCC UPSTREAM PLAN

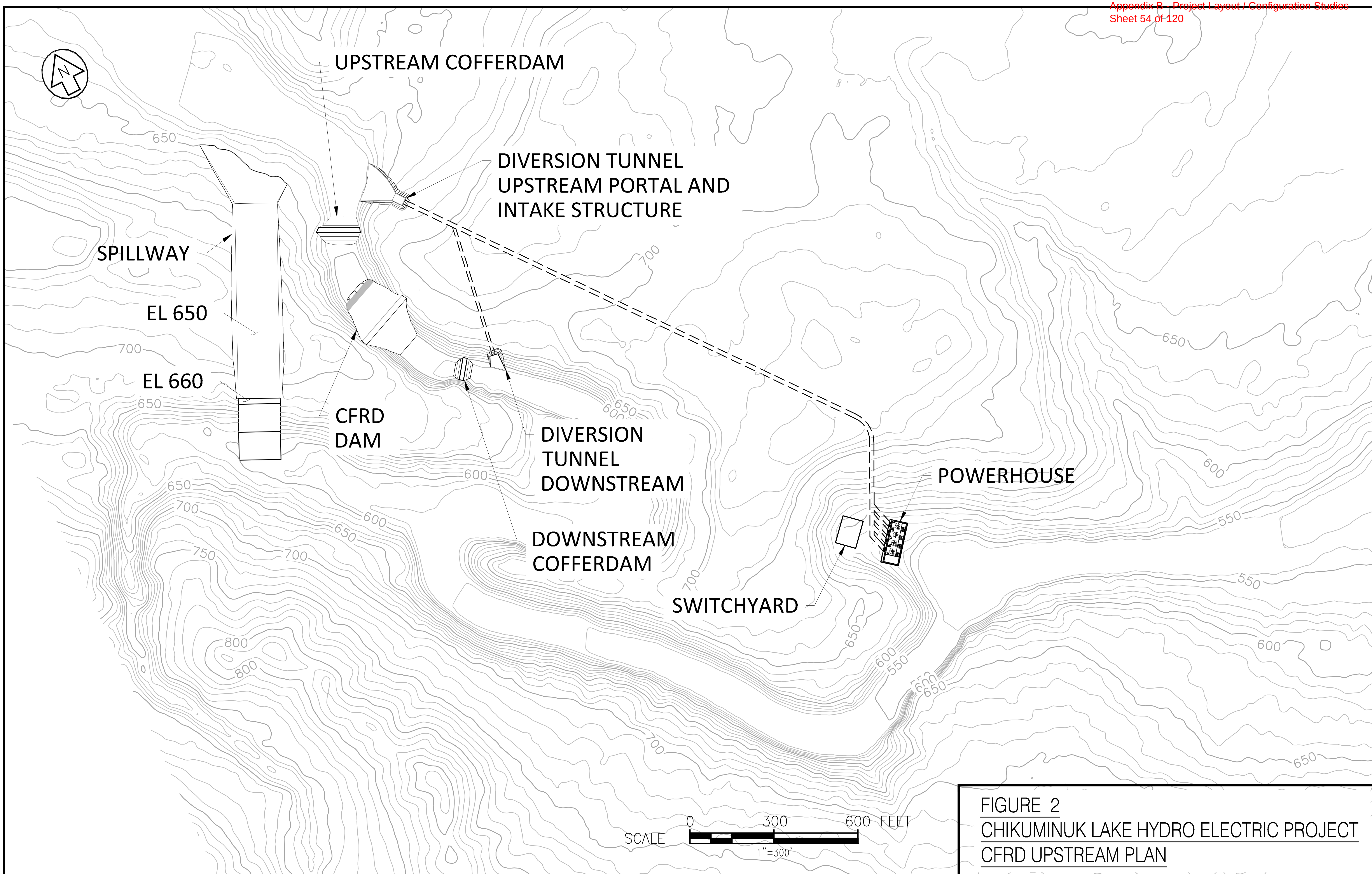


FIGURE 2
CHIKUMINUK LAKE HYDRO ELECTRIC PROJECT
CFRD UPSTREAM PLAN

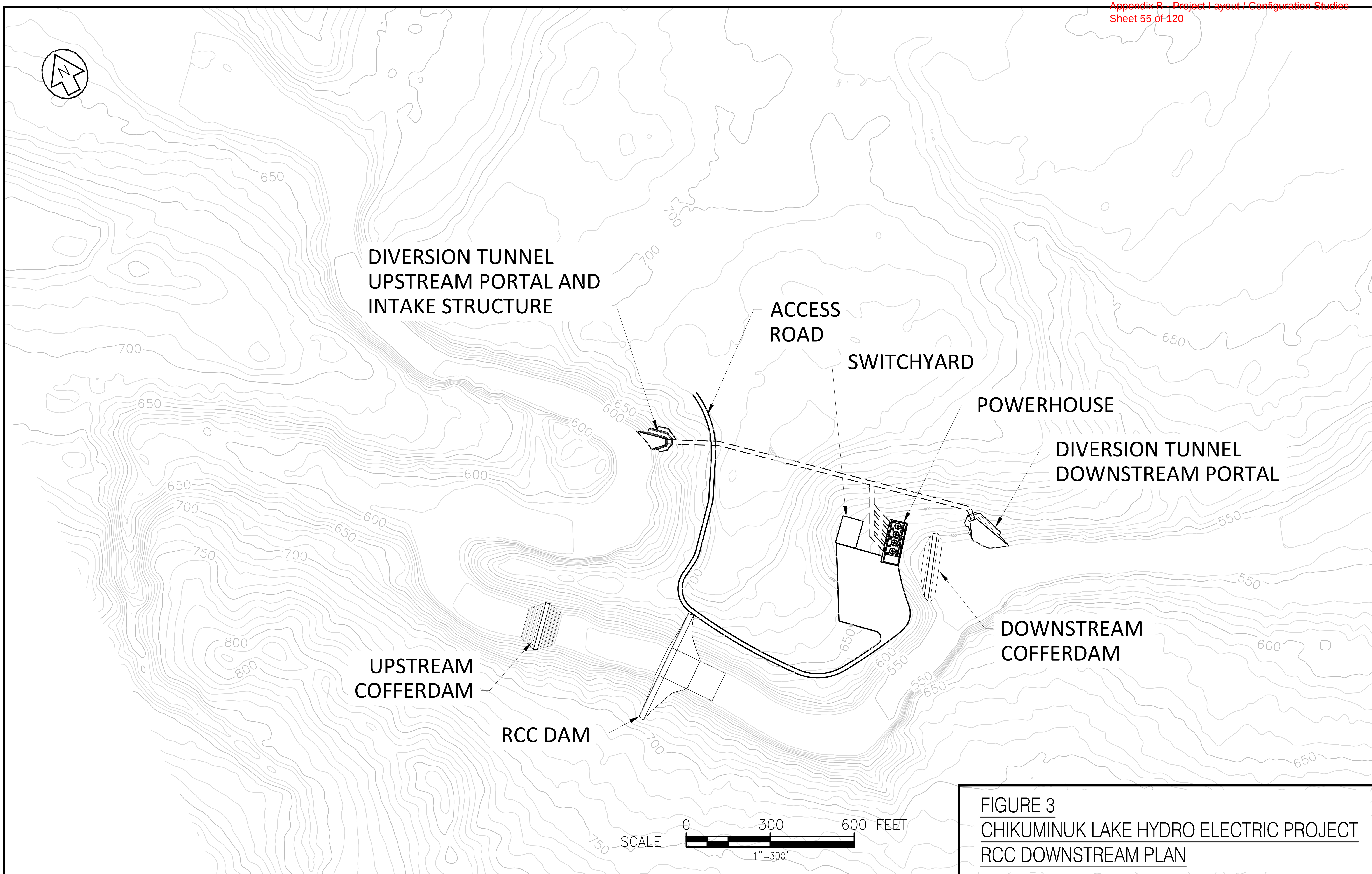


FIGURE 3
CHIKUMINUK LAKE HYDRO ELECTRIC PROJECT
RCC DOWNSTREAM PLAN

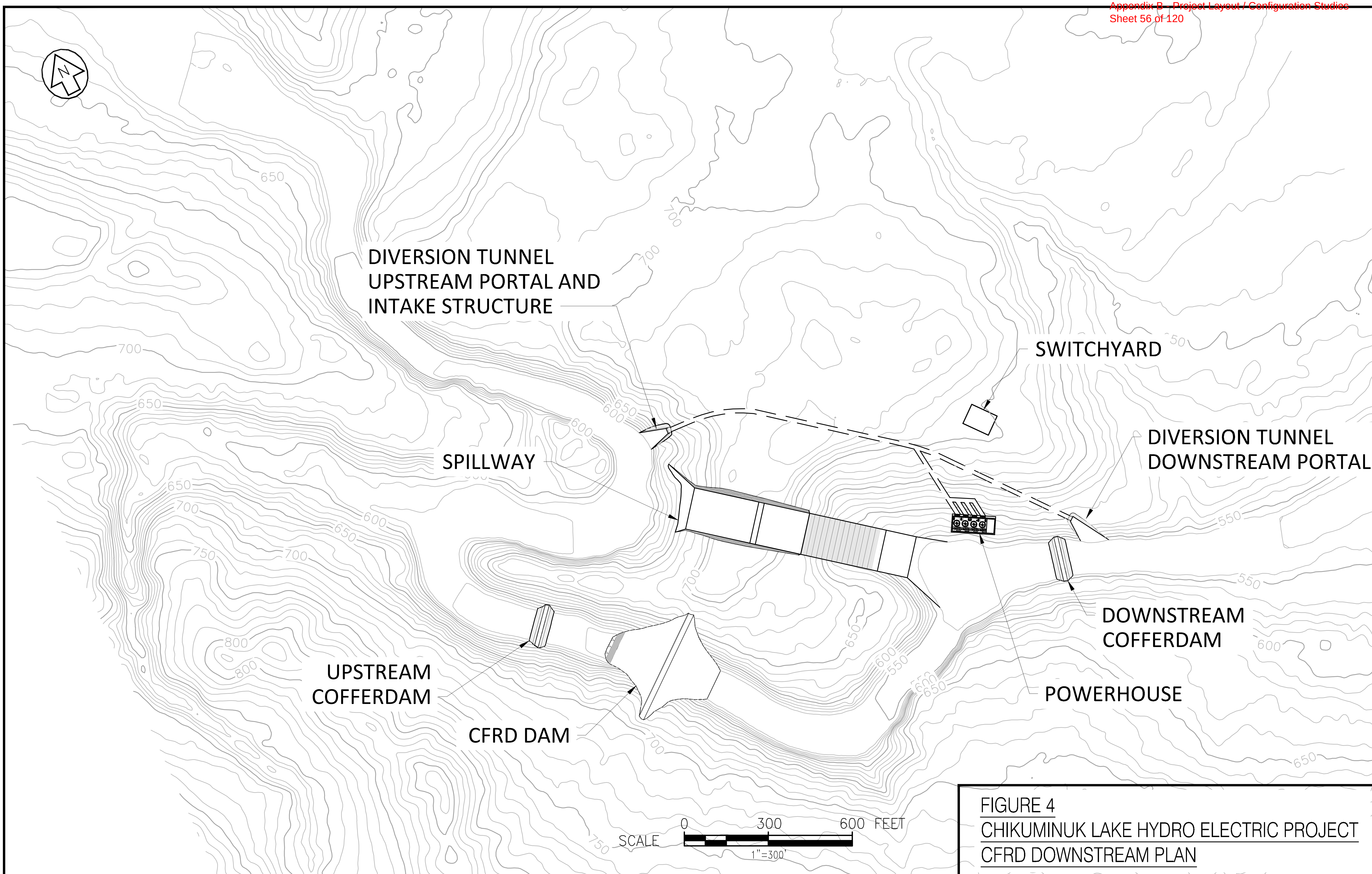


FIGURE 4
CHIKUMINUK LAKE HYDRO ELECTRIC PROJECT
CFRD DOWNSTREAM PLAN

Appendix B

Internal Memo: Unit Cost Review

Memo

H342022

October 9, 2013

To: Dick Griffith From: Eli Sanders

cc: Steve Hart

Nuvista Light and Power Cooperative
Chikuminuk Hydro Project

Unit Cost Review

An internal review of the unit costs for the Chikuminuk Hydro Project ("Chikuminuk" or "Project") was undertaken by Eli Sanders and Steve Hart in the Hatch Seattle office. The unit costs under review were previously computed as part of the selection of the preferred site and dam alternative for the Project. Two dam types, Roller Compacted Concrete ("RCC") and Concrete Faced Rockfill Dam ("CFRD"), were considered at two locations for the Project with the downstream RCC location selected for further analysis due to it having the lowest total cost. This analysis seeks to evaluate the reasonableness of the unit costs which were used as the basis of selection. Different unit pricing was offered where costs appeared low or high. The unit costs derived to date are assumed to be at the pre-feasibility level.

Hatch reviewed unit costs for the major Project features including the dam, spillway and tunnels. Powerhouse, turbine generator equipment, transmission line, switchyard and access costs were not reviewed. The unit costs at Chikuminuk were compared to unit costs derived for pre-feasibility level cost estimates performed for three projects which included RCC and CFRD structures as well as various other hydropower related appurtenances. Additionally, empirical formulas used to calculate RCC unit costs and historical cost databases for tunnelling and concrete lining were reviewed. In almost all cases, the Chikuminuk unit costs were between two and five times the rates that would be expected for more traditional and easily accessible project sites. Due to the remoteness of the Project and the requirement that all equipment be flown in by airplane, it is expected that unit costs at Chikuminuk would be between two and three times what would be seen at a more typically accessible sites. The one exception for the apparent accuracy of the unit rates is for the cost of the rockfill for the CFRD option. Hatch reviewed CFRD unit rates escalated to present day for a reference project in Wyoming. The reference project's rockfill quantity was approximately 45 times what is required at Chikuminuk while the unit rate used at Chikuminuk is equal to that which was used for the Wyoming project. Furthermore, the site conditions at Chikuminuk could easily multiply the Wyoming unit rate by a factor of 2 to 3. Thus, this will likely result in increased total project costs for the two CFRD dam options. Table 1 below provides a summary of the unit rates reviewed by Project feature.

Table 1 – Unit Rates by Feature

Item		Unit	Chikuminuk - Average Cost	Reference[1] - Cost	Reference[2] - Cost	Reference[3] - Cost	Reference[4] - Cost
Dam							

Item		Unit	Chikuminuk - Average Cost	Reference1 - Cost	Reference2 - Cost	Reference3 - Cost	Reference4 - Cost
	Excavation	CY	$75.00	$19.70	$38.23	$38.45	--
	Str. Concrete (upstream facing)	CY	$1,362.50	$703.00	$750.00	$615.00	--
	RCC Concrete	CY	$425.00	$62.00	$108.00	--	--
	Rock Fill	CY	$15.00	$7.00	--	$15.62	--
Spillway							
	Excavation	CY	$60.00	$15.30	--	$21.00	--
	Structural Concrete	CY	$1,362.50	$590.00	--	--	--
Diversion Tunnel							
	Excavation	CY	$600.00	$252.00	$176.00	--	$318.00
	Concrete Liner	CY	$1,462.50	$513.00	$716.00	--	$191.00
Power Tunnel							
	Excavation	CY	$600.00	$252.00	$176.00	--	$258.00
	Concrete Liner	CY	$1,462.50	$513.00	$716.00	--	$247.00
	Steel Liner	lbs	$10.67	$6.22	$7.71	$3.77	--

1. British Columbia Project; pre-feasibility study.
2. British Columbia Study of several projects.
3. Wyoming Project, feasibility study.
4. USBR tunnel cost data.

As noted in the unit pricing comparison shown in Table 1, the stated unit pricing is from about 2 times higher for dam excavation and structural concrete, which is appropriate for a site that is located in a remote Alaska location. Using an empirical formula for adjusting the unit pricing of the BC referenced project based on volume of RCC for placement, we would expect the unit pricing for RCC could be reduced in half. This assumes that indirects, construction camps and other costs missing from the estimate is estimated separately.

For the CFRD, the unit pricing is low and should be increased as follows:

- If the rockfill source is from the spillway excavation, then the unit pricing assumed for the Project is on the high side. If the rockfill source is to come from a quarry, then the unit price should be increased to about $40/cubic yard.
- The unit pricing for the CFRD concrete is sufficiently high so long as the price does not include cement and rebar. These items should be estimated separately and added to the estimate if not included.
- The proxy comparison for tunnelling unit pricing is misleading as the unit pricing is a function of the tunnel diameter. We understand that the power tunnel is about 15-ft diameter. On this basis, and assuming the location index is 2.0, the unit cost for concrete lining would be $2,750/LF.

Cement and reinforcement would need to be estimated separately. Similarly the unit pricing for excavation would be $4,650/LF. Rock support would need to be estimated separately.

- The steel liner should be checked to be sure it meets the Norwegian formula for its length. The thickness would appear to be based on internal pressure as Amstutz formula for thickness from external loading would appear to be reasonably low due to low rock cover. The unit pricing appears reasonable.

Certain items were not included in the cost estimate which was used as the basis for selecting the downstream RCC location. Those items not included were the low-level outlet, grouting program, mobilization, construction camp, and indirect costs. The dam structures did not include low level outlet structures, such as may be required for flushing sediment. However, we understand that a lake just upstream of the dam site will act as a sediment trap; thereby not conveying much sediment loading. Further investigation during feasibility studies will need to confirm this assumption.

A low-level outlet ("LLO") has not been considered in the current cost estimate. If required, an RCC structure would more easily and inexpensively be able to incorporate a LLO structure into the body of the dam than a CFRD structure which would either require a free-standing LLO or incorporate the outlet into an abutment.

The grouting program for both dam types may include 3-line curtain grouting, however, the RCC option would also require consolidation or contact grouting. This would have the effect of increasing the project cost slightly for the RCC dam options versus the CFRD options.

Mobilization, construction camp and indirect costs for this level of study could be computed on a percentage basis of either the civil or total project costs. These costs would not affect the ranking of the four dam options or the ultimate selection of the downstream RCC option but would serve to substantially increase the computed total project costs.

If sedimentation were to be an issue for the Project, it is likely that the CFRD option would be ruled out as it would not have the capacity to easily and cost effectively incorporate "undershoot" gates which would serve to flush sediment downstream. However, the Hatch Project Manager indicated that due to the large size of the reservoir no sedimentation issues are expected.

The unit costs reviewed as part of the selection of the downstream RCC option as the preferred alternative are in line with what would be expected based on recent project experience. None of the items possibly omitted from the cost estimate nor the suggested change in the unit rate for rockfill for the CFRD option would change the comparative rankings of the four dams. This review confirms that the unit pricing is valid as computed and supports the selection of the downstream RCC option as the preferred alternative.

Other design considerations for the options are:

1. As the diversion tunnel also serves as the power tunnel, the diameter of the tunnel, or power conduit should be constant or decreasing (e.g. increasing flow velocity) as the conduit reaches the unit. The power tunnel bifurcation from the diversion tunnel became a larger diameter, thereby slowing the water velocity. In this instance, the diversion tunnel was sized for meeting the 10-year return period in meeting the minimum tunnel size for diversion. However, the tunnel was not sized properly for power waterway requirements. The 10% headloss criteria should be

revised to be in the range of 5 to 7% and both power and diversion tunnel segments should have the same diameter until the manifold splits the conduits into the 3 or 4 turbine units.

2. The cofferdam structure shown is relatively large structure, and it may be that the structure needs to be smaller. For the RCC dam, the cofferdam could actually be an RCC structure built into the main dam. As the RCC structure will be constructed rapidly following foundation treatment, e.g. 6 to 8 weeks, it may be reasonable to limit the criteria for diversion to a 5-year return period. This would reduce the height of the cofferdam as the diversion tunnel would be sized for power tunnel flow velocity criteria.

ES:es
Attachment(s)/Enclosure

Chikuminuk Lake Hydroelectric Project Evaluation of Alternative Transmission Routes Chikuminuk Lake to Bethel

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TABLE OF CONTENTS

1 Introduction

PURPOSE OF THE EVALUATION

The purpose of this evaluation is to identify possible transmission line routes from the proposed Chikuminuk Lake Hydroelectric Project to the community of Bethel and to determine which route should be studied in more detail. This is primarily an office evaluation using United States Geological Survey (USGS) maps and Google Maps. One route "West" has been flown by helicopter to identify general soil conditions and avalanche paths.

LINE CONFIGURATION

The transmission line associated with this hydro facility is expected to transmit a peak of approximately 14 MW to Bethel and would conceptually require a voltage of 69 kV or 138 kV. Final design will determine which voltage is appropriate, but a 138 kV line on wooden H-structures has been assumed for this evaluation. 138 kV is a typical transmission voltage throughout Alaska and is commonly placed on wooden or steel H-structures. Transmission lines are built to a higher standard than local distribution lines and as such are more expensive to construct and normally require less maintenance.

LINE ROUTES

Three separate line routes into Bethel, shown in **Figure 1**, have been identified based on maps, agency requests, and knowledge of transmission lines in Alaska:

- The North Route is east of the easterly border of the Yukon Delta National Wildlife Refuge to Aniak where it then runs southerly along the west side of the Kuskokwim River.
- The North Alternative Route shares a beginning and an ending with the North Route, but takes a westerly route towards Tuluksak, staying primarily on patented or selected native lands.
- The West Route into Bethel is as direct a path as possible while minimizing mountainous areas and soft soils.

ENGINEERING EVALUATION

The following pages present an assessment of the conditions for constructing a transmission line along the defined routes. All of the routes present significant challenges for design and construction.

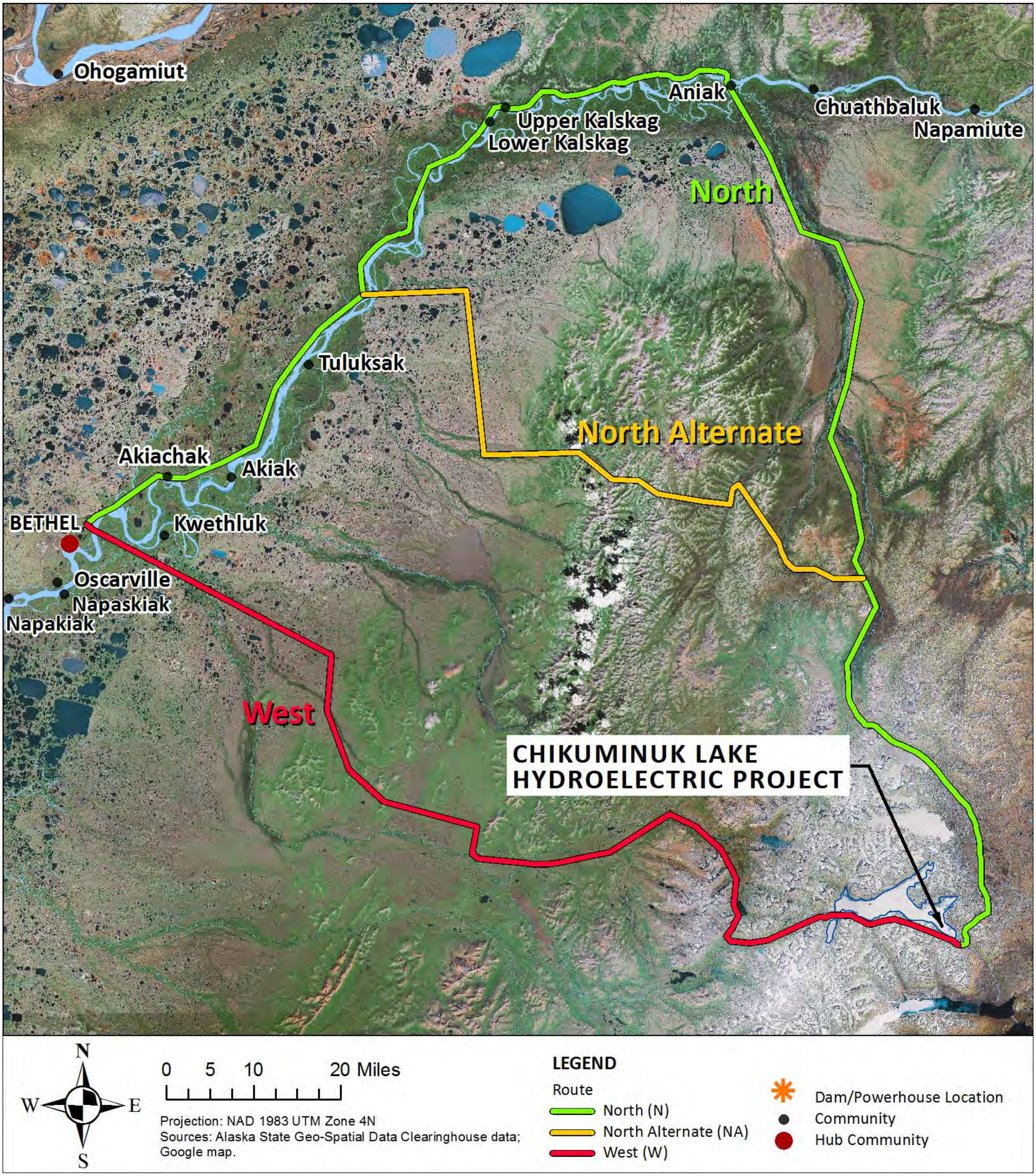

Figure 1 **Alternative Chikuminuk Lake / Bethel Transmission Routes**

2 Criteria Used for Evaluation

The criteria used in this evaluation are identified in this section with a brief explanation of how they are applied. Each route is divided into segments to allow for different types of access and terrain (see **Figure 2**). The following criteria and comparisons are based on construction knowledge of other Alaskan transmission lines in similar locations.

2.1 Access

Soft and wet soils for significant portions of any transmission line route will preclude a permanent access trail. Construction will involve large crews with specialized equipment, neither of which will be available for maintenance. For construction comparisons, each line route is divided into sections depending on the anticipated type of access. Access types are estimated to be:

- **Air (helicopter) -** This form of access will limit any ground disturbance to the immediate vicinity of each structure. Helicopter is the most expensive form of access with poor construction efficiency.

- **Overland in summer -** This access will utilize low ground pressure equipment for construction. Some helicopter support is expected. This access also takes advantage of the Kuskokwim River on which materials and equipment can be transported by barge during the summer months. Structure locations will be some distance from the river and summer access is not expected to be practical due to the extensive effort needed to get equipment off the river, up the steep river bank and back through the brush to reach the line. This effort would need to be done multiple times, possibly for each tower. Building the transmission line adjacent to the river is not feasible due to soft soils, steep river banks and the risk of river channel changes washing out the tower foundations. These conditions limit the ability to construct a transmission line directly from the river.

- **Overland in winter -** This access requires adequate frost and snow cover, and ice roads for construction. Equipment suitable for travel over frozen ground will be required. During winter, frozen conditions allow the use of existing rivers and Chikuminuk Lake as a limited ice road for construction. This will allow transport of materials and equipment without ground disturbance. However, structure locations will be some distance from the rivers or lake and will require suitable ground crossing equipment. Other rivers parallel to the line route, such as the Aniak River, can be utilized in the winter to access the right-of-way, but are not expected be able to support large summer operations.

Access for maintenance will be limited to helicopter and/or snow track equipment. The access criterion will compare the estimated miles of each type of construction access.

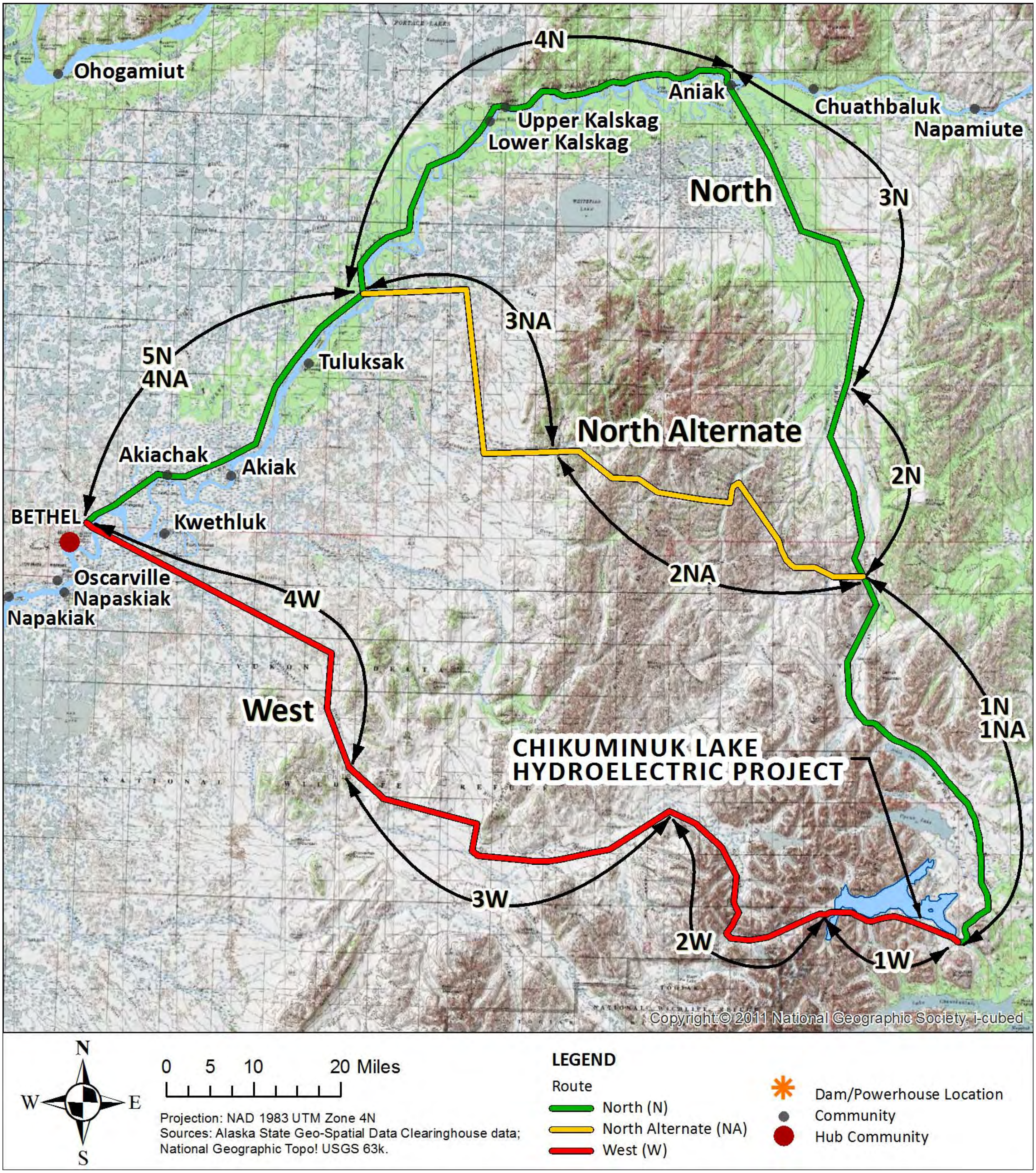

Figure 2 Alternative Chikuminuk Lake / Bethel Transmission Routes – Line Segment Map

2.2 Terrain

The ideal transmission line route would be placed on well-drained soils that never heave and in places where climatological loadings are minimized. However, all routes will pass through varying terrain. The following terrain types are intended to provide an overview of the impacts to design and construction:

- **Mountainous –** This terrain is primarily rocky with minimal top soil at higher elevations. Avalanches, strong funneling winds and potential icing conditions make this terrain challenging for transmission lines. Almost any design condition can be accommodated by varying the strength capacity of the line components. However, there is no available climatological data for these areas to specifically determine design conditions. A conservative design with reasonable costs will be required. The least number of miles in this terrain is preferred.

- **Highlands –** This terrain consists of areas with reasonably well drained soils based on map designations. It is anticipated low ground pressure equipment can be utilized in this terrain even during thawed conditions. The number of equipment crossings in an area may also be limited by permit stipulations and some air transportation of crews and materials may be required. Primarily overland travel is assumed in this terrain; therefore summer will be the most efficient construction season possible. Maximizing the route on this terrain is preferred for reliability and construction costs.

- **Lowlands –** This terrain includes soft and wet soils with open water or muskeg. Construction in this terrain is expected to be limited to appropriate frozen conditions. Only construction during the winter using ice roads is assumed. The least number of miles in this terrain is preferred.

2.3 Reliability

The purpose of a transmission facility is to provide reliable electrical power for consumption. Reliability of a transmission line is dependent on many variables, some of which are controllable and others that are not.

Controllable variables include:

- location of the transmission line, which will affect the climatological loadings that it will be required to withstand, such as wind and ice loading;
- the soil conditions, which will impact the mechanical stability of the line; and others.

For these reasons, it is better to minimize the miles of line in terrain that will reduce the reliability.

For this evaluation, the reliability of each route is estimated based on the factors discussed above. Routes will be ranked first, second, and third.

2.4 Stream Crossings

This criterion will tabulate the number of named rivers and streams shown on USGS maps. It is anticipated that natural buffer zones will be required at most stream crossings to minimize visual impacts. The buffer zones typically increase the span between structures and therefore increase construction costs. The least number of stream crossings is preferred.

2.5 Village Visibility

The majority of most routes will not be visible from permanent buildings. This criterion only takes into account the number of villages that are adjacent to each route. It is assumed that most village residents would prefer to not have a transmission line in their visual landscape. Reducing village proximity to the transmission line is preferred.

2.6 Line Loss

Electrical line loss (energy loss) is dependent on the magnitude of the load being supplied and the length of transmission line. For this comparison it is assumed the average electrical load at Bethel is 10 MW. Longer lines will have more line loss and be less efficient.

2.7 Construction, Operation, & Maintenance Costs

Transmission lines are built to a higher standard than local distribution lines and as such are more expensive to construct and normally require less maintenance. The following construction, operation and maintenance costs criteria are evaluated:

- **Construction –** In simplified terms, construction of a transmission line consists of the following items: equipment needed to transport and construct the materials, transportation of equipment and crews to and from the jobsite, and conditions under which a crew can work most efficiently. Access and terrain types along each alignment will dictate different construction methods from helicopters in the mountains, low ground pressure equipment in the highlands, and ice roads in the lowlands. This project is large in terms of Alaska transmission lines and with a limited work force will require multiple seasons to construct. Construction cost will reflect all of these variables and will be substantially different for each route alternative. The major cost difference between the alternative routes will be the length of the line.

- **Operations –** Transmission lines are constructed to operate continuously for at least 50 years and often last longer. The components of the transmission line are all designed for long life with no operational requirement. Operation is primarily limited to the substation equipment installed at the terminuses. Substation equipment at Chikuminuk Lake is expected to be designed for remote operation but will require regular visits by personnel. Bethel will use substation personnel for regular operation. Operation is not expected to be different for the alternative routes unless more substations are added.

- **Maintenance –** Construction of this transmission line is typical of many other Alaskan lines that will mobilize large crews and specialized equipment such as heavy lift helicopters. Once construction is complete, all of this special equipment will leave the state and will not be available for line maintenance. Because of the high reliability of the lines, they seldom require major repairs. It is expected that small helicopters and snow track equipment will normally be available and adequate for most maintenance activities. However, if incidents such as an avalanche cause major damage to the line it will require a contracted operation for repair and will result in an extended service interruption. Refined maintenance costs will need to be determined after construction and are generally proportional to the miles of line. Maintenance costs for this report will be proportional to costs of construction.

2.8 Land Status

This criterion will tabulate the miles of each route within the categories of land ownership such as Native, State, and Federal. A preliminary assessment of land status is reflected in **Figure 3** in **Section 3.4**.

2.9 Added Revenue From Adjacent Village Loads

Assuming 14 MW peak is provided by the hydroelectric plant (size subject to further study), it is expected that after a short period of time this capacity will be completely utilized by the load in Bethel and adjacent villages. The northern transmission line routes would pass near additional villages. Added revenue from additional villages will not be possible because of the limited capacity.

3 Evaluation of Routes

Following is an engineering comparison of the three possible line routes from the Chikuminuk Lake Hydroelectric Project to the load center at Bethel based on the Construction Comparison Matrix and a general understanding of the area.

3.1 Access and Terrain

For comparison purposes each route has been divided into segments representing different methods of access and terrain and detailed in **Table 3-1** below. Mountainous terrain on each route is classified according to miles above 1000 ft in elevation and highest elevation along the route. This is important to identify relative reliability risk and construction costs. Data is from line routes drawn on USGS 1:250,000 scale maps and Google Map and shown in **Figure 2**.

- Air access is assumed in mountainous areas which will dictate expensive construction methods. The North Route is 77 miles, North Alt. Route is 96 miles and West Route is 47 miles. Only avalanche paths in the West Route have been field confirmed with 29 noted paths in the 47 miles. The North Route traverses the same mountain range and, assuming the number of avalanche paths is proportional to total length, is expected to have more avalanche paths. The North Alt. Route crosses additional mountain terrain as it traverses westerly. This area has many north-facing slopes and is, therefore, expected to have more avalanche paths than what would be expected with additional line length.

- Overland access allowed in summer will be the most economical construction method. The North Route has 38 miles of overland access allowed in summer, North Alt. has no miles and West Route has 43 miles.

- Overland winter access will require some form of ground cover for transportation of heavy pile driving equipment. It is assumed an ice road is the most practical for this work. Construction and maintenance of an ice road is weather dependent. Adequate frost penetration and continuous cold weather are required. Weather in the Bethel area could be problematic for full winter season construction. The winter construction season with adequate ice and snow cover would potentially not begin until January and would end in early March. The North Route has 105 miles of overland access allowed in winter, North Alt. Route has 91 miles and the West Route has 46 miles.

Table 3-1 Access and Terrain Comparison

ROUTE		NORTH	NORTH ALT.	WEST
ACCESS	Air (helicopter)	1N-51mi.	1NA-51mi.	1W-17mi.
		2N-26mi.	2NA-45mi.	2W-30mi.
	Overland-Summer	3N-38mi.		3W-43mi.
	Overland-Winter	4N-58mi.	3NA-44mi.	4W-46mi.
		5N-47mi.	4NA-47mi.	
TERRAIN	Mountainous	1N-max. 1395’	1NA-max. 1395’	1W-max. 1614’
		1N-30mi.>1,000’	1NA-30mi.>1,000’	1W-3mi.>1,000’
		2N-max. 1023’	2NA-max. 1965’	2W-max. 2068’
		2N-2mi.>1,000’	2NA-23mi.>1,000’	2W-22mi.>1,000’

Highlands	3N-max. 409’		3W-max. 1482’ 3W-32mi.>1000’
Lowlands	4N-max. 695’ 5N-max. 50’	3NA-max. 349’ 4NA-max. 50’	4W-max. 578’

3.2 Line Length

Each additional mile of line length adds to the complexity of designing, constructing, and maintaining a transmission line, including the following:

- Increased exposure to damaging climatological conditions
- Increased exposure to avalanche damage in mountainous terrain
- more ground disturbance
- additional stream crossings
- additional general construction impacts
- additional operational impacts due to inspections
- additional maintenance impacts
- additional materials installed
- additional costs for construction, operation and maintenance

Anticipated total line lengths are: North Route 220 miles, North Alt. Route 187 miles, and West Route 136 miles.

3.3 Reliability

This transmission line will not be part of an electrical grid but will be a single radial line. Any disturbance to the transmission line will result in an outage to Bethel. The following conditions will improve the overall line reliability:

- Less miles reduces the number of towers and conductor
- Less miles in poor soil conditions improves the long-term stability of towers
- Less potential avalanche paths reduces risk of line damage due to avalanches
- Less miles at higher elevations reduces risk of “in-cloud-icing” events. On the western Alaska coastline, with its proximity to the ocean, icing occurs in the 700-800’ elevation range. Interior Alaska experiences this type of icing at about 2000’ elevation. There is no available data for icing in the Kuskokwim region and the best estimate is that the icing elevation will occur somewhere in between the western coast and interior elevations at elevations above 1000 ft.
- Less miles in mountainous terrain reduces severe winds, avalanche and icing conditions, which are more prevalent in mountainous terrain
- Based on the above conditions the North Route is expected to be the least reliable. The North Alt. will be the next least reliable route and the West Route the most reliable.

3.4 Land Status

For comparison purposes the land ownership along each route has been investigated on a large scale basis and is shown in **Table 3-2** and **Figure 3** below. Acquisition time and cost of an easement for the transmission line will not be the same for each route. Easements across state lands will follow a normal permitting process. Lands under other ownership may require additional effort possibly including the following:

- Federal Refuge lands will require compliance with ANILCA Title XI Transportation and Utility Systems in and across conservation system units. This will impact both the North Alt. (25 miles) and the West (57miles).
- State Park lands will require modification of the Management Plan. This will impact all routes: North & North Alt (33 miles) and West (19miles).
- Native corporation lands will require compliance in accordance with Federal and State acquisition laws. This would impact the North (121 miles), North Alt. (69 miles) and West (29 miles).
- It is anticipated Native Allotments will also be impacted by easement acquisition in accordance with Title 25 USC. Historically, easements through allotments have required additional time for acquisition. The number of allotments is expected to be proportional to the miles of line on Native Corporation and Native Allotments lands on each route: North (121 miles), North Alt. (69 miles) and West (29 miles).

Table 3-2 Land Status Ownership along each Proposed Route

ROUTE	NORTH	NORTH ALT.	WEST
LAND STATUS			
BLM		12 miles	
DPOR Wood-Tikchik	33 miles	33 miles	19 miles
NATIVE	121 miles	69 miles	29 miles
STATE OF ALASKA	66 miles	48 miles	31 miles
USFWS		22 miles	57 miles
USFWS-VILLAGE SELECTED		3 miles	

3.5 Transmission Construction and O&M Cost Estimates

The estimated range of direct construction cost for each route is provided in **Appendix A**. The costs are provided only for comparing alternatives and based on information obtained in a largely tabletop investigation. These costs cannot be assumed as applicable to budgeting or any other purposes outside this report. Operation and maintenance (O&M) costs are expected to be a percentage of construction cost and will therefore have the same relative comparison.

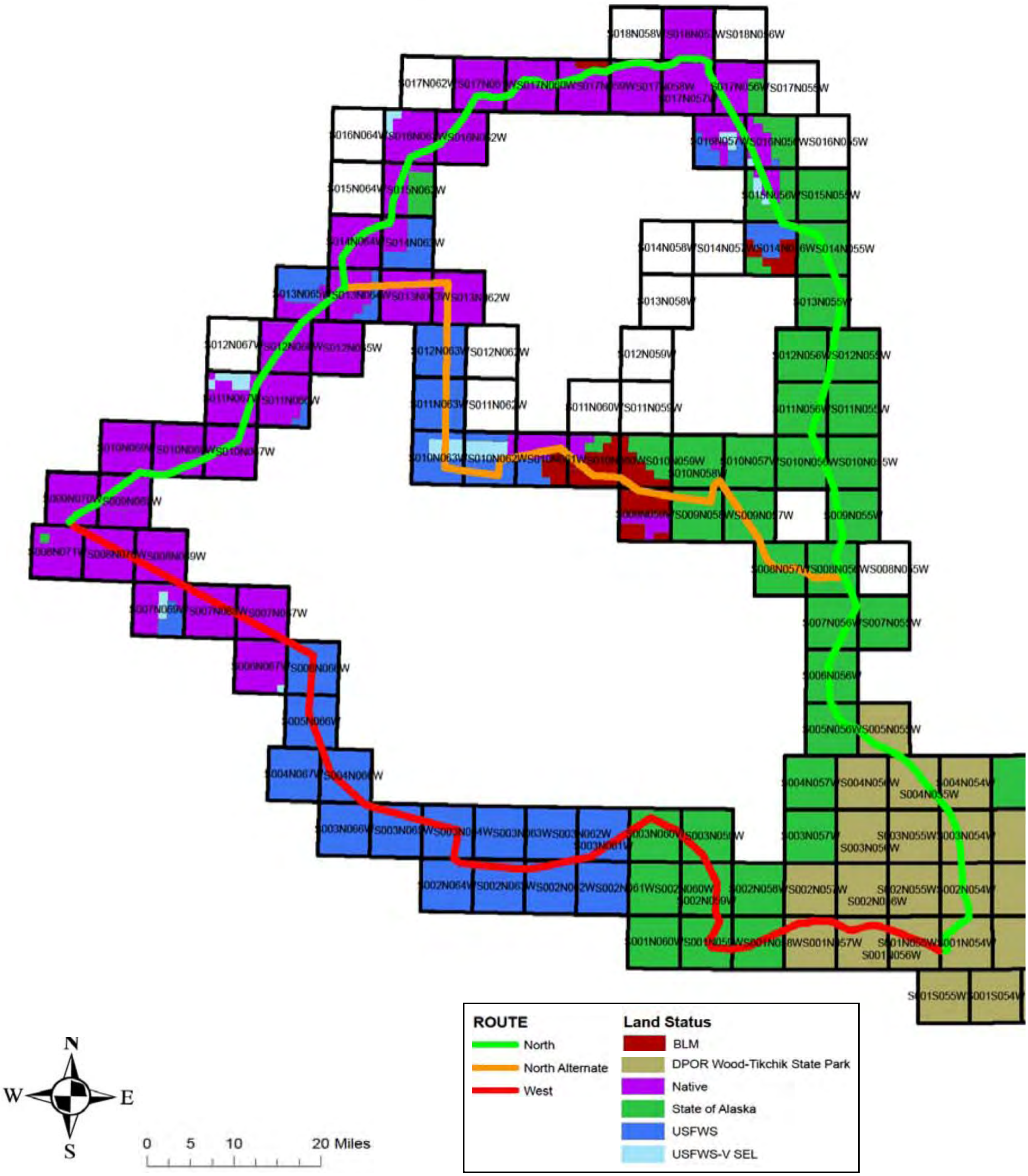

Figure 3 **Alternative Chikuminuk Lake / Bethel Transmission Routes – Land Status**

4 Summary and Conclusion

4.1 Criteria Evaluation Matrix

The Criteria Evaluation Matrix, **Table 4-1**, is based on interpretation of USGS maps and Google Maps. The types of construction methods required by access and terrain are based on engineering judgment of similar transmission lines in Alaska.

Table 4-1 Criteria Evaluation Matrix

ROUTE	COMPARISON	NORTH	NORTH ALT.	WEST
ACCESS SUMMARY <2>				
Air	less is better	77 miles	96 miles	47 miles
Overland-Summer	more is better	38 miles	0 miles	43 miles
Overland-Winter	less is better	105 miles	91 miles	46 miles
TOTAL MILES	less is better	220 miles	187 miles	136 miles
TERRAIN SUMMARY <3>				
Mountainous - summer const.	less is better	77 miles	96 miles	47 miles
Maximum elevation	less is better	1395'	1965'	2068'
Miles> 1,000'	less is better	32 miles	53 miles	25 miles
Highlands summer const.	more is better	38 miles	0 miles	43 miles
Maximum elevation	less is better	409'		1482'
Miles> 1,000'	less is better	0 miles	0 miles	32 miles
Lowlands - winter const.	less is better	105 miles	91 miles	46 miles
RELIABILITY	first is best	Second	Third	First
STREAM CROSSINGS	less is better	8	11	8
VILLAGE VISIBILITY	less is better	4	2	1
APPROX. LINE LOSS	less is better	2.90%	2.30%	1.50%
(10MW load at Bethel)				
EST. RANGE CONST. COST $M	less is better	228-273	206-268	137-150

Notes:

Colored bars only compare within each criterion (green is best, yellow is next and red is worst). For example: West is shortest route for Air criterion.

<2> Access is a gross interpretation of soil conditions based on USGS Maps and Google Map

<3> More severe icing conditions will exist at higher elevations. An arbitrary elevation of 1,000' is selected.

4.2 Conclusion

Three separate transmission line routes were identified based on maps, agency requests and knowledge of best transmission route selection for Alaskan conditions. Alternatives were segmented into terrain and access types for construction and O&M expenses. Finally, a range of construction costs were developed for each alternative.

Based on the comparisons noted in Section 3 and summarized in **Table 4.1**, the West Route is the most reasonable choice. The estimated costs shown in Section 3 are only for the direct construction of the transmission line itself. The North and North Alt. routes will add between 50% and 70% more to the financed cost of power in Bethel as compared to the West Route. This impact will significantly burden the project feasibility. This analysis did not consider other possible impacts such as environmental; however many environmental impacts are a function of miles of line. The longer line routes generally result in more environmental impacts. This again supports the West Route because of its considerably shorter line length.

Appendix A – Detailed Construction Cost Estimates

The following pages explain the development of the construction cost estimates for the alternative line routes.

- CONSTRUCTION COST ESTIMATE DETAILS – show material and labor estimates for major line components for the three types of access and terrain: Air, Overland Summer and Overland Winter
- CONSTRUCTION COST ESTIMATE UNITS – using Detail Sheets the components are combined into units, for example line sections with average for structures, foundations, and miscellaneous
- CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS – using ESTIMATE UNIT SHEETS additional costs such as mobilization/demobilization are added to the typical line sections
- CONSTRUCTION COST ESTIMATE SUMMARY – using the TYPICAL LINE SECTIONS SHEETS cost per mile of each type of construction, a summary table is shown

CONSTRUCTION COST ESTIMATE DETAILS

					Crew Hr	$1,200					
Air (Helicopter) (Mountainous)	**Qnty**	**Unit Cost Materials**	**Mult.**	**Unit Material**	**Material $**	**Crew Hr**	**Labor**	**Labor Mult.**	**Unit Labor**	**$Labor**	**Total**
Tangent Wood 138kV H-Frame, 1000 ft.											
Insulator Strings	3	$600	1.10	$660	$1,980	1	$1,200	1.30	$1,560	$4,680	$6,660
70' Wood H-Frame	1	$8,000	1.10	$8,800	$8,800	8	$9,600	1.30	$12,480	$12,480	$21,280
					$10,780					$17,160	$27,940
Large Angle/DE Wood 138kV, 3 pole											
Insulator Strings	6	$700	1.10	$770	$4,620	2	$2,400	1.30	$3,120	$18,720	$23,340
80' Single poles	3	$10,000	1.10	$11,000	$33,000	28	$33,600	1.30	$43,680	$131,040	$164,040
					$37,620					$149,760	
Small/Medium Angle Wood 138kV, 3 pole											
Insulator Strings	3	$600	1.10	$660	$1,980	1	$1,200	1.30	$1,560	$4,680	$6,660
80' Single poles	3	$8,000	1.10	$8,800	$26,400	22	$26,400	1.30	$34,320	$102,960	$129,360
					$28,380					$107,640	
Driven Pile	1	$3,600	1.10	$3,960	$3,960	4	$4,800	1.30	$6,240	$6,240	$10,200
Rock Foundations	1	$5,000	1.10	$5,500	$5,500	10	$12,000	1.30	$15,600	$15,600	$21,100
Drake Conductor (1,000')	3	$1,500	1.10	$1,650	$4,950	7	$8,400	1.30	$10,920	$32,760	$37,710

CONSTRUCTION COST ESTIMATE DETAILS

Overland Summer (Highlands)	Qnty	Unit Cost Materials	Mult.	Unit Material	$ Material	Crew Hr	Labor	Labor Mult.	Unit Labor	$Labor	Total
Tangent Wood 138kV H-Frame, 1000 ft.											
Insulator Strings	3	$600	1.00	$600	$1,800	1	$1,200	1.00	$1,200	$3,600	$5,400
70' Wood H-Frame	1	$8,000	1.00	$8,000	$8,000	6	$7,200	1.00	$7,200	$7,200	$15,200
					$9,800					$10,800	$20,600
Large Angle/DE Wood 138kV, 3 pole											
Insulator Strings	6	$700	1.00	$700	$4,200	2	$2,400	1.00	$2,400	$14,400	$18,600
80' Single poles	3	$10,000	1.00	$10,000	$30,000	22	$26,400	1.00	$26,400	$79,200	$109,200
					$34,200					$93,600	
Small/Medium Angle Wood 138kV, 3 pole											
Insulator Strings	3	$600	1.00	$600	$1,800	1	$1,200	1.00	$1,200	$3,600	$5,400
80' Single poles	3	$8,000	1.00	$8,000	$24,000	16	$19,200	1.00	$19,200	$57,600	$81,600
					$25,800					$61,200	
Driven Pile	1	$3,600	1.00	$3,600	$3,600	3	$3,600	1.00	$3,600	$3,600	$7,200
Rock Foundations	1	$5,000	1.00	$5,000	$5,000	6	$7,200	1.00	$7,200	$7,200	$12,200
Drake Conductor (1,000')	3	$1,500	1.00	$1,500	$4,500	5	$6,000	1.00	$6,000	$18,000	$22,500

CONSTRUCTION COST ESTIMATE DETAILS

Overland Winter (Lowlands)	Qnty	Unit Cost Materials	Mult.	Unit Material	$ Material	Crew Hr	Labor	Labor Mult.	Unit Labor	$Labor	Total
Tangent Wood 138kV H-Frame, 1000 ft.											
Insulator Strings	3	$600	1.10	$660	$1,980	1	$1,200	1.20	$1,440	$4,320	$6,300
70' Wood H-Frame	1	$8,000	1.10	$8,800	$8,800	8	$9,600	1.20	$11,520	$11,520	$20,320
					$10,780					$15,840	$26,620
Large Angle/DE Wood 138kV, 3 pole											
Insulator Strings	6	$700	1.10	$770	$4,620	2	$2,400	1.20	$2,880	$17,280	$21,900
80' Single poles	3	$10,000	1.10	$11,000	$33,000	28	$33,600	1.20	$40,320	$120,960	$153,960
					$37,620					$138,240	
Small/Medium Angle Wood 138kV, 3 pole											
Insulator Strings	3	$600	1.10	$660	$1,980	1	$1,200	1.20	$1,440	$4,320	$6,300
80' Single poles	3	$8,000	1.10	$8,800	$26,400	22	$26,400	1.20	$31,680	$95,040	$121,440
					$28,380					$99,360	
Driven Pile	1	$3,600	1.10	$3,960	$3,960	4	$4,800	1.20	$5,760	$5,760	$9,720
Rock Foundations	1	$5,000	1.10	$5,500	$5,500	10	$12,000	1.20	$14,400	$14,400	$19,900
Drake Conductor (1,000')	3	$1,500	1.10	$1,650	$4,950	7	$8,400	1.10	$9,240	$27,720	$32,670

CONSTRUCTION COST ESTIMATE UNITS

Air (Helicopter) (Mountainous)

Example-Section 1N & 2N = 77 miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr. Cost
Tangent Structure	249	ea	$10,780	$17,160	$27,940	$6,957,060	Str.	$16,543	$46,151
DE/Large Angle	40	ea	$37,620	$149,760	$187,380	$7,495,200			
Medium Angle	50	ea	$28,380	$107,640	$136,020	$6,801,000			
Pipe Pile Fdn	0	ea	$3,960	$6,240	$10,200	$0	Fnd.	$5,500	$15,600
Rock Foundations	519	ea	$5,500	$15,600	$21,100	$10,950,900			
Cond. Drake	77	crkt mi	$26,136	$172,973	$199,109	$15,331,378			
OPGW	77	mi	$12,000	$22,000	$34,000	$2,618,000			
OHSW	77	mi	$2,800	$18,000	$20,800	$1,601,600	Misc.	$20,321	$70,026
Grounding	339	ea	$150	$500	$650	$220,350			
Dampers	1017	ea	$50	$600	$650	$661,050			
Aerial Balls/Bird	681	ea	$400	$2,000	$2,400	$1,635,336			
Structure Signs	339	ea	$150	$500	$650	$220,350			
Clearing	0	mi	$0	$30,000	$30,000	$0			
						$54,492,224			

CONSTRUCTION COST ESTIMATE UNITS

Air (Helicopter) (Mountainous)

Example-Section 2W= 30 miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr Cost
Tangent Structure	96	ea	$10,780	$17,160	$27,940	$2,682,240	Str.	$16,420	$45,665
DE/Large Angle	12	ea	$37,620	$149,760	$187,380	$2,248,560			
Medium Angle	24	ea	$28,380	$107,640	$136,020	$3,264,480			
Rock Foundations	204	ea	$5,500	$15,600	$21,100	$4,304,400	Fnd.	$5,500	$15,600
Cond. Drake	30	crkt mi	$26,136	$172,973	$199,109	$5,973,264			
OPGW	30	mi	$12,000	$22,000	$34,000	$1,020,000			
OHSW	30	mi	$2,800	$18,000	$20,800	$624,000	Misc.	$20,318	$70,008
Grounding	132	ea	$150	$500	$650	$85,800			
Dampers	396	ea	$50	$600	$650	$257,400			
Aerial Balls/Bird	265	ea	$400	$2,000	$2,400	$636,768			
Structure Signs	132	ea	$150	$500	$650	$85,800			
Clearing	0	mi	$0	$30,000	$30,000	$0			
						$21,182,712			

CONSTRUCTION COST ESTIMATE UNITS

Overland Summer (Highlands)

Example-Section 3W= 43 miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr. Cost
Tangent Structure	138	ea	$9,800	$10,800	$20,600	$2,842,800	Str.	$15,152	$28,345
DE/Large Angle	22	ea	$34,200	$93,600	$127,800	$2,811,600			
Medium Angle	30	ea	$25,800	$61,200	$87,000	$2,610,000			
Pile Foundations	294	ea	$3,600	$3,600	$7,200	$2,116,800	Fnd.	$3,600	$3,600
Cond. Drake	43	crkt mi	$23,760	$95,040	$118,800	$5,108,400			
OPGW	43	mi	$12,000	$22,000	$34,000	$1,462,000			
OHSW	43	mi	$2,800	$18,000	$20,800	$894,400	Misc.	$20,341	$70,135
Grounding	190	ea	$150	$500	$650	$123,500			
Dampers	570	ea	$50	$600	$650	$370,500			
Aerial Balls/Bird	382	ea	$400	$2,000	$2,400	$916,560			
Structure Signs	190	ea	$150	$500	$650	$123,500			
Clearing	0	mi	$0	$30,000	$30,000	$0			
						$19,380,060			

CONSTRUCTION COST ESTIMATE UNITS

Overland Winter (Lowlands)

Example-Section 3N,4N,5N,3NA,4NA,4W 3N=38miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr. Cost
Tangent Structure	121	ea	$10,780	$15,840	$26,620	$3,221,020	Str.	$16,804	$43,834
DE/Large Angle	20	ea	$37,620	$138,240	$175,860	$3,517,200			
Medium Angle	27	ea	$28,380	$99,360	$127,740	$3,448,980			
Pile Foundations	262	ea	$3,960	$5,760	$9,720	$2,546,640	Fnd.	$3,960	$5,760
Cond. Drake	38	crkt mi	$26,136	$146,362	$172,498	$6,554,909			
OPGW	38	mi	$12,000	$22,000	$34,000	$1,292,000			
OHSW	38	mi	$2,800	$18,000	$20,800	$790,400	Misc.	$20,344	$232,783
Grounding	168	ea	$150	$500	$650	$109,200			
Dampers	504	ea	$50	$600	$650	$327,600			
Aerial Balls/Bird	338	ea	$400	$2,000	$2,400	$810,432			
Structure Signs	168	ea	$150	$500	$650	$109,200			
Clearing	16	mi	$0	$30,000	$30,000	$480,000			
Ice Road	38	mi	$0	$150,000	$150,000	$5,700,000			
						$28,907,581			

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS

Section 1N & 2N

Air (Helicopter) (Mountainous) 77 miles

Description	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Structures	339	ea	$16,543	$46,151	$62,694	$21,253,260
Foundations	519	ea	$5,500	$15,600	$21,100	$10,950,900
Conductor	77	crkt mi	$26,136	$172,973	$199,109	$15,331,378
Other*	39	crkt mi	$20,321	$70,026	$90,347	$3,523,516
Subtotal						$51,059,054
Mob/Demob @10%						$5,105,905
Helicopter Construction Cost adder @ 25%						$14,041,240
Contingency @20% Total						$14,041,240
Estimated Total Construction Cost						$84,247,439
Average Cost per Mile						$1,094,123

* Includes: OH ground & fiber, ground, dampers, aerial balls, bird diverters, signs, clearing

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS

Section 2W

Air (Helicopter) (Mountainous) 30 miles

Description	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Structures	132	ea	$16,420	$45,665	$62,085	$8,195,280
Foundations	204	ea	$5,500	$15,600	$21,100	$4,304,400
Conductor	30	crkt mi	$26,136	$172,973	$199,109	$5,973,264
Other*	30	crkt mi	$20,318	$70,008	$90,326	$2,709,768
Subtotal						$21,182,712
Mob/Demob @10%						$2,118,271
Helicopter Construction Cost adder @ 25%						$5,825,246
Contingency @20% Total						$5,825,246
Estimated Total Construction Cost						$34,951,475
Average Cost per Mile						$1,165,049

* Includes: OH ground & fiber, ground, dampers, aerial balls, bird diverters, signs, clearing

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS

Section 3W

Overland Summer 43 miles

Description	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Structures	346	ea	$15,152	$28,345	$43,497	$15,049,907
Foundations	294	ea	$3,600	$3,600	$7,200	$2,116,800
Conductor	43	crkt mi	$23,760	$95,040	$118,800	$5,108,400
Other*	30	crkt mi	$20,341	$70,135	$90,476	$2,714,274
Subtotal						$24,989,382
Mob/Demob @8%						$1,999,151
Helicopter support adder @5%						$1,349,427
Contingency @20% Total						$5,667,592
Estimated Total Construction Cost						$34,005,551
Average Cost per Mile						$790,827

* Includes: OH ground & fiber, ground, dampers, aerial balls, bird diverters, signs, clearing

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS

Section 3N

Overland Winter		38 miles				
Description	**Qty**	**Unit**	**Material Cost**	**Labor Cost**	**Material & Labor Cost**	**Total Cost**
Structures	168	ea	$16,804	$43,834	$60,638	$10,187,200
Foundations	262	ea	$3,960	$5,760	$9,720	$2,546,640
Conductor	38	crkt mi	$26,136	$146,362	$172,498	$6,554,909
Other*	38	crkt mi	$20,344	$232,783	$253,127	$9,618,832
Subtotal						$28,907,581
Mob/Demob @10%						$2,890,758
Helicopter Support @5%						$1,589,917
Contingency @20% Total						$6,677,651
Estimated Total Construction Cost						$40,065,907
Average Cost per Mile						$1,054,366

* Includes: OH ground & fiber, ground, dampers, aerial balls, bird diverters, signs, clearing

CONSTRUCTION COST ESTIMATE SUMMARY

Alternative	Description	Low	High
North	Air = 77 miles, Overland-Summer = 38 miles, Overland Winter = 105 miles	$227,800,000	$273,360,000
North Alternate	Air = 96 miles, Overland-Winter = 91 miles	$206,200,000	$268,060,000
West	Air = 47 miles, Overland-Summer = 43 miles, Overland Winter = 46 miles	$136,800,000	$149,600,000
	Based on the values from the previous pages, the following section costs are used to develop the route costs above.		
	Air	$1,200,000	per mile
	Overland-Summer	$800,000	per mile
	Overland-Winter	$1,000,000	per mile
	Existing Road	$600,000	per mile

Note: These are only construction costs and do not include other costs such as: Design, Owners Cost, Permitting, Environmental Compliance, etc.

Chikuminuk Lake Hydroelectric Project
Evaluation of
Alternative Transmission Routes
Chikuminuk Lake to Dillingham

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1 Introduction

PURPOSE OF THE EVALUATION

The purpose of this evaluation is to identify possible transmission line routes from the proposed Chikuminuk Lake Hydroelectric Project to the community of Dillingham and to determine which route should be studied in more detail. This is an office evaluation using United States Geological Survey (USGS) maps and Google Maps.

LINE CONFIGURATION

The transmission line associated with this hydro facility is expected to transmit a peak of approximately 4 MW to Dillingham. This is comparable to the present peak load of the utility, but does not consider possible seasonal fisheries loads that are presently supplied from self-generation. Based on a 4MW load and the length of the line routes a conceptual voltage of 69 kV is selected. Final design will determine the appropriate voltage, but a 69 kV line on wooden poles has been assumed for this evaluation. 69 kV is a typical transmission voltage throughout Alaska and is commonly placed on wooden poles.

LINE ROUTES

Two separate line routes into Dillingham, shown in **Figure 1**, have been identified based on maps, agency requests, and knowledge of transmission lines in Alaska:

- The South Route crosses the northern portion of the Wood-Tikchik State Park for approximately 23 miles and then parallels outside the eastern boundary of the Park to the south for approximately 77 miles. The route follows the existing roadway for 19 miles from Aleknagik into Dillingham.
- The South Loop Route crosses the northern portion of the Wood-Tikchik State Part for approximately 23 miles and then proceeds southeasterly for approximately 40 miles to the Nushagak River. It then generally parallels the river for approximately 69 miles into Aleknagik where it joins the South Route into Dillingham. This route will allow the transmission line to possibly supply several local villages.

ENGINEERING EVALUATION

The following pages present an assessment of the conditions for constructing a transmission line along the defined routes. Both of the routes present significant challenges for design and construction.

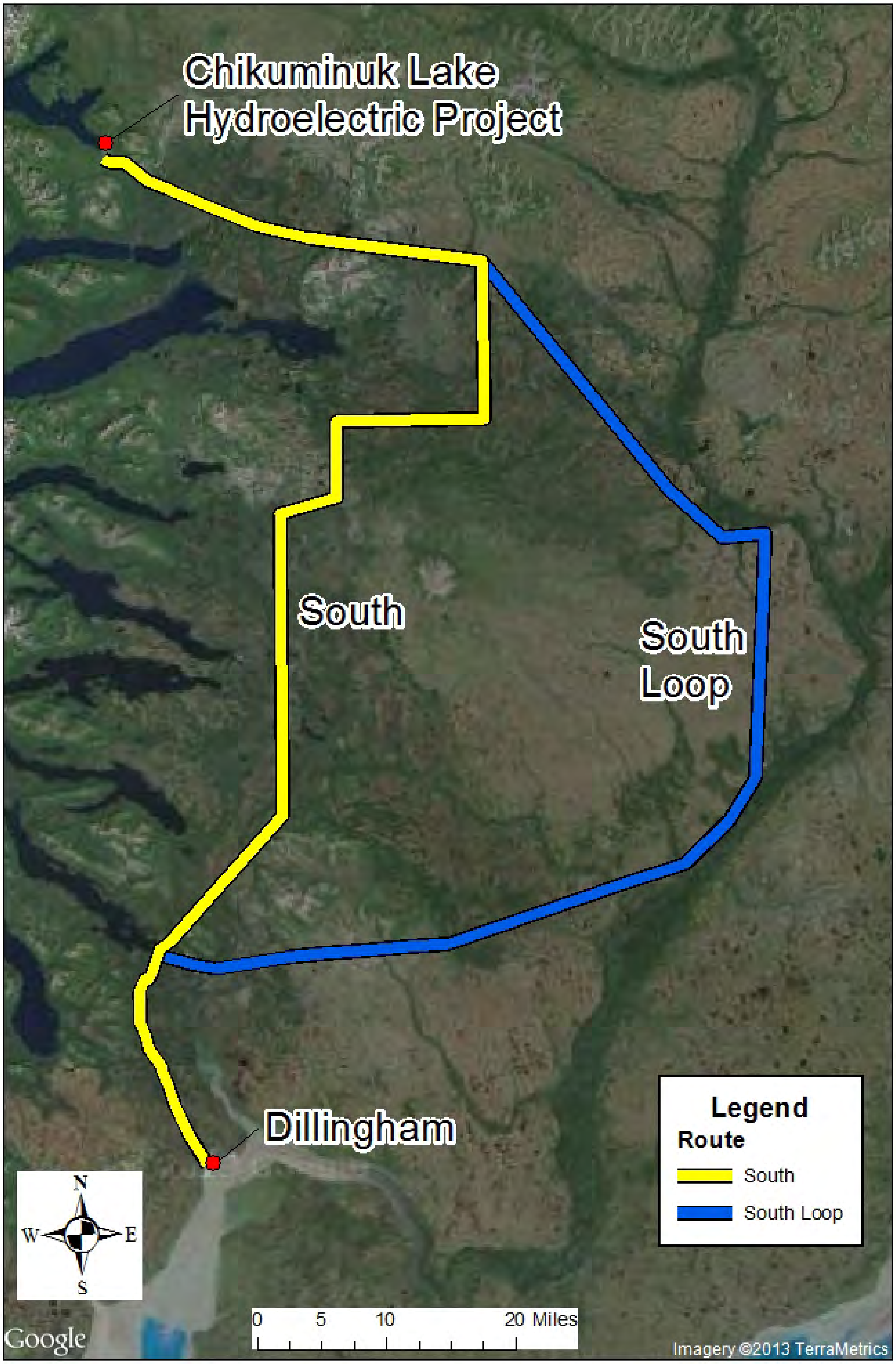

Figure 1 **Alternative Chikuminuk Lake / Dillingham Transmission Routes**

2 Criteria Used for Evaluation

The criteria used in this evaluation are identified in this section with a brief explanation of how they are applied. Each route is divided into segments to allow for different types of access and terrain (see **Figure 2**). The following criteria and comparisons are based on construction knowledge of other Alaskan transmission lines in similar locations.

2.1 Access

Soft and wet soils for significant portions of any transmission line route will preclude a permanent access trail. Construction will involve large crews with specialized equipment, neither of which will be available for maintenance. For construction comparisons, each line route is divided into sections depending on the anticipated type of access. Access types are estimated to be:

- **Air (helicopter) -** This form of access will limit any ground disturbance to the immediate vicinity of each pole. Helicopter is the most expensive form of access with poor construction efficiency.

- **Overland in summer -** This access will utilize low ground pressure equipment for construction. Some helicopter support is expected particularly to transport crews. This access may also take advantage of the various lakes of the Wood-Tikchik Park for material transport if it is acceptable. The specialized equipment for this access will allow movement across softer soils and be functional in the forested areas with higher ground. Because of the advantages of summer construction, this form of access is more efficient than others. The existing road from Dillingham to Aleknagik will also be available for construction

- **Overland in winter -** This access requires adequate frost and snow cover, and ice roads for construction. Equipment suitable for travel over frozen ground will be required. During winter, frozen conditions allow the use of existing rivers as a limited ice road for construction. This will allow transport of materials and equipment without ground disturbance. However, pole locations will be some distance from the rivers and will require suitable ground crossing equipment. Maintaining an ice road during the winter season may be difficult in this semi-maritime climate and will be highly dependent on the particular winter conditions. This form of access is expensive because of the extra cost of ice road construction and maintenance as well as winter working conditions.

Access for maintenance will be limited to helicopter and/or snow track equipment. The access criterion will compare the estimated miles of each type of construction access.

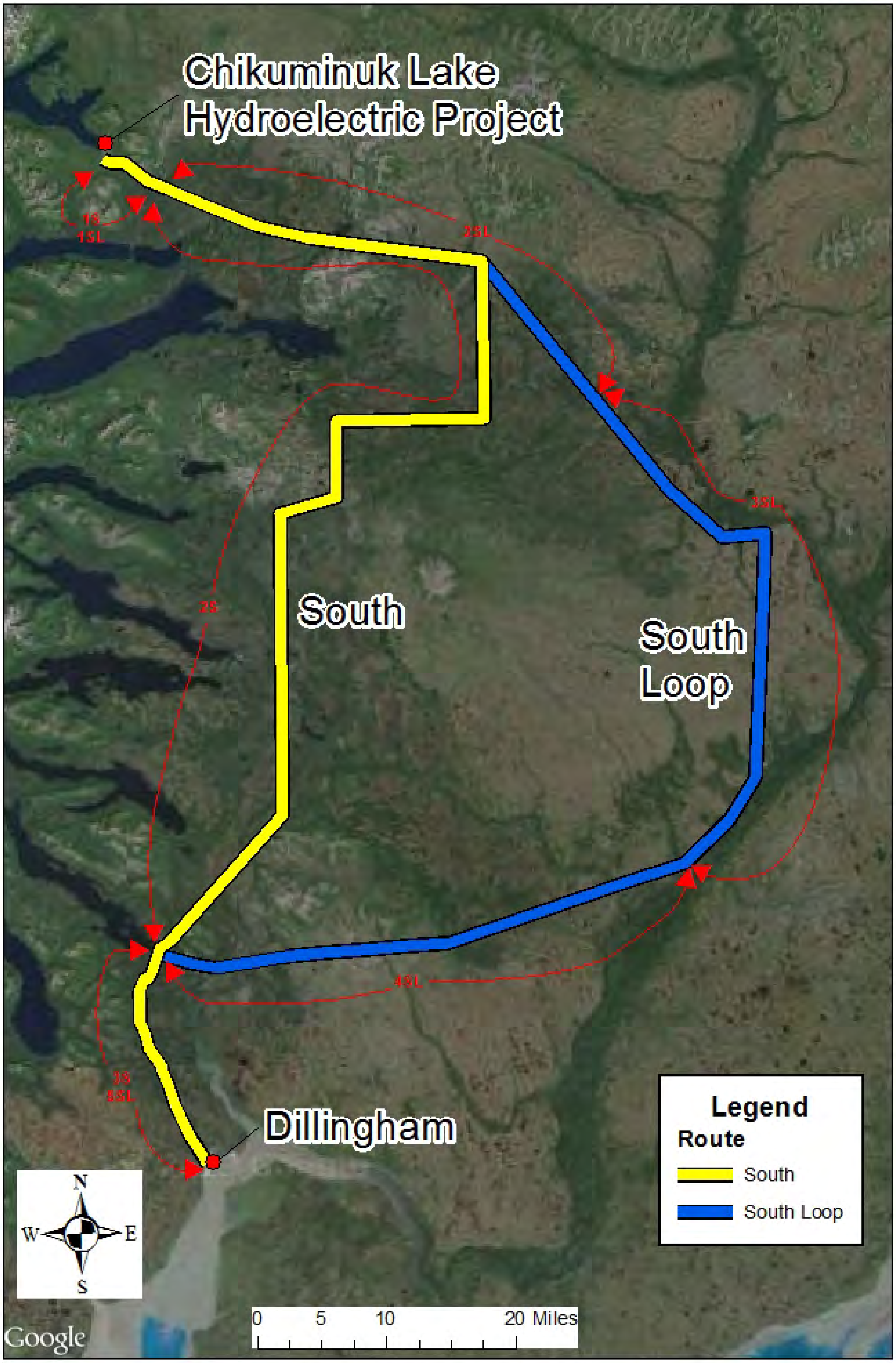

Figure 2 **Alternative Chikuminuk Lake / Dillingham Transmission Routes – Line Segment Map**

2.2 Terrain

The ideal transmission line route would be placed on well-drained soils that never heave and in places where climatological loadings are minimized. However, all routes will pass through varying terrain that do not match the ideal. The following terrain types are intended to provide an overview of the impacts to design and construction:

- **Mountainous –** This terrain is primarily rocky with minimal top soil at higher elevations. Avalanches, strong funneling winds and potential icing conditions make this terrain challenging for transmission lines. Almost any design condition can be accommodated by varying the strength capacity of the line components. However, there is no available climatological data for these areas to specifically determine design conditions. A conservative design with reasonable costs will be required. The least number of miles in this terrain is preferred.

- **Highlands –** This terrain consists of areas with reasonably well drained soils based on map designations. It is anticipated low ground pressure equipment can be utilized in this terrain even during thawed conditions. The number of equipment crossings in an area may also be limited by permit stipulations and some air transportation of crews and materials will be required. Primarily overland travel is assumed in this terrain; therefore summer will be the most efficient construction season possible. Maximizing the route on this terrain is preferred for reliability and construction costs.

- **Lowlands –** This terrain includes soft and wet soils with open water or muskeg. Construction in this terrain is expected to be limited to appropriate frozen conditions. Only construction during the winter using ice roads is assumed. The least number of miles in this terrain is preferred.

2.3 Reliability

The purpose of a transmission facility is to provide reliable electrical power for consumption. Reliability of a transmission line is dependent on many variables, some of which are controllable and others that are not.

Controllable variables include:

- location of the transmission line, which will affect the climatological loadings that it will be required to withstand, such as wind and ice loading;
- the soil conditions, which will impact the mechanical stability of the line; and others.

For these reasons, it is better to minimize the miles of line in terrain that will reduce the reliability.

For this evaluation, the reliability of each route is estimated based on the factors discussed above. Routes will be compared and ranked first or second.

2.4 Stream Crossings

This criterion will tabulate the number of named rivers and streams shown on USGS maps. It is anticipated that natural buffer zones will be required at most stream crossings to minimize visual impacts. The buffer zones typically increase the span between poles and therefore increase construction costs. The least number of stream crossings is preferred.

2.5 Village Visibility

The majority of the routes will not be visible from permanent buildings. This criterion only takes into account the number of villages that are adjacent to each route. It is assumed that most village residents would prefer to not have a transmission line in their visual landscape. Reducing village proximity to the transmission line is preferred.

2.6 Line Loss

Electrical line loss (power loss) is dependent on the magnitude of the load being supplied and the transmission line characteristics. For this comparison it is assumed the average electrical load at Dillingham is 4 MW. Longer lines will have more line loss and be less efficient.

2.7 Construction, Operation, & Maintenance Costs

Transmission lines are built to a higher standard than local distribution lines and as such are more expensive to construct and normally require less maintenance. The following construction, operation and maintenance costs criteria are evaluated:

- **Construction –** In simplified terms, construction of a transmission line consists of the following items: equipment needed to transport and construct the materials, transportation of equipment and crews to and from the jobsite, and conditions under which a crew can work most efficiently. Access and terrain types along each alignment will dictate different construction methods from helicopters in the mountains, low ground pressure equipment in the highlands, and ice roads in the lowlands. This project is large in terms of Alaska transmission lines and with a limited work force will require multiple seasons to construct. Construction cost will reflect all of these variables and will be substantially different for each route alternative. The major cost difference between the alternative routes will be the length of the line.

- **Operations –** Transmission lines are constructed to operate continuously for at least 50 years and often last longer. The components of the transmission line are all designed for long life with no operational requirement. Operation is primarily limited to the substation equipment installed at the terminuses. Substation equipment at Chikuminuk Lake is expected to be designed for remote operation but will require regular visits by personnel. Dillingham will have substation personnel for regular operation. If there are village substations, they are also expected to be remote operation with regular visits. Operation costs will be proportional to the number of substations.

- **Maintenance –** Construction of this transmission line is typical of many other Alaskan lines that will mobilize large crews and specialized equipment such as heavy lift helicopters and low ground pressure carriers. Once construction is complete, all of this special equipment will leave the state and will not be available for line maintenance. Because of the high reliability of the lines, they seldom require major repairs. It is expected that small helicopters and snow track equipment will normally be available and adequate for most maintenance activities. However, if incidents such as an avalanche or wind storms cause major damage to the line it will require a contracted operation for repair and will result in an extended service interruption. Refined maintenance costs will need to be determined after construction and are generally proportional to the miles of line. Maintenance costs for this report will be proportional to costs of construction.

2.8 Land Status

This criterion will tabulate the miles of each route within the categories of land ownership such as Native, State, and Federal. A preliminary assessment of land status is reflected in **Figure 3** in **Section 3.4**.

3 Evaluation of Routes

Following is an engineering comparison of the two possible line routes from the Chikuminuk Lake Hydroelectric Project to the load center at Dillingham based on the Construction Comparison Matrix and a general understanding of the area.

3.1 Access and Terrain

For comparison purposes each route has been divided into segments representing different methods of access and terrain and detailed in **Table 3-1** below. Mountainous terrain on each route is classified according to miles above 700 ft in elevation and highest elevation along the route. This is important to identify relative reliability risk and construction costs. Data is from line routes drawn on USGS 1:250,000 scale maps and Google Map and shown in **Figure 2**.

Air access is assumed in mountainous areas which will dictate expensive construction methods. Both the South and South Loop Routes will have about 4 miles of this access.

- Overland access allowed in summer will be the most economical construction method. The South Route has 96 miles of overland access allowed in summer and South Loop has 40 miles.

- Overland winter access will require some form of ground cover for transportation of heavy pile driving equipment. It is assumed an ice road is the most practical for this work. Construction and maintenance of an ice road is weather dependent. Adequate frost penetration and continuous cold weather are required. Weather in the Dillingham area will be problematic for full winter season construction. The winter construction season with adequate ice and snow cover would potentially not begin until January and could end in early March. The South Loop Route has 88 miles.

Table 3-1 Access and Terrain Comparison

ROUTE		**SOUTH**	**SOUTH LOOP**
ACCESS	Air (helicopter)	1S-4mi.	1SL-4mi.
	Overland-Summer	2S-96mi.	2SL-40mi.
	Overland-Winter		3SL-46mi.

			4SL-42mi.
	Existing Road	3S-19mi.	5SL-19mi.
TERRAIN	Mountainous	1S-max. 720'	1SL-max. 720'
	Highlands	2S-max.761' 3S-max. 360'	2SL-max. 675' 5SL-max. 360'
	Lowlands		3SL-max. 371' 4SL-max. 529'

3.2 Line Length

Each additional mile of line length adds to the complexity of designing, constructing, and maintaining a transmission line, including the following:

- Increased exposure to damaging climatological conditions
- more ground disturbance
- additional stream crossings
- additional general construction impacts
- additional operational impacts due to inspections
- additional maintenance impacts
- additional materials installed
- additional costs for construction, operation and maintenance

Anticipated total line lengths are: South Route 119 miles and South Loop Route 151 miles.

3.3 Reliability

This transmission line will not be part of an electrical grid but will be a single radial line. Any disturbance to the transmission line will result in an outage to Dillingham. The following conditions will improve the overall line reliability:

- Less miles reduces the number of poles and conductor
- Less miles in poor soil conditions improves the long-term stability of poles
- Based on the above conditions the South Loop Route is expected to be less reliable than the South Route.

3.4 Land Status

For comparison purposes the land ownership along each route has been investigated on a large scale basis and is shown in **Table 3-2** and **Figure 3** below. Acquisition time and cost of an easement for the transmission line will not be the same for each route. Easements across state lands will follow a normal permitting process. Lands under other ownership may require additional effort possibly including the following:

- BLM lands will require compliance with the Federal Land Policy Management Act and 43 CFR 5200. In the event refuge lands are crossed by the project, the provisions of Title XI of ANILCA will apply to BLM lands also.
- State Park lands will require modification of the Management Plan. This will impact both routes: South & South Loop (23 miles).
- Native lands including in-holdings will require compliance in accordance with Federal and State acquisition laws. This would impact the South (44 miles), and the South Loop (54 miles).

- It is anticipated Native Allotments will also be impacted by easement acquisition in accordance with Title 25 USC. Historically, easements through allotments have required additional time for acquisition. The number of allotments is expected to be proportional to the miles of line on Native lands.

Table 3-2 Land Status Ownership along each Proposed Route

ROUTE	SOUTH	SOUTH LOOP
LAND STATUS		
BLM		9 miles
DPOR Wood-Tikchik	23 miles	23 miles
NATIVE	38 miles	54 miles
STATE OF ALASKA	58 miles	65 miles

3.5 Transmission Construction and O&M Cost Estimates

The estimated range of direct construction cost for each route is provided in **Appendix A**. The costs are provided only for comparing alternatives and based on information obtained in a tabletop investigation. These costs cannot be assumed as applicable to budgeting or any other purposes outside this report.

Operation costs are dependent on the routine work as determined by the operating company. It is anticipated the transmission line will primarily consist of an annual inspection. This is normally completed using a helicopter and some form of imaging, either photographic or thermal. The result of this inspection should identify if any systemic issues are present. For this report it is assumed the materials selected and the construction techniques did not create any problems. The substations associated with the transmission line have mechanically operating equipment and as such would typically be inspected monthly. For this report it is assumed monthly inspections and typical operating activities such as snow removal, lighting, and travel to remote villages.

Design and construction of long transmission lines in remote Alaska present several major challenges including; estimating the climatological conditions that will impact the poles and wires with no site specific meteorological information. Possible wind and ice conditions will be estimated by using available data from nearby towns, but environments especially at higher elevations are unknown. For this report it is assumed a major event will occur within 10 year and require an outside contractor for repairs.

Also, soil conditions in this area are categorized as “Isolated Permafrost” according to the Institute of Northern Engineering, University of Alaska Fairbanks. Foundations along both of these potential routes will need to accommodate a variety of soil conditions. An economical foundation design that will provide the necessary support without overdesign and the associated higher cost is difficult. Transmission lines over 100 miles in length with economical designs that cross varying soils and terrain will undoubtedly experience some foundation issues. It is not practical to acquire soil borings for each pole location to determine precisely the best foundation type and depth. To cover these variables, several foundation types will be developed during design and then applied in-the-field as the various conditions are encountered. This is not an exact science and judgments of applications will be required. For this report it is anticipated some foundations will need maintenance within the first 5 years and will taper off after that period.

Substations will require regular maintenance of equipment typically about 5 year intervals. For this report the following table is an estimate of annual O&M costs. These costs cannot be assumed as applicable to budgeting or any other purposes outside this report.

	SOUTH	**SOUTH LOOP**
	Transmission (119mi.)	Transmission (151mi.)
	Substations (2)	Substations (5)
Est. Annual Operation & Maintenance	$350,000	$675,000

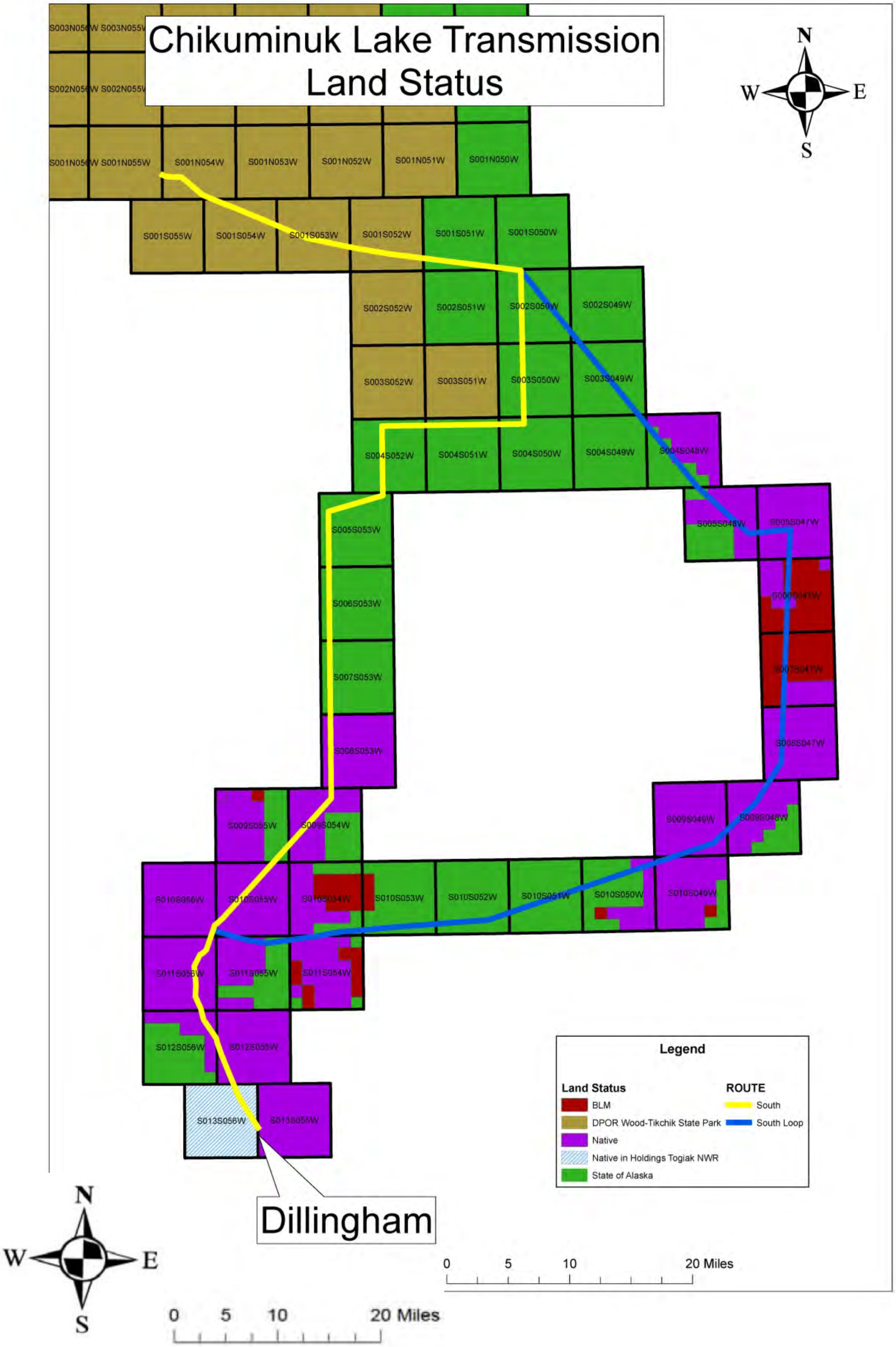

Figure 3 **Alternative Chikuminuk Lake / Bethel Transmission Routes – Land Status**

4 Summary and Conclusion

4.1 Criteria Evaluation Matrix

The Criteria Evaluation Matrix, **Table 4-1**, is based on interpretation of USGS maps and Google Maps. The types of construction methods required by access and terrain are based on engineering judgment of similar transmission lines in Alaska.

Table 4-1 Criteria Evaluation Matrix

ROUTE	COMPARISON	SOUTH	SOUTH LOOP
ACCESS SUMMARY <2>			
Air	less is better	4 miles	4 miles
Overland-Summer	more is better	96 miles	40 miles
Overland-Winter	less is better	0 miles	88 miles
Existing Road	more is better	19 miles	19 miles
TOTAL MILES		119 miles	151 miles
TERRAIN SUMMARY <3>			
Mountainous - summer const.	less is better	4 miles	4 miles
Maximum elevation	less is better	1,250'	1,250'
Miles> 700'	less is better	5 miles	5 miles
Highlands/Road summer const.	more is better	115 miles	59 miles
Maximum elevation	less is better	700'	550'
Miles> 700'	less is better	0 miles	0 miles
Lowlands - winter const.	less is better	0 miles	88 miles
RELIABILITY	first is best	First	Second
STREAM CROSSINGS	less is better	7	16
VILLAGE VISIBILITY	less is better	2	5
APPROX. LINE LOSS (4MW)	less is better	3%	4%
EST. RANGE CONST. COST $M	less is better	37-45	72-93

Notes:

Colored bars only compare within each criterion (green is best, yellow is tied and red is worse). For example: South is shortest route for Overland Summer Access criterion.

<2> Access is a gross interpretation of soil conditions based on USGS Maps and Google Map

<3> More severe icing conditions will exist at higher elevations. An arbitrary elevation of 700' is selected.

4.2 Conclusion

Two separate transmission line routes were identified based on maps, agency requests and knowledge of best transmission route selection for Alaskan conditions. Alternatives were segmented into terrain and access types for construction and O&M expenses. Finally, a range of construction costs were developed for each alternative.

Based on the comparisons noted in Section 3 and summarized in **Table 4.1**, the South Route is the most reasonable choice. The estimated costs shown in Appendix A support the South Route and are only for the direct construction of the transmission line itself, other costs will be required. The South Loop Route will add between 95% and 107% more to the financed cost of power in Dillingham as compared to the South Route. This impact will significantly burden the project feasibility. This analysis did not consider other possible impacts such as environmental; however most impacts are proportional to the miles of line. The longer line route generally results in more environmental impacts. Also, poor soil conditions and more stream crossings again substantiate the South Route as the better choice.

Appendix A – Detailed Construction Cost Estimates

The following pages explain the development of the construction cost estimates for the alternative line routes.

- CONSTRUCTION COST ESTIMATE DETAILS – show material and labor estimates for major line components for the three types of access and terrain: Air, Overland Summer and Overland Winter
- CONSTRUCTION COST ESTIMATE UNITS – using Detail Sheets the components are combined into units, for example line sections with average for structures, foundations, and miscellaneous
- CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS – using ESTIMATE UNIT SHEETS additional costs such as mobilization/demobilization are added to the typical line sections
- CONSTRUCTION COST ESTIMATE SUMMARY – using the TYPICAL LINE SECTIONS SHEETS cost per mile of each type of construction, a summary table is shown.

CONSTRUCTION COST ESTIMATE DETAILS

Crew Hr $1,200

Air (Helicopter) (Mountainous)	Qty	Unit Cost Materials	Mtl. Mult.	Unit Material	Material $	Crew Hr	Labor	Labor Mult.	Unit Labor	Labor $	Mtl & Lbr Total
Tangent Wood 69kV Single Pole, 400 ft.											
Crossarm Assembly	1	$150	1.10	$165	$165	1	$1,200	1.30	$1,560	$1,560	$1,725
50' Wood Pole	1	$2,000	1.10	$2,200	$2,200	4	$4,800	1.30	$6,240	$6,240	$8,440
					$2,365					$7,800	
Large Angle/DE Single Pole, 69kV											
Insulator Assembly	3	$100	1.10	$110	$330	2	$2,400	1.30	$3,120	$9,360	$9,690
60' Single pole w/guys	1	$2,500	1.10	$2,750	$2,750	6	$7,200	1.30	$9,360	$9,360	$12,110
					$3,080					$18,720	
Small/Medium Angle Single Pole, 69kV											
Insulator Assembly	3	$200	1.10	$220	$660	1	$1,200	1.30	$1,560	$4,680	$5,340
50' Single pole w/guys	1	$2,000	1.10	$2,200	$2,200	5	$6,000	1.30	$7,800	$7,800	$10,000
					$2,860					$12,480	
Driven Pile	1	$2,500	1.10	$2,750	$2,750	4	$4,800	1.30	$6,240	$6,240	$8,990
Rock Foundations	1	$5,000	1.10	$5,500	$5,500	8	$9,600	1.30	$12,480	$12,480	$17,980
Oriole Conductor (1,000')	3	$500	1.10	$550	$1,650	6	$7,200	1.30	$9,360	$28,080	$29,730

CONSTRUCTION COST ESTIMATE DETAILS

Overland Summer (Highlands)	Qty	Unit Cost Materials	Mtl. Mult.	Unit Material	Material $	Crew Hr	Labor	Labor Mult.	Unit Labor	Labor $	Mtl & Lbr Total
					Crew Hr	$1,200					
Tangent Wood 69kV Single Pole, 400 ft.											
Crossarm Assembly	1	$150	1.00	$150	$150	0.5	$600	1.00	$600	$600	$750
50' Wood Pole	1	$2,000	1.00	$2,000	$2,000	3	$3,600	1.00	$3,600	$3,600	$5,600
					$2,150					$4,200	
Large Angle/DE Single Pole, 69kV											
Insulator Assembly	3	$100	1.00	$100	$300	1	$1,200	1.00	$1,200	$3,600	$3,900
60' Single pole w/guys	1	$2,500	1.00	$2,500	$2,500	6	$7,200	1.00	$7,200	$7,200	$9,700
					$2,800					$10,800	
Small/Medium Angle Single Pole, 69kV											
Insulator Assembly	3	$200	1.00	$200	$600	0.5	$600	1.00	$600	$1,800	$2,400
50' Single pole w/guys	1	$2,000	1.00	$2,000	$2,000	4	$4,800	1.00	$4,800	$4,800	$6,800
					$2,600					$6,600	
Driven Pile	1	$2,500	1.00	$2,500	$2,500	3	$3,600	1.00	$3,600	$3,600	$6,100
Rock Foundations	1	$5,000	1.00	$5,000	$5,000	6	$7,200	1.00	$7,200	$7,200	$12,200
Oriole Conductor (1,000')	3	$500	1.00	$500	$1,500	4	$4,800	1.00	$4,800	$14,400	$15,900

CONSTRUCTION COST ESTIMATE DETAILS

Overland Winter (Lowlands)	Qty	Unit Cost Materials	Mtl. Mult.	Unit Material	Material $	Crew Hr	Labor	Labor Mult.	Unit Labor	Labor $	Mtl & Lbr Total
					Crew Hr	$1,200					
Tangent Wood 69kV Single Pole, 400 ft.											
Crossarm Assembly	1	$150	1.10	$165	$165	1	$1,200	1.20	$1,440	$1,440	$1,605
50' Wood Pole	1	$2,000	1.10	$2,200	$2,200	4	$4,800	1.20	$5,760	$5,760	$7,960
					$2,365					$7,200	
Large Angle/DE Single Pole, 69kV											
Insulator Assembly	3	$100	1.10	$110	$330	1	$1,200	1.20	$1,440	$4,320	$4,650
60' Single pole w/guys	1	$2,500	1.10	$2,750	$2,750	6	$7,200	1.20	$8,640	$8,640	$11,390
					$3,080					$12,960	
Small/Medium Angle Single Pole, 69kV											
Insulator Assembly	3	$200	1.10	$220	$660	1	$1,200	1.20	$1,440	$4,320	$4,980
50' Single pole w/guys	1	$2,000	1.10	$2,200	$2,200	5	$6,000	1.20	$7,200	$7,200	$9,400
					$2,860					$11,520	
Driven Pile	1	$2,500	1.10	$2,750	$2,750	4	$4,800	1.20	$5,760	$5,760	$8,510
Rock Foundations	1	$5,000	1.10	$5,500	$5,500	8	$9,600	1.20	$11,520	$11,520	$17,020
Oriole Conductor (1,000')	3	$500	1.10	$550	$1,650	5	$6,000	1.20	$7,200	$21,600	$23,250

CONSTRUCTION COST ESTIMATE DETAILS

Road Summer	Qty	Unit Cost Materials	Mtl. Mult.	Unit Material	Material $	Crew Hr	Labor	Labor Mult.	Unit Labor	Labor $	Mtl & Lbr Total
				Crew Hr	$1,200						
Tangent Wood 69kV Single Pole, 400 ft.											
Crossarm Assembly	1	$150	1.00	$150	$150	0.5	$600	1.00	$600	$600	$750
50' Wood Pole	1	$2,000	1.00	$2,000	$2,000	1	$1,200	1.00	$1,200	$1,200	$3,200
					$2,150					$1,800	
Large Angle/DE Single Pole, 69kV											
Insulator Assembly	3	$100	1.00	$100	$300	1	$1,200	1.00	$1,200	$3,600	$3,900
60' Single pole w/guys	1	$2,500	1.00	$2,500	$2,500	4	$4,800	1.00	$4,800	$4,800	$7,300
					$2,800					$8,400	
Small/Medium Angle Single Pole, 69kV											
Insulator Assembly	3	$200	1.00	$200	$600	0.5	$600	1.00	$600	$1,800	$2,400
50' Single pole w/guys	1	$2,000	1.00	$2,000	$2,000	3	$3,600	1.00	$3,600	$3,600	$5,600
					$2,600					$5,400	
Driven Pile	1	$2,500	1.00	$2,500	$2,500	3	$3,600	1.00	$3,600	$3,600	$6,100
Rock Foundations	1	$5,000	1.00	$5,000	$5,000	4	$4,800	1.00	$4,800	$4,800	$9,800
Oriole Conductor (1,000')	3	$500	1.00	$500	$1,500	3	$3,600	1.00	$3,600	$10,800	$12,300

CONSTRUCTION COST ESTIMATE UNITS

Air (Helicopter) (Mountainous)

Example-Section 1S & 1SL = 4 miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr. Cost
Tangent Structure	47	ea	$2,365	$7,800	$10,165	$477,755	Str.	$2,433	$8,683
DE/Large Angle	3	ea	$3,080	$18,720	$21,800	$65,400			
Medium Angle	3	ea	$2,860	$12,480	$15,340	$46,020			
Pipe Pile Fdn	0	ea	$2,750	$6,240	$8,990	$0	Fnd.	$5,500	$12,480
Rock Foundations	53	ea	$5,500	$12,480	$17,980	$952,940			
Cond. Oriole	4	crkt mi	$8,712	$148,262	$156,974	$627,898			
OPGW	4	mi	$2,000	$20,000	$22,000	$88,000			
Dampers	32	ea	$50	$200	$250	$7,950	Misc.	$74	$297
Aerial Balls/Bird	6	ea	$400	$2,000	$2,400	$15,264			
Structure Signs	53	ea	$50	$150	$200	$10,600			
Clearing	1	mi	$0	$10,000	$10,000	$10,000			
						$2,301,827			

CONSTRUCTION COST ESTIMATE UNITS

Overland Summer (Highlands)

Example-Section 2S= 96 miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr. Cost
Tangent Structure	1163	ea	$2,150	$4,200	$6,350	$7,385,050	Str.	$2,194	$4,548
DE/Large Angle	45	ea	$2,800	$10,800	$13,600	$612,000			
Medium Angle	60	ea	$2,600	$6,600	$9,200	$552,000			
Pipe Pile Fnd.	254	ea	$2,500	$3,600	$6,100	$1,549,400	Fnd.	$2,500	$3,600
Cond. Oriole	96	crkt mi	$7,920	$76,032	$83,952	$8,059,392			
OPGW	96	mi	$2,000	$15,000	$17,000	$1,632,000			
Dampers	761	ea	$50	$200	$250	$190,200	Misc.	$74	$169
Aerial Balls/Bird	152	ea	$400	$1,000	$1,400	$213,024			
Structure Signs	1268	ea	$50	$50	$100	$126,800			
Clearing	70	mi	$0	$10,000	$10,000	$700,000			
						$21,019,866			

CONSTRUCTION COST ESTIMATE UNITS

Overland Winter (Lowlands)

Example-Section 3SL = 46 miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr. Cost
Tangent Structure	553	ea	$2,365	$7,200	$9,565	$5,289,445	Str.	$2,417	$7,638
DE/Large Angle	20	ea	$3,080	$12,960	$16,040	$320,800			
Medium Angle	35	ea	$2,860	$11,520	$14,380	$503,300			
Pipe Pile Fnd.	575	ea	$2,750	$5,760	$8,510	$4,893,250	Fnd.	$2,750	$5,760
Cond. Oriole	46	crkt mi	$8,712	$114,048	$122,760	$5,646,960			
OPGW	46	mi	$2,000	$20,000	$22,000	$1,012,000			
Dampers	365	ea	$50	$600	$650	$237,120	Misc.	$74	$436
Aerial Balls/Bird	73	ea	$400	$2,000	$2,400	$175,104			
Structure Signs	608	ea	$50	$150	$200	$121,600			
Clearing	15	mi	$0	$20,000	$20,000	$300,000			
Ice Road	46	mi	$0	$100,000	$100,000	$4,600,000			
						$23,099,579			

CONSTRUCTION COST ESTIMATE UNITS

Road

Section 3S & 5SL = 19 miles

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost		Avg Mtl. Cost	Avg Lbr. Cost
Tangent Structure	228	ea	$2,150	$1,800	$3,950	$900,600	Str.	$2,198	$2,237
DE/Large Angle	9	ea	$2,800	$8,400	$11,200	$100,800			
Medium Angle	14	ea	$2,600	$5,400	$8,000	$112,000			
Pipe Pile Fdn	51	ea	$2,500	$3,600	$6,100	$311,100	Fnd.	$2,500	$3,600
Rock Foundations	0	ea	$5,000	$4,800	$9,800	$0			
Cond. Oriole	19	crkt mi	$7,920	$57,024	$64,944	$1,233,936			
OPGW	19	mi	$2,000	$12,000	$14,000	$266,000			
Dampers	151	ea	$50	$200	$250	$37,650	Misc.	$74	$169
Aerial Balls/Bird	30	ea	$400	$1,000	$1,400	$42,168			
Structure Signs	251	ea	$50	$50	$100	$25,100			
Clearing	12	mi	$0	$6,000	$6,000	$72,000			
						$3,101,354			

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS
DILLINGHAM

Section 1S & 1SL

Air (Helicopter) (Mountainous) 1S & 1SL = 4 miles

Description	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Structures	**53**	ea	$2,433	$8,683	$11,117	$589,175
Foundations	**53**	ea	$5,500	$12,480	$17,980	$952,940
Conductor	**4**	crkt mi	$8,712	$148,262	$156,974	$627,898
OPGW	**4**	crkt mi	$2,000	$20,000	$22,000	$88,000
Other*	**1**	lump	$74	$297	$371	$33,814
Clearing	**1**	mi	$0	$10,000	$10,000	$10,000
Subtotal						$2,301,827
Mob/Demob @10%						$230,183
Helicopter Construction Cost adder @ 25%						$633,002
Contingency @20% Total						$633,002
Estimated Total Construction Cost						**$3,798,014**
Average Cost per Mile						$949,503

* Includes:dampers, aerial balls, bird diverters, signs

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS
DILLINGHAM

Section 2S & 2SL
Overland Summer **2S = 96 miles**

Description	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Structures	1268	ea	$2,194	$4,548	$6,742	$8,549,050
Foundations	254	ea	$2,500	$3,600	$6,100	$1,549,400
Conductor	96	crkt mi	$7,920	$76,032	$83,952	$8,059,392
OPGW	96	crkt mi	$2,000	$15,000	$17,000	$1,632,000
Other*	1	lump	$74	$169	$243	$530,024
Clearing	70	mi	$0	$10,000	$10,000	$700,000
Subtotal						$21,019,866
Mob/Demob @8%						$1,681,589
Helicopter support adder @10%						$2,270,146
Contingency @20% Total						$4,994,320
Estimated Total Construction Cost						**$29,965,921**
Average Cost per Mile						$312,145

* Includes:dampers, aerial balls, bird diverters, signs

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS
DILLINGHAM

Section 3SL & 4SL
Overland Winter 3SL = 46 miles

Description	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Structures	608	ea	$2,417	$7,638	$10,055	$6,113,545
Foundations	46	ea	$2,750	$5,760	$8,510	$391,460
Conductor	46	crkt mi	$8,712	$114,048	$122,760	$5,646,960
OPGW	46	crkt mi	$2,000	$20,000	$22,000	$1,012,000
Other*	1	lump	$74	$436	$510	$533,824
Clearing	15	mi	$0	$20,000	$20,000	$300,000
Ice Road	46	mi	$0	$100,000	$100,000	$4,600,000
Subtotal						$18,597,789
Mob/Demob @10%						$1,859,779
Helicopter support adder @10%						$2,045,757
Contingency @20% Total						$4,500,664.94
Estimated Total Construction Cost						**$27,003,990**
Average Cost per Mile						$587,043

* Includes:dampers, aerial balls, bird diverters, signs

CONSTRUCTION COST ESTIMATE TYPICAL LINE SECTIONS
DILLINGHAM

Section 3S & 5SL
Road Summer **19 miles**

Description	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Structures	251	ea	$2,198	$2,237	$4,436	$1,113,400
Foundations	51	ea	$2,500	$3,600	$6,100	$311,100
Conductor	19	crkt mi	$7,920	$57,024	$64,944	$1,233,936
OPGW	19	crkt mi	$2,000	$12,000	$14,000	$266,000
Other*	1	lump	$74	$169	$243	$104,918
Clearing	12	mi	$0	$6,000	$6,000	$72,000
Subtotal						$3,101,354
Mob/Demob @5%						$155,068
Contingency @20% Total						$651,284
Estimated Total Construction Cost						**$3,907,706**
Average Cost per Mile						$205,669

* Includes:dampers, aerial balls, bird diverters, signs

CONSTRUCTION COST ESTIMATE SUMMARY

Alternative	Description	Low	High
South	Air = 4 miles, Overland-Summer = 96 miles, Road = 19 miles	$37,666,000	$45,199,200
South Loop	Air = 4 miles, Overland-Summer = 40 miles, Overland-Winter = 88 miles, Road = 19 miles	$71,850,000	$93,405,000

Based on the values from the previous pages, the following section costs are used to develop the route costs above.

Air	$950,000	per mile
Overland-Summer	$312,000	per mile
Overland-Winter	$587,000	per mile
Existing Road	$206,000	per mile

Note these are only construction costs and do not include other costs such as:
Design, Owners Cost, Permitting, Environmental compliance, etc.

Chikuminuk Lake Hydroelectric Project
FERC No. 14369

Interim Feasibility Report
Volume I – Technical Studies

Appendix C – Project Operations Modeling

DRAFT April, 2014
Prepared By:

HATCH™

HATCH™

Project Memo

H342022

31 Mar 2013

To: Dick Griffith

From: Carl Mannheim

cc:

Nuvista Electric Cooperative
Chikuminuk Lake Hydroelectric Project Interim Feasibility Study

Project Operations Modeling

1. Introduction

This memo describes the operations modeling of the selected project arrangement and presents expected energy generation to meet existing load patterns, expected Lake Chikuminuk water level fluctuations, and regulated flows from the proposed Chikuminuk Hydroelectric project (Project).

The purpose of this memo is to provide information on expected Project operations, such as energy generation and reservoir fluctuations.

2. Project Arrangement

The preferred project arrangement includes a roller compacted concrete (RCC) dam with a 110 ft long uncontrolled spillway. The spillway crest elevation is 660 ft, which means that the normal maximum lake level will be raised 47 feet from elevation 613 ft. A 13 ft wide and approximately 900 feet long concrete lined power tunnel will route water to the powerhouse, in which four 5.5 MW vertical Francis turbines will be installed. The tailrace elevation is approximately 544 ft, resulting in a maximum gross head on the units of 116 feet.

3. Operations Modeling

3.1 Model Selection

HEC-ResSim 3.0 by the U.S. Army Corps of Engineers' Hydrologic Engineering Center was selected to simulate the Project operations. This software comprises a graphical user interface and a computational program to simulate reservoir operations. The software is public domain and can be downloaded for free from www.hec.usace.army.mil.

3.2 Model Input Requirements

Attachment A presents the model input parameters used, excluding the long term monthly flow record and average monthly energy demand, which are presented below. The parameters include, but are not limited to:

HATCH™

- Reservoir area and storage data (Table A-1)
- Spillway configuration and any other outlet configuration (Table A-2 and A-3)
- Turbine unit description, including headlosses, tailwater level (Table A-2)
- Any other required flow releases, e.g. instream flow requirements (Table A-3)
- Reservoir operation rules (Table A-4)

3.2.1 Hydrology

Inflow to the Project is based on the extended monthly stream flow record for the Allen River USGS gage (USGS 15301500) presented in Table 1. The stream flow extension is based on correlation to the USGS gage on the Nuyakuk River. A more detailed description on the development of the extended stream flow record for the Allen River is presented in the Draft Interim Feasibility Report (Hatch, 2014).

Table 1 Estimated average monthly flows at dam site, using measured values if available (cfs)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1953						3996	2954	1917	1189	896	472	425	
1954	392	366	344	335	677	2469	1239	679	788	631	968	486	781
1955	440	409	392	386	531	2894	5609	3187	1510	1163	475	409	1460
1956	373	344	335	344	546	4407	2901	1302	2154	808	455	425	1197
1957	373	344	344	366	939	3271	1396	477	2780	1499	2037	738	1211
1958	444	407	392	389	559	5520	6106	2789	1343	1034	459	420	1663
1959	404	366	335	344	571	3466	2639	891	706	2009	664	449	1074
1960	417	376	347	287	989	4382	3144	2238	1323	1111	787	487	1325
1961	448	425	386	366	1262	4153	3087	2310	2038	1097	486	396	1375
1962	379	373	359	359	678	4112	3995	1207	718	686	463	435	1150
1963	445	449	442	379	562	3620	2966	1492	2239	1071	478	571	1228
1964	474	406	314	255	339	4870	2908	1986	2039	1571	625	520	1358
1965	460	400	370	348	494	4702	3476	2132	4554	1576	569	460	1628
1966	400	350	300	260	367	3900	3226	2010	2300	2497	910	480	1421
1967	437	407	386	375	404	2699	2209	1059	1164	987	438	382	914
1968	357	348	344	344	708	2659	1429	1689	1016	477	418	397	849
1969	378	359	351	351	771	6650	4145	1167	805	2781	1858	489	1678
1970	402	378	366	359	790	3915	3279	2209	1852	593	442	391	1251
1971	368	354	348	346	559	3618	4935	3523	1377	1095	552	441	1468
1972	403	374	351	346	412	2987	4211	1687	1390	1258	974	472	1241
1973	421	389	367	354	563	3697	4242	1574	1691	1284	472	408	1293
1974	375	355	351	352	657	2907	2274	840	1097	1255	573	426	957
1975	390	373	364	363	549	3521	3709	1322	1164	1614	611	425	1205
1976	372	339	307	299	434	2616	2614	1857	2329	2770	1037	489	1291
1977	450	423	387	361	446	5117	7611	6897	2281	902	473	416	2162
1978	406	391	379	379	2716	3826	4018	1975	1926	938	706	527	1523
1979	455	405	378	404	1356	5006	3722	3708	2007	2963	2092	654	1937
1980	431	424	414	414	1400	5523	5026	2476	885	1486	1031	440	1666
1981	428	433	421	415	1452	4934	3073	1935	1096	526	530	444	1310
1982	404	419	401	384	626	4829	5152	1800	2772	2959	584	454	1738
1983	432	408	380	381	1278	5216	3537	1348	494	496	481	1108	1300
1984	494	428	392	374	697	3283	3450	1106	503	640	437	402	1019
1985	398	416	374	339	367	3564	4426	2714	1748	1798	594	465	1440

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Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	431	399	385	374	433	2565	3919	2666	2489	2159	1544	458	1491
1987	425	398	389	381	500	4623	6438	3210	1181	1698	862	453	1723
1988	420	412	398	384	877	5638	5131	3031	2750	1765	1076	480	1865
1989	429	388	386	373	499	4214	3434	2154	4519	3273	1038	452	1766
1990	428	400	378	395	533	3273	1793	1448	1540	1536	529	430	1058
1991	410	397	389	404	749	3778	2159	1374	2185	3390	1162	426	1405
1992	386	377	368	373	1015	3744	3388	2450	2323	587	434	398	1321
1993	381	373	374	422	2182	5274	3200	1935	2490	2394	744	467	1691
1994	438	418	391	402	881	4910	3975	2492	1475	2722	948	498	1636
1995	448	409	384	406	2171	4891	3181	1933	2759	2727	1253	459	1756
1996	405	390	402	394	1254	2541	2018	1090	612				
2002							3164	1303	637	1692	3294	2696	
2003	743	486	451	406	595	3222	2944	1717	876	1592	831	443	1196
2004	409	390	377	393	1761	3736	1930	1092	485				
2007							2005	2032	2422	1624	774	493	
2008	423	394	387	373	825	4321	3734	1370	1909	1566	442	412	1347
2009	384	375	368	370	2084	4893	2498	3236	1322	2662	1335	460	1673
2010	412	394	377	365	800	4428	3236	3537	1893	649	488	439	1423
2011	410	380	367	359	1159	4453	3153	1684	1540	870	431	390	1269
2012	303	322	340	314	535	4795	3933	1564	1920				
2013					499	4074	2368	2890	1451	2144	1610	541	
Avg	**419**	**391**	**373**	**365**	**864**	**4071**	**3450**	**2032**	**1705**	**1559**	**842**	**516**	**1386**
Min	**303**	**322**	**300**	**255**	**339**	**2469**	**1239**	**477**	**485**	**477**	**418**	**382**	**781**
Max	**743**	**486**	**451**	**422**	**2716**	**6650**	**7611**	**6897**	**4554**	**3390**	**3294**	**2696**	**2162**

3.2.2 Average Monthly Energy Demand

One primary input requirement is the average monthly energy demand, which is presented in Table 2 below. The computer program will determine the flow required to generate sufficient power to meet the monthly energy demand at each time step, subject to any water level or flow restrictions, such as instream flow requirements. Per Table 2, the total annual energy demand is expected to be 82.1 GWh.

Table 2. Average monthly energy demand (Hatch, 2013)

Month	Energy Demand (MWh)
Jan	8,000
Feb	6,800
Mar	7,200
Apr	6,700
May	6,500
Jun	6,000
Jul	6,800
Aug	6,500
Sep	6,300
Oct	6,600
Nov	7,400
Dec	7,300
Annual	**82,100**

3.2.3 Instream Flow Requirements

An instream flow requirement of approximately 150 cfs, or 10 percent of the annual average flow (1,386 cfs) was assumed during the primary fish spawning season of June through November. A reduced value of 50 cfs was assumed for the remaining months. The instream flow would be released at the dam and would ensure that the short reach from the dam to the powerhouse would not be dewatered during normal operation or during short periods when the powerhouse is not in operation. A low level outlet with higher discharge capacity would ensure normal river flows would be maintained during longer periods of powerhouse outage.

3.2.4 Reservoir Operation Rules

The reservoir operation zones are presented in Table A-4. Two zones were considered appropriate based on the reservoir water level: 1) A power generation zone; and 2) a conservation zone. These are described in more detail below.

Power Generation Zone (WL > 641 ft)

The power generation zone is defined as the range of reservoir levels for which water will be drawn through the powerhouse to generate power to meet the average monthly energy demand. Within this zone, project discharges are prioritized as follows:

1) Instream flow requirements: 150 cfs for June through October; 50 cfs November through May.
2) Power generation flows: The turbines will draw as much flow as is necessary to meet the average monthly energy demand.

Conservation Zone (WL < 641 ft)

The conservation zone is defined as the range of reservoir levels for which water will be used to only satisfy the instream flow requirements and no water will be used to generate power. The purpose of this zone is to ensure that, on average, the reservoir fills back up within a few hydrologic cycles. Otherwise, during extended periods of low flow, the energy demand may be greater than what can be generated with available head and flow, resulting in the reservoir being emptied. A reservoir elevation of 641 was estimated as the top of conservation zone based on maximization of the generated energy. Within this zone, project discharges are prioritized as follows:

1) Instream flow requirements: 150 cfs for June through October; 50 cfs November through May.
2) Power generation flows: The turbines will draw only as much flow as is available to maintain a reservoir elevation of 641 ft (reservoir inflow less the instream flow requirement).

3.3 Results

The analysis and results presented herein assume that the Project will be operated to meet the full average monthly demand of the served communities to the greatest extent possible.

Table B-1 in Attachment B presents the full monthly output from HEC-ResSim of selected parameters.

3.3.1 *Energy Generation*

The expected average monthly energy generation is presented in Table 3. The expected average annual energy generation is 78,100 MWh, compared to an average annual demand of 82,100 MWh, which is presented in Table 4.

The results in Tables 3 and 4 indicate that, on average, project generation may not be able to meet the estimated average monthly demand in the winter and spring months of November through May. However, the Project is very likely to be able to meet the demand during the summer months (June through October). Also, the results indicate that the Project would be able to meet the annual average demand approximately 70 percent of the time (29 years out of 41), but that dry periods may cause reduced generation for several years (e.g. 1960-1964) if the reservoir cannot fill up at the end of each year.

Table 5 summarizes selected generation statistics. The average power factor for the project is 0.40, which compares very well to other hydroelectric projects in Alaska as well as nationwide. The minimum reservoir water level for the period of record is 641 ft, due to the limitation of the Conservation Zone.

3.3.2 *Reservoir Water Levels and Regulated Flows*

Figures 1 and 2 show the resulting reservoir fluctuations and Project inflows and outflows for the period of record, respectively. Figure 1 shows that the Project would spill only during the wettest years of the record, which indicates efficient use of available flow for generation.

Table 3 Expected average monthly energy generation

Month	Average Energy Demand (MWh)	Average Project Generation (MWh)	Average Difference (MWh)
Jan	8,000	7,694	-306
Feb	6,800	6,416	-384
Mar	7,200	6,242	-958
Apr	6,700	5,143	-1,557
May	6,500	5,959	-541
Jun	6,000	6,000	0
Jul	6,800	6,800	0
Aug	6,500	6,500	0
Sep	6,300	6,300	0
Oct	6,600	6,600	0
Nov	7,400	7,264	-136
Dec	7,300	7,165	-135
Annual	**82,100**		

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Table 4 Expected average annual energy generation

Year	Average Demand (GWh)	Average Generation (GWh)	Average Difference (MWh)
1955	82.1	82.2	0
1956	82.1	81.9	0
1957	82.1	82.2	0
1958	82.1	76.6	-6
1959	82.1	82.2	0
1960	82.1	76.3	-6
1961	82.1	76.9	-5
1962	82.1	75.4	-7
1963	82.1	59.9	-22
1964	82.1	66.4	-16
1965	82.1	82.2	0
1966	82.1	82.2	0
1967	82.1	82.2	0
1968	82.1	59.5	-23
1969	82.1	58.9	-23
1970	82.1	82.2	0
1971	82.1	82.2	0
1972	82.1	81.9	0
1973	82.1	82.2	0
1974	82.1	82.2	0
1975	82.1	57.8	-24
1976	82.1	67.3	-15
1977	82.1	73.9	-8
1978	82.1	82.2	0
1979	82.1	82.2	0
1980	82.1	81.9	0
1981	82.1	82.2	0
1982	82.1	82.2	0
1983	82.1	82.2	0
1984	82.1	81.9	0
1985	82.1	66.8	-15
1986	82.1	82.2	0
1987	82.1	82.2	0
1988	82.1	81.9	0
1989	82.1	82.2	0
1990	82.1	82.2	0
1991	82.1	82.2	0
1992	82.1	81.9	0
1993	82.1	82.2	0
1994	82.1	82.2	0
1995	82.1	82.2	0
Average	**82.1**	**78.1**	**-4**

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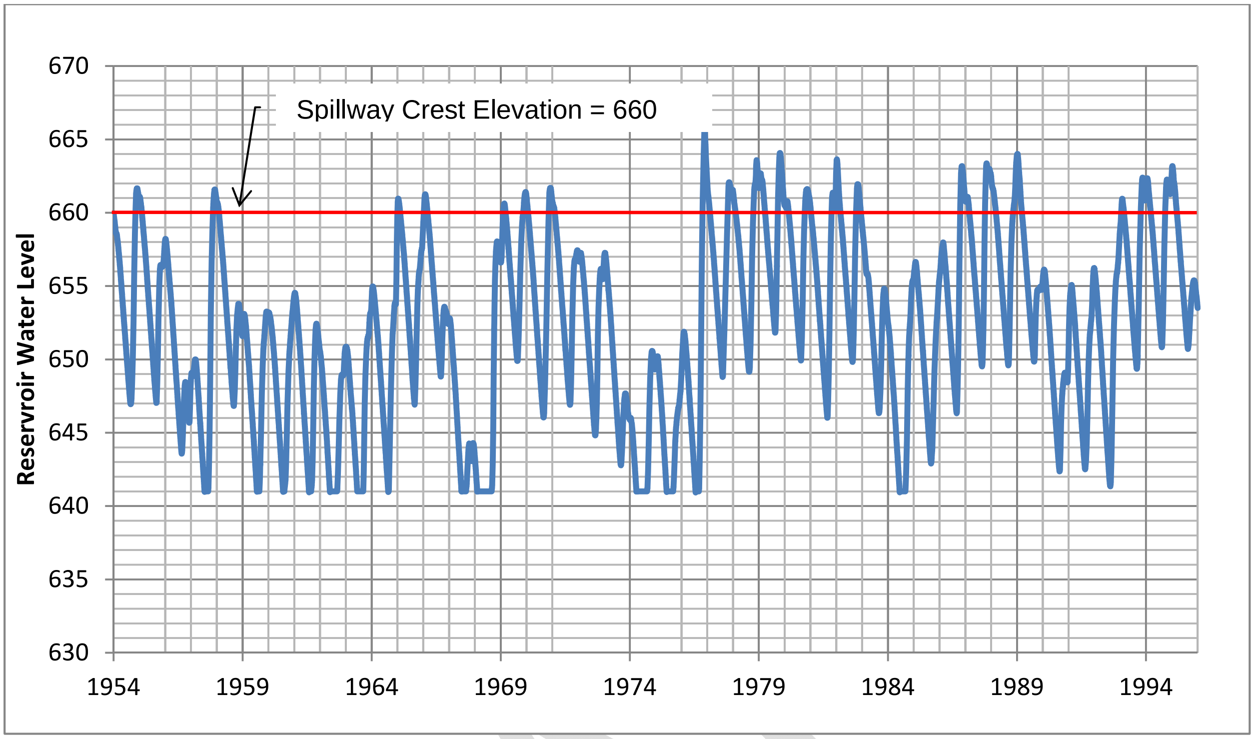

Figure 1. Reservoir water level (spillway crest elevation 660 ft)

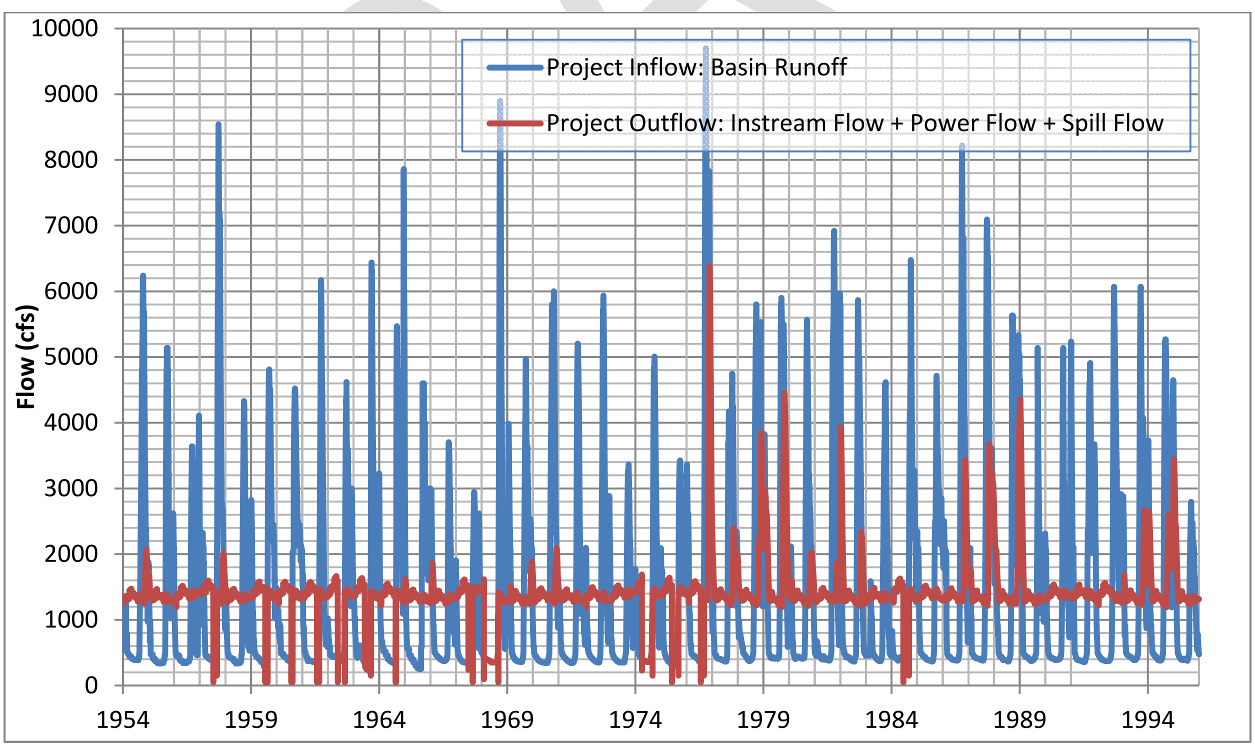

Figure 2. Estimated average Project inflow and outflow

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Table 5. Summary of generation statistics

Parameter	Average	Max	Min
Generation Efficiency	0.9	0.9	0.9
Power Head (ft)	98.1	111.6	86.9
Energy Generated per Time Step (MWh)	214.1	258.1	0
Power Generated (MW)	8.9	10.8	0
Plant Factor	0.4	0.5	0
Flow Power (cfs)	1203.9	1640	0

4. Summary and Conclusions

A reservoir model was set up using the computer program HEC-ResSim 3.0, which facilitated the estimation of the regulated reservoir operations, including energy generation and outflow estimation. The following is a summary of the results; model output of selected parameters is included in Attachment B:

- The average annual energy potential of the Project, based on the estimated long term (42 years) reservoir inflow record, is approximately 78.1 GWh.
- A conservation zone at elevation 641 ft, below which flow to the turbines is limited to reservoir inflow, was necessary reduce risk of emptying the reservoir during periods of low inflow.
- The simulated average monthly reservoir level is 652.1 ft, which reflects the need to maintain available storage for large runoff events to fully utilize the energy potential of the site and minimize spill.
- On average: 1) project generation will likely not meet the estimated average monthly demand in the winter and spring months of November through May; 2) project generation will likely be able to meet the demand during the summer months (June through October).
- Project will likely meet the annual average demand approximately 70 percent of the time.

5. References

1. Hatch. (2014). *Draft Interim Feasibility Report, Chikuminuk Lake Hydroelectric Project.*
2. Hatch. (2013). *Draft Preliminary Application Document for Chikuminuk Hydroelectric Development.*

Carl Mannheim

CM:cm
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Attachment A

HEC-ResSim 3.0 Model Input Parameters

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Table A-1. Reservoir area and storage

Elevation (ft)	Storage (ac-ft)	Surface Area (ac)
600.00	0	24047
700.00	2991615	36198

Table A-2. Reservoir and powerhouse input parameters and values

Parameter	Value	Comment
Tailwater El	544 ft	Constant tailwater elevation for all river flows
Powerplant Capacity	22 MW	Nameplate capacity; Based on estimated total peak demand from served communities
Powerplant Overload Factor	1.0	The Overload Factor (OF) is a multiplier for the Installed Capacity to determine the maximum energy the power plant can produce in a time interval. To use the full Installed Capacity, an OF of 1.0 is used; to overload a plant's capacity by 10%, an OF of 1.1 would be used.
Powerplant Efficiency	89%	Constant; Total efficiency (generator efficiency × turbine efficiency) of the power plant over range of flows and head.
Station Use	0 cfs	The portion of the total plant flow that is not used to generate power to meet the demand from the grid.
Hydraulic Losses	10 ft	Constant over range of flows and head
Spillway Length	100 ft	Effective crest length due to abutments and piers
Spillway discharge coefficient	3.9	Average coefficient over expected range of flows.
Controlled outlet flow capacity	150 cfs	Maximum instream flow release.

Table A-3. Instream flow release schedule

Month	Instream Flow Release (cfs)
Nov – May	50 cfs
Jun – Oct	150 cfs

Table A-4. Reservoir operation zones

Month	Reservoir Elevation	Zone	Flow Priorities
Jan – Dec	641 < EL < 676 ft	Power generation	1) Instream flow requirements 2) Power flows to meet energy demand
Jan – Dec	EL < 641	Conservation	1) Instream flow requirements 2) Power flows only as necessary to maintain water level

Attachment B

HEC-ResSim 3.0 Selected Model Output

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Table B-1. Model results of selected model parameters (Note: time step = 1 day). Average values.

Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1954	10	816	1125	0	150	658.7	213	1275
1954	11	788	1312	0	50	658.0	247	1362
1954	12	471	1273	0	50	656.3	235	1323
1955	1	440	1423	0	50	654.3	258	1473
1955	2	409	1364	0	50	652.5	243	1414
1955	3	392	1332	0	50	650.4	232	1382
1955	4	386	1307	0	50	648.5	223	1357
1955	5	1218	1248	0	50	647.0	210	1298
1955	6	4812	1155	0	150	650.1	200	1305
1955	7	5170	1162	0	150	658.7	219	1312
1955	8	2107	1078	834	150	661.7	210	2062
1955	9	1844	1086	427	150	661.1	210	1662
1955	10	694	1108	71	150	660.3	213	1329
1955	11	475	1304	0	50	658.6	247	1354
1955	12	409	1267	0	50	656.8	235	1317
1956	1	373	1418	0	50	654.7	258	1468
1956	2	344	1313	0	50	652.7	234	1363
1956	3	335	1329	0	50	650.6	232	1379
1956	4	344	1305	0	50	648.6	223	1355
1956	5	1884	1247	0	150	647.1	210	1397
1956	6	5138	1118	0	150	653.3	200	1268
1956	7	1095	1185	0	150	656.4	219	1335
1956	8	1699	1133	0	150	656.4	210	1283
1956	9	1889	1116	0	150	658.2	210	1266
1956	10	471	1141	0	50	657.2	213	1191
1956	11	467	1345	0	50	655.4	247	1395
1956	12	398	1309	0	50	653.5	235	1359
1957	1	373	1468	0	50	651.2	258	1518
1957	2	344	1411	0	50	649.2	243	1461
1957	3	344	1382	0	50	646.9	232	1432
1957	4	366	1359	0	50	644.9	223	1409
1957	5	2533	1290	0	50	644.0	210	1340
1957	6	2620	1180	0	150	647.9	200	1330

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1957	7	535	1293	0	150	647.8	219	1443
1957	8	479	1262	0	150	645.9	210	1412
1957	9	2620	1229	0	150	648.7	210	1379
1957	10	1592	1242	0	150	648.9	213	1392
1957	11	1467	1422	0	50	650.0	247	1472
1957	12	449	1376	0	50	648.6	235	1426
1958	1	440	1547	0	50	646.2	258	1597
1958	2	404	1490	0	50	644.1	243	1540
1958	3	392	1463	0	50	641.8	232	1513
1958	4	386	336	0	50	641.0	53	386
1958	5	1298	1248	0	50	641.0	196	1298
1958	6	7688	1164	0	150	649.5	200	1314
1958	7	3921	1156	0	150	659.1	219	1306
1958	8	2244	1079	764	150	661.6	210	1992
1958	9	965	1089	248	150	660.7	210	1487
1958	10	535	1111	1	150	660.0	213	1262
1958	11	435	1308	0	50	658.3	247	1358
1958	12	420	1271	0	50	656.5	235	1321
1959	1	404	1422	0	50	654.4	258	1472
1959	2	366	1364	0	50	652.5	243	1414
1959	3	335	1333	0	50	650.4	232	1383
1959	4	344	1309	0	50	648.4	223	1359
1959	5	1638	1250	0	50	646.9	210	1300
1959	6	4046	1141	0	150	651.2	200	1291
1959	7	1761	1218	0	150	653.7	219	1368
1959	8	666	1173	0	150	652.9	210	1323
1959	9	2028	1191	0	150	651.6	210	1341
1959	10	1095	1190	0	150	653.0	213	1340
1959	11	502	1400	0	50	651.5	247	1450
1959	12	435	1364	0	50	649.5	235	1414
1960	1	409	1533	0	50	647.1	258	1583
1960	2	366	1425	0	50	645.0	234	1475
1960	3	344	1450	0	50	642.6	232	1500
1960	4	283	233	0	50	641.0	37	283
1960	5	3365	1326	0	150	641.6	210	1476

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1960	6	4362	1183	0	150	647.8	200	1333
1960	7	2201	1248	0	150	651.4	219	1398
1960	8	1638	1170	0	150	653.2	210	1320
1960	9	1424	1172	0	150	653.2	210	1322
1960	10	901	1193	0	50	652.8	213	1243
1960	11	535	1400	0	50	651.5	247	1450
1960	12	487	1363	0	50	649.6	235	1413
1961	1	445	1530	0	50	647.3	258	1580
1961	2	425	1472	0	50	645.2	243	1522
1961	3	386	1444	0	50	642.9	232	1494
1961	4	366	316	0	50	641.0	50	366
1961	5	2033	1322	0	50	641.8	210	1372
1961	6	4015	1186	0	150	647.5	200	1336
1961	7	2504	1253	0	150	650.9	219	1403
1961	8	2287	1174	0	150	652.9	210	1324
1961	9	1844	1159	0	150	654.3	210	1309
1961	10	558	1179	0	150	653.9	213	1329
1961	11	458	1392	0	50	652.0	247	1442
1961	12	373	1357	0	50	650.0	235	1407
1962	1	373	1525	0	50	647.5	258	1575
1962	2	373	1469	0	50	645.4	243	1519
1962	3	359	1442	0	50	643.0	232	1492
1962	4	359	0	0	50	641.0	0	50
1962	5	1981	1332	0	50	641.2	210	1382
1962	6	5800	1197	0	150	646.7	200	1347
1962	7	2361	1239	0	150	652.1	219	1389
1962	8	666	1186	0	150	651.8	210	1336
1962	9	983	1203	0	150	650.6	210	1353
1962	10	494	1238	0	150	649.1	213	1388
1962	11	463	1466	0	50	647.1	247	1516
1962	12	435	1433	0	50	644.9	235	1483
1963	1	445	1615	0	50	642.4	258	1665
1963	2	449	399	0	50	641.0	63	449
1963	3	440	390	0	50	641.0	61	440
1963	4	379	329	0	50	641.0	52	379

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1963	5	1615	0	0	50	641.1	0	50
1963	6	3500	1209	0	150	645.7	200	1359
1963	7	1760	1280	0	150	648.8	219	1430
1963	8	2300	1221	0	150	649.1	210	1371
1963	9	1440	1200	0	150	650.9	210	1350
1963	10	704	1224	0	150	650.2	213	1374
1963	11	420	1448	0	50	648.2	247	1498
1963	12	610	1409	0	50	646.4	235	1459
1964	1	450	1585	0	50	644.0	258	1635
1964	2	380	1476	0	50	641.8	234	1526
1964	3	280	230	0	50	641.0	36	280
1964	4	260	210	0	50	641.0	33	260
1964	5	704	554	0	150	641.0	87	704
1964	6	4160	1177	0	150	648.3	200	1327
1964	7	1950	1248	0	150	651.3	219	1398
1964	8	2620	1177	0	150	652.7	210	1327
1964	9	3200	1163	0	150	654.1	210	1313
1964	10	760	1171	0	50	654.6	213	1221
1964	11	580	1378	0	50	653.0	247	1428
1964	12	520	1339	0	50	651.3	235	1389
1965	1	460	1501	0	50	649.1	258	1551
1965	2	400	1443	0	50	647.1	243	1493
1965	3	370	1415	0	50	644.8	232	1465
1965	4	336	1394	0	50	642.6	223	1444
1965	5	2230	1332	0	50	641.2	210	1382
1965	6	4420	1181	0	150	647.9	200	1331
1965	7	2420	1237	0	150	652.2	219	1387
1965	8	1230	1162	0	150	653.9	210	1312
1965	9	4210	1096	12	150	660.2	210	1258
1965	10	677	1107	85	150	660.3	213	1343
1965	11	560	1301	0	50	658.8	247	1351
1965	12	460	1263	0	50	657.2	235	1313
1966	1	400	1412	0	50	655.1	258	1462
1966	2	350	1355	0	50	653.1	243	1405
1966	3	300	1324	0	50	651.0	232	1374

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1966	4	260	1302	0	50	648.8	223	1352
1966	5	580	1248	0	50	646.9	210	1298
1966	6	4600	1131	0	150	652.1	200	1281
1966	7	2500	1193	0	150	655.9	219	1343
1966	8	2300	1124	0	150	657.3	210	1274
1966	9	3000	1105	0	150	659.3	210	1255
1966	10	1732	1098	547	150	661.3	213	1795
1966	11	510	1287	0	50	660.0	247	1337
1966	12	458	1248	0	50	658.4	235	1298
1967	1	420	1394	0	50	656.4	258	1444
1967	2	398	1335	0	50	654.6	243	1385
1967	3	379	1302	0	50	652.7	232	1352
1967	4	379	1276	0	50	650.8	223	1326
1967	5	458	1220	0	50	649.1	210	1270
1967	6	3365	1133	0	150	651.8	200	1283
1967	7	1095	1219	0	150	653.5	219	1369
1967	8	938	1172	0	150	653.0	210	1322
1967	9	1904	1178	0	150	652.7	210	1328
1967	10	483	1202	0	150	652.0	213	1352
1967	11	404	1422	0	50	649.9	247	1472
1967	12	366	1389	0	50	647.8	235	1439
1968	1	351	1565	0	50	645.2	258	1615
1968	2	344	1458	0	50	642.9	234	1508
1968	3	344	294	0	50	641.0	46	344
1968	4	344	294	0	50	641.0	46	344
1968	5	2038	1331	0	150	641.2	210	1481
1968	6	2476	1234	0	150	643.8	200	1384
1968	7	763	1353	0	150	643.6	219	1503
1968	8	2134	1288	0	150	644.2	210	1438
1968	9	613	1301	0	150	643.3	210	1451
1968	10	435	1351	0	50	641.1	213	1401
1968	11	404	354	0	50	641.0	56	404
1968	12	386	336	0	50	641.0	53	386
1969	1	366	316	0	50	641.0	50	366
1969	2	351	301	0	50	641.0	47	351

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1969	3	351	301	0	50	641.0	47	351
1969	4	351	301	0	50	641.0	47	351
1969	5	2447	1329	0	50	641.4	210	1379
1969	6	7513	1133	0	150	652.1	200	1283
1969	7	2137	1171	0	150	657.7	219	1321
1969	8	613	1120	0	150	657.5	210	1270
1969	9	1132	1133	0	150	656.6	210	1283
1969	10	3034	1117	0	150	659.6	213	1267
1969	11	917	1283	99	50	660.4	247	1432
1969	12	440	1243	0	50	658.8	235	1293
1970	1	386	1389	0	50	656.7	258	1439
1970	2	373	1331	0	50	654.9	243	1381
1970	3	366	1298	0	50	653.0	232	1348
1970	4	359	1272	0	50	651.1	223	1322
1970	5	2227	1208	0	50	650.1	210	1258
1970	6	4235	1094	0	150	655.3	200	1244
1970	7	2447	1154	0	150	659.3	219	1304
1970	8	2447	1085	377	150	661.0	210	1612
1970	9	1007	1085	462	150	661.1	210	1697
1970	10	469	1116	0	150	659.5	213	1266
1970	11	409	1315	0	50	657.8	247	1365
1970	12	379	1278	0	50	655.9	235	1328
1971	1	359	1431	0	50	653.7	258	1481
1971	2	351	1374	0	50	651.8	243	1424
1971	3	344	1343	0	50	649.6	232	1393
1971	4	359	1319	0	50	647.6	223	1369
1971	5	1502	1261	0	50	646.1	210	1311
1971	6	5800	1149	0	150	650.6	200	1299
1971	7	5733	1172	0	150	657.9	219	1322
1971	8	2335	1078	842	150	661.7	210	2070
1971	9	1062	1088	271	150	660.8	210	1509
1971	10	871	1109	34	150	660.2	213	1293
1971	11	467	1304	0	50	658.7	247	1354
1971	12	420	1265	0	50	656.9	235	1315
1972	1	386	1416	0	50	654.8	258	1466

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1972	2	366	1310	0	50	653.0	234	1360
1972	3	344	1325	0	50	650.9	232	1375
1972	4	351	1301	0	50	648.9	223	1351
1972	5	576	1246	0	150	647.1	210	1396
1972	6	5138	1151	0	150	650.4	200	1301
1972	7	2533	1189	0	150	656.2	219	1339
1972	8	1709	1127	0	150	657.0	210	1277
1972	9	788	1125	0	150	657.3	210	1275
1972	10	1909	1142	0	50	657.2	213	1192
1972	11	545	1332	0	50	656.4	247	1382
1972	12	440	1294	0	50	654.7	235	1344
1973	1	404	1449	0	50	652.5	258	1499
1973	2	379	1390	0	50	650.6	243	1440
1973	3	359	1360	0	50	648.5	232	1410
1973	4	351	1336	0	50	646.4	223	1386
1973	5	1356	1278	0	50	644.8	210	1328
1973	6	5733	1162	0	150	649.6	200	1312
1973	7	2562	1198	0	150	655.4	219	1348
1973	8	816	1137	0	150	656.0	210	1287
1973	9	2418	1132	0	150	656.8	210	1282
1973	10	613	1146	0	150	656.8	213	1296
1973	11	430	1351	0	50	655.0	247	1401
1973	12	392	1315	0	50	653.1	235	1365
1974	1	366	1475	0	50	650.7	258	1525
1974	2	351	1418	0	50	648.7	243	1468
1974	3	351	1389	0	50	646.4	232	1439
1974	4	366	1367	0	50	644.3	223	1417
1974	5	1825	1307	0	50	642.8	210	1357
1974	6	3244	1205	0	150	646.0	200	1355
1974	7	1398	1296	0	150	647.7	219	1446
1974	8	938	1254	0	150	646.5	210	1404
1974	9	1095	1264	0	150	645.9	210	1414
1974	10	858	1287	0	150	645.5	213	1437
1974	11	458	1524	0	50	643.5	247	1574
1974	12	409	1494	0	50	641.2	235	1544

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1975	1	379	329	0	50	641.0	52	379
1975	2	366	316	0	50	641.0	50	366
1975	3	359	309	0	50	641.0	49	359
1975	4	379	329	0	50	641.0	52	379
1975	5	1095	1045	0	50	641.0	164	1095
1975	6	5007	1213	0	150	645.5	200	1363
1975	7	2389	1263	0	150	650.2	219	1413
1975	8	683	1207	0	150	650.1	210	1357
1975	9	2091	1215	0	150	649.7	210	1365
1975	10	1290	1225	0	150	650.2	213	1375
1975	11	471	1444	0	50	648.5	247	1494
1975	12	398	1410	0	50	646.3	235	1460
1976	1	366	1590	0	50	643.7	258	1640
1976	2	318	1484	0	50	641.4	234	1534
1976	3	303	253	0	50	641.0	40	303
1976	4	303	253	0	50	641.0	40	303
1976	5	825	675	0	150	641.0	106	825
1976	6	3426	1236	0	150	643.7	200	1386
1976	7	2125	1319	0	150	646.1	219	1469
1976	8	1991	1248	0	150	647.0	210	1398
1976	9	2620	1225	0	150	648.9	210	1375
1976	10	2022	1205	0	50	651.8	213	1255
1976	11	629	1407	0	50	651.0	247	1457
1976	12	458	1369	0	50	649.1	235	1419
1977	1	440	1538	0	50	646.8	258	1588
1977	2	415	1481	0	50	644.7	243	1531
1977	3	366	1453	0	50	642.4	232	1503
1977	4	362	312	0	50	641.0	49	362
1977	5	751	701	0	50	641.0	110	751
1977	6	9589	1175	0	150	648.8	200	1325
1977	7	7164	1134	512	150	661.4	219	1796
1977	8	4394	1042	4742	150	665.2	210	5935
1977	9	1058	1074	1254	150	662.1	210	2478
1977	10	586	1107	115	150	660.4	213	1372
1977	11	435	1303	0	50	658.7	247	1353

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1977	12	409	1265	0	50	657.0	235	1315
1978	1	398	1415	0	50	654.9	258	1465
1978	2	386	1356	0	50	653.0	243	1406
1978	3	366	1324	0	50	651.0	232	1374
1978	4	445	1299	0	50	649.1	223	1349
1978	5	3858	1185	0	50	652.1	210	1235
1978	6	3580	1075	0	150	657.1	200	1225
1978	7	3034	1125	1055	150	662.0	219	2330
1978	8	1458	1080	688	150	661.5	210	1918
1978	9	1502	1081	709	150	661.5	210	1940
1978	10	788	1109	49	150	660.2	213	1308
1978	11	613	1299	0	50	659.0	247	1349
1978	12	485	1259	0	50	657.5	235	1309
1979	1	430	1406	0	50	655.5	258	1456
1979	2	386	1347	0	50	653.7	243	1397
1979	3	386	1315	0	50	651.7	232	1365
1979	4	440	1288	0	50	649.9	223	1338
1979	5	3274	1210	0	50	650.1	210	1260
1979	6	4650	1073	0	150	657.4	200	1223
1979	7	3034	1127	876	150	661.7	219	2153
1979	8	3889	1059	2639	150	663.6	210	3848
1979	9	1547	1078	907	150	661.7	210	2136
1979	10	2289	1085	1606	150	662.6	213	2841
1979	11	1290	1267	849	50	661.7	247	2166
1979	12	452	1231	0	50	659.8	235	1281
1980	1	425	1374	0	50	657.9	258	1424
1980	2	417	1268	0	50	656.2	234	1318
1980	3	420	1279	0	50	654.4	232	1329
1980	4	418	1252	0	50	652.7	223	1302
1980	5	4172	1174	0	150	653.0	210	1324
1980	6	5269	1034	492	150	661.3	200	1676
1980	7	3983	1103	3134	150	664.0	219	4387
1980	8	1302	1072	1250	150	662.1	210	2472
1980	9	1290	1091	138	150	660.5	210	1379
1980	10	2016	1105	222	50	660.7	213	1376

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1980	11	499	1289	0	50	659.9	247	1339
1980	12	409	1250	0	50	658.2	235	1300
1981	1	435	1397	0	50	656.1	258	1447
1981	2	425	1337	0	50	654.4	243	1387
1981	3	415	1303	0	50	652.6	232	1353
1981	4	413	1276	0	50	650.8	223	1326
1981	5	4015	1196	0	50	651.2	210	1246
1981	6	4204	1062	0	150	658.4	200	1212
1981	7	2447	1130	681	150	661.5	219	1961
1981	8	1547	1080	640	150	661.4	210	1870
1981	9	558	1092	105	150	660.4	210	1347
1981	10	671	1123	0	150	658.9	213	1273
1981	11	480	1321	0	50	657.3	247	1371
1981	12	409	1283	0	50	655.5	235	1333
1982	1	420	1436	0	50	653.4	258	1486
1982	2	398	1377	0	50	651.5	243	1427
1982	3	398	1345	0	50	649.5	232	1395
1982	4	379	1320	0	50	647.6	223	1370
1982	5	2235	1260	0	50	646.2	210	1310
1982	6	6715	1120	0	150	653.2	200	1270
1982	7	3093	1138	257	150	660.8	219	1545
1982	8	951	1085	351	150	660.9	210	1585
1982	9	5236	1068	1857	150	662.9	210	3075
1982	10	881	1089	1183	150	662.1	213	2422
1982	11	488	1288	0	50	659.9	247	1338
1982	12	450	1249	0	50	658.3	235	1299
1983	1	427	1396	0	50	656.3	258	1446
1983	2	386	1337	0	50	654.5	243	1387
1983	3	373	1304	0	50	652.5	232	1354
1983	4	419	1278	0	50	650.7	223	1328
1983	5	3426	1201	0	50	650.7	210	1251
1983	6	4747	1062	0	150	658.5	200	1212
1983	7	2346	1124	1063	150	662.0	219	2338
1983	8	597	1087	261	150	660.7	210	1497
1983	9	475	1104	0	150	659.2	210	1254

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1983	10	476	1136	0	150	657.7	213	1286
1983	11	638	1339	0	50	655.9	247	1389
1983	12	700	1284	0	50	655.5	235	1334
1984	1	454	1435	0	50	653.5	258	1485
1984	2	409	1327	0	50	651.7	234	1377
1984	3	379	1343	0	50	649.7	232	1393
1984	4	373	1318	0	50	647.7	223	1368
1984	5	1810	1256	0	150	646.4	210	1406
1984	6	4394	1151	0	150	650.4	200	1301
1984	7	2025	1207	0	150	654.6	219	1357
1984	8	510	1158	0	150	654.2	210	1308
1984	9	683	1178	0	150	652.6	210	1328
1984	10	451	1212	0	50	651.1	213	1262
1984	11	415	1435	0	50	649.1	247	1485
1984	12	377	1401	0	50	646.9	235	1451
1985	1	430	1579	0	50	644.4	258	1629
1985	2	395	1522	0	50	642.2	243	1572
1985	3	359	309	0	50	641.0	49	359
1985	4	320	270	0	50	641.0	42	320
1985	5	497	447	0	50	641.0	70	497
1985	6	6136	1212	0	150	645.7	200	1362
1985	7	2650	1241	0	150	651.9	219	1391
1985	8	2447	1153	0	150	654.7	210	1303
1985	9	2349	1145	0	150	655.6	210	1295
1985	10	986	1148	0	150	656.6	213	1298
1985	11	487	1350	0	50	655.1	247	1400
1985	12	449	1312	0	50	653.3	235	1362
1986	1	409	1470	0	50	651.1	258	1520
1986	2	392	1412	0	50	649.1	243	1462
1986	3	379	1382	0	50	647.0	232	1432
1986	4	366	1359	0	50	644.9	223	1409
1986	5	788	1304	0	50	643.0	210	1354
1986	6	4490	1214	0	150	645.4	200	1364
1986	7	2944	1259	0	150	650.5	219	1409
1986	8	2708	1170	0	150	653.3	210	1320

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1986	9	2072	1145	0	150	655.6	210	1295
1986	10	1930	1141	0	150	657.3	213	1291
1986	11	502	1316	0	50	657.7	247	1366
1986	12	440	1278	0	50	655.9	235	1328
1987	1	409	1430	0	50	653.8	258	1480
1987	2	392	1371	0	50	652.0	243	1421
1987	3	386	1339	0	50	649.9	232	1389
1987	4	386	1314	0	50	648.0	223	1364
1987	5	1132	1257	0	50	646.3	210	1307
1987	6	7864	1124	0	150	652.9	200	1274
1987	7	4683	1119	1560	150	662.6	219	2829
1987	8	2007	1068	1633	150	662.6	210	2851
1987	9	917	1087	312	150	660.8	210	1550
1987	10	1638	1100	446	150	661.1	213	1696
1987	11	479	1289	0	50	659.8	247	1339
1987	12	435	1251	0	50	658.1	235	1301
1988	1	415	1398	0	50	656.1	258	1448
1988	2	409	1292	0	50	654.4	234	1342
1988	3	392	1305	0	50	652.5	232	1355
1988	4	379	1279	0	50	650.6	223	1329
1988	5	2361	1212	0	150	649.8	210	1362
1988	6	6544	1064	0	150	658.4	200	1214
1988	7	3214	1110	2371	150	663.3	219	3631
1988	8	3610	1065	1986	150	663.0	210	3201
1988	9	2033	1071	1508	150	662.4	210	2729
1988	10	1732	1095	753	50	661.6	213	1898
1988	11	757	1283	78	50	660.3	247	1412
1988	12	440	1244	0	50	658.7	235	1294
1989	1	398	1389	0	50	656.7	258	1439
1989	2	386	1331	0	50	654.9	243	1381
1989	3	386	1297	0	50	653.0	232	1347
1989	4	379	1271	0	50	651.2	223	1321
1989	5	1058	1214	0	50	649.6	210	1264
1989	6	5007	1094	0	150	655.4	200	1244
1989	7	2238	1150	0	150	659.6	219	1300

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1989	8	2767	1084	461	150	661.2	210	1695
1989	9	4426	1058	2998	150	663.9	210	4206
1989	10	1981	1083	1753	150	662.7	213	2986
1989	11	472	1281	154	50	660.5	247	1485
1989	12	440	1242	0	50	658.8	235	1292
1990	1	420	1388	0	50	656.8	258	1438
1990	2	386	1329	0	50	655.1	243	1379
1990	3	379	1296	0	50	653.1	232	1346
1990	4	420	1269	0	50	651.3	223	1319
1990	5	1290	1211	0	50	649.9	210	1261
1990	6	2885	1110	0	150	653.8	200	1260
1990	7	1306	1206	0	150	654.7	219	1356
1990	8	1269	1149	0	150	655.0	210	1299
1990	9	2295	1146	0	150	655.4	210	1296
1990	10	757	1156	0	150	655.9	213	1306
1990	11	445	1361	0	50	654.2	247	1411
1990	12	420	1325	0	50	652.3	235	1375
1991	1	409	1486	0	50	650.0	258	1536
1991	2	386	1428	0	50	648.0	243	1478
1991	3	398	1398	0	50	645.9	232	1448
1991	4	420	1375	0	50	643.8	223	1425
1991	5	2218	1312	0	50	642.5	210	1362
1991	6	2944	1186	0	150	647.4	200	1336
1991	7	1732	1279	0	150	648.9	219	1429
1991	8	951	1222	0	150	648.9	210	1372
1991	9	4812	1207	0	150	650.6	210	1357
1991	10	1742	1170	0	150	654.7	213	1320
1991	11	483	1361	0	50	654.3	247	1411
1991	12	398	1324	0	50	652.4	235	1374
1992	1	386	1486	0	50	650.0	258	1536
1992	2	373	1379	0	50	648.0	234	1429
1992	3	359	1399	0	50	645.8	232	1449
1992	4	420	1377	0	50	643.7	223	1427
1992	5	2218	1305	0	150	643.0	210	1455
1992	6	4909	1183	0	150	647.8	200	1333

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1992	7	2111	1241	0	150	651.9	219	1391
1992	8	3672	1160	0	150	654.2	210	1310
1992	9	962	1137	0	150	656.2	210	1287
1992	10	467	1169	0	50	654.7	213	1219
1992	11	409	1381	0	50	652.8	247	1431
1992	12	386	1346	0	50	650.8	235	1396
1993	1	379	1512	0	50	648.4	258	1562
1993	2	373	1455	0	50	646.3	243	1505
1993	3	379	1427	0	50	644.0	232	1477
1993	4	494	1405	0	50	641.9	223	1455
1993	5	5203	1299	0	50	643.6	210	1349
1993	6	4172	1137	0	150	651.6	200	1287
1993	7	2361	1199	0	150	655.3	219	1349
1993	8	2101	1132	0	150	656.6	210	1282
1993	9	2137	1108	0	150	658.9	210	1258
1993	10	1502	1102	364	150	661.0	213	1615
1993	11	491	1292	0	50	659.6	247	1342
1993	12	449	1253	0	50	658.0	235	1303
1994	1	430	1400	0	50	656.0	258	1450
1994	2	409	1340	0	50	654.2	243	1390
1994	3	386	1307	0	50	652.3	232	1357
1994	4	425	1281	0	50	650.4	223	1331
1994	5	2418	1214	0	50	649.7	210	1264
1994	6	4909	1079	0	150	656.8	200	1229
1994	7	3672	1127	900	150	661.8	219	2178
1994	8	1278	1076	964	150	661.8	210	2190
1994	9	2418	1084	549	150	661.3	210	1783
1994	10	1502	1091	1088	150	662.0	213	2328
1994	11	613	1283	79	50	660.3	247	1412
1994	12	463	1243	0	50	658.8	235	1293
1995	1	440	1388	0	50	656.8	258	1438
1995	2	386	1329	0	50	655.1	243	1379
1995	3	379	1296	0	50	653.1	232	1346
1995	4	467	1269	0	50	651.3	223	1319
1995	5	4877	1172	0	50	653.2	210	1222

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Year	Month	Project Inflow (cfs)	Power Plant Flow (cfs)	Spillway Flow (cfs)	Instream Flow (cfs)	Reservoir Pool Elevation (ft)	Energy Generation per Model Time Step (Day) (MWh)	Project Outflow (cfs)
1995	6	4015	1042	51	150	660.4	200	1244
1995	7	2361	1122	1292	150	662.2	219	2564
1995	8	1356	1079	741	150	661.5	210	1970
1995	9	4586	1069	1770	150	662.8	210	2989
1995	10	2043	1090	1173	150	662.1	213	2413
1995	11	535	1280	189	50	660.6	247	1519
1995	12	425	1242	0	50	658.9	235	1292
1996	1	392	1387	0	50	656.9	258	1437
1996	2	398	1282	0	50	655.1	234	1332
1996	3	398	1294	0	50	653.2	232	1344
1996	4	428	1268	0	50	651.4	223	1318
1996	5	2349	1192	0	150	651.4	210	1342
1996	6	2447	1108	0	150	653.9	200	1258
1996	7	1629	1199	0	150	655.3	219	1349
1996	8	627	1150	0	150	654.9	210	1300
1996	9	475	1167	0	150	653.5	210	1317
Average		**1399**	**1203**	**115**	**92**	**652.1**	**214**	**1410**
Min		**260**	**0**	**0**	**50**	**641.0**	**0**	**50**
Max		**9589**	**1615**	**4742**	**150**	**665.2**	**258**	**5935**

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Project Memo

H342022

28 Mar 2013

To: Dick Griffith From: Carl Mannheim

cc:

Nuvista Electric Cooperative
Chikuminuk Lake Hydroelectric Project Interim Feasibility Study

Project Impact on Lake Chauekuktuli and Tikchik/Nuyakuk Lake Water Levels

1. Introduction

This memo presents the expected change in water level fluctuations for Lake Chauekuktuli and Tikchik/Nuyakuk Lake due to the regulated flows from the Project.

The purpose of this memo is to provide supporting information for future assessments of impact on fish spawning in the two downstream lakes affected by the Project. The analysis is based on the preferred project arrangement and overall hydrology described in detail in the Draft Interim Feasibility Report (Hatch, 2014a) and summarized herein.

2. Project Arrangement

The preferred project arrangement includes a roller compacted concrete (RCC) dam with a 110 ft long uncontrolled spillway. The spillway crest elevation is 660 ft, which means that the normal maximum lake level will be raised 47 feet from elevation 613 ft. A 13 ft wide and approximately 900 feet long concrete lined power tunnel will route water to the powerhouse, in which four 5.5 MW vertical Francis turbines will be installed. The tailrace elevation is approximately 544 ft, resulting in a maximum gross head on the units of 116 feet.

3. Hydrology

The following is a summary of the relevant hydrology for the analysis presented herein. A more detailed description of the hydrology, including how the available short-term record at the USGS Allen River gage was extended to a long-term record, is presented in the Draft Interim Feasibility Report (Hatch, 2014a).

Daily flow and water level fluctuations are not expected to change significantly; monthly records are therefore considered sufficient.

3.1 Drainage Areas

The drainage areas of each individual basin and their cumulative drainage areas are presented in Table 1. These drainage areas are used with the stream flow records to estimate the runoff per unit area.

Table 1 Drainage areas and normal water surface elevations

Lake/Drainage Basin	Drainage Area (mi^2)	Cumulative Drainage Area (mi^2) (incl. upstream basins)	Normal Water Surface Elevation (ft)	Comment
Lake Chikuminuk	348	348	613	USGS gage 15301500
Lake Chauekuktuli	259	607	315	Location of R&M stream gage on Northwest Passage
Tikchik/Nuyakuk Lake	878	1485	305	USGS gage 15302000

3.2 Unregulated Monthly Average Flows

Monthly average flows from the extended record at the USGS Allen River gage (15301500) and the USGS Nuyakuk River gage (15302000) in Tables 2 and 3, respectively, were used to represent unregulated (pre-project or existing) flow conditions into Lake Chauekuktuli and out of Tikchick/Nuyakuk Lake.

The unregulated flows into Tikchick/Nuyakuk Lake are estimated based on the calculated runoff per unit area.

3.3 Regulated Monthly Average Flows

The regulated average monthly outflow from the Project into Lake Chauekuktuli is summarized in Table 4 (Hatch, 2014b). Regulated flows into Tikchick/Nuyakuk Lake are estimated based on the expected runoff per unit area.

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Table 2 Average monthly flows on Nuyakuk River (cfs) (USGS 15302000), unregulated conditions

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1954	2100	1700	1400	1300	3919	10360	6794	5191	5589	5058	6111	4029	4463
1955	3000	2400	2100	2000	3359	11790	20420	12730	7485	6592	3800	2400	6506
1956	1800	1400	1300	1400	3298	16680	11880	7006	9277	5395	3333	2732	5458
1957	1800	1400	1400	1700	4806	13080	7232	3855	11540	7500	8886	4887	5674
1958	3097	2354	2100	2050	3854	19900	21850	11460	7098	6255	3450	2600	7172
1959	2300	1700	1300	1400	3415	13680	10910	5836	5271	9049	5092	3190	5262
1960	2545	1855	1448	800	5084	16650	12630	9579	7068	6531	5586	4100	6156
1961	3176	2700	2000	1700	5890	15930	12460	9820	8813	6402	4010	2187	6257
1962	1897	1800	1600	1600	4161	15640	15370	6707	5351	5228	3500	2900	5480
1963	3100	3200	3041	1900	3550	14230	11480	6306	10770	6702	3057	1848	5765
1964	1397	1252	1097	1100	1719	16370	13740	7720	7620	7364	4225	2700	5525
1965	2000	1600	1700	2300	3247	18910	14940	9255	14370	11520	5300	3100	7354
1966	2000	1700	1600	1500	2010	10900	12870	9103	8684	10470	5900	3916	5888
1967	2939	2371	2003	1833	2323	11280	9625	6397	6573	6015	2976	1939	4690
1968	1574	1462	1400	1400	3942	11030	7297	8098	6127	3816	2570	2187	4242
1969	1887	1600	1500	1500	4090	23290	15760	6564	5633	11470	8567	3806	7139
1970	2284	1871	1700	1600	4360	15130	13100	9471	8407	4636	3057	2094	5643
1971	1726	1532	1461	1423	3519	14130	18350	13830	7192	6490	4572	3026	6438
1972	2290	1814	1497	1433	2496	12220	16070	7980	7187	6755	6065	3727	5795
1973	2629	2050	1713	1533	3567	14350	16130	7718	8201	6901	3680	2377	5904
1974	1832	1554	1500	1510	4162	11850	9749	5721	6497	6863	4573	2723	4878
1975	2068	1804	1665	1653	3774	13860	14470	7034	6526	7734	4807	2710	5675
1976	1787	1348	990.3	905	2565	10990	10860	8261	9851	11400	6249	3983	5766
1977	3216	2654	2026	1623	2894	18620	26220	24190	9861	5923	3747	2523	8625
1978	2332	2075	1900	1910	11320	14890	15490	8829	8593	6037	5325	4467	6931
1979	3333	2336	1881	2309	6930	18580	14540	14420	9039	12040	9192	4693	8274
1980	2820	2678	2495	2496	6748	20160	18650	10470	5877	7480	6170	3045	7424
1981	2756	2850	2615	2497	6988	18370	12410	8600	6442	4268	4489	3095	6282
1982	2303	2604	2248	1977	3706	17980	18950	8398	11660	12100	4815	3310	7504
1983	2844	2379	1913	1936	6349	19230	13920	7060	4167	4282	3857	6500	6203
1984	4005	2759	2097	1817	4085	13060	13620	6407	4099	4933	2950	2281	5176
1985	2205	2527	1823	1350	1817	14040	16710	11210	8146	8212	4790	3555	6365
1986	2823	2221	1981	1823	2708	10760	15170	11050	10440	9273	7477	3397	6594
1987	2700	2207	2048	1933	3340	17260	22850	12830	6660	7928	5567	3284	7384
1988	2603	2452	2197	1967	4958	20400	18920	12280	11320	8065	6400	3719	7940
1989	2781	2036	2000	1797	3410	16010	13570	9173	17070	13010	5978	3272	7509
1990	2761	2243	1881	2160	3777	13030	8359	7373	7651	7569	4247	2796	5321
1991	2419	2179	2045	2300	4687	14700	9258	7184	9811	13350	6399	2748	6423
1992	2006	1869	1732	1810	5474	14570	13410	10240	10040	4583	2893	2213	5903
1993	1932	1804	1816	2692	9715	19400	12830	8505	10440	10130	5377	3600	7353
1994	2974	2571	2090	2273	5206	18230	15370	10520	7543	11240	6050	4177	7354
1995	3177	2393	1965	2365	9564	18230	12770	8641	11420	11280	6793	3452	7671
Average	**2458**	**2079**	**1816**	**1776**	**4447**	**15471**	**14214**	**9120**	**8367**	**7806**	**5045**	**3221**	**6318**
Max	**4005**	**3200**	**3041**	**2692**	**11320**	**23290**	**26220**	**24190**	**17070**	**13350**	**9192**	**6500**	**8625**
Min	**1397**	**1252**	**990**	**800**	**1719**	**10360**	**6794**	**3855**	**4099**	**3816**	**2570**	**1848**	**4242**

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Table 3 Estimated average monthly flows on Allen River (USGS 15301500), pre-project conditions

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1954	392	366	344	335	677	2469	1239	679	788	631	968	486	781
1955	440	409	392	386	531	2894	5609	3187	1510	1163	475	409	1460
1956	373	344	335	344	546	4407	2901	1302	2154	808	455	425	1197
1957	373	344	344	366	939	3271	1396	477	2780	1499	2037	738	1211
1958	444	407	392	389	559	5520	6106	2789	1343	1034	459	420	1663
1959	404	366	335	344	571	3466	2639	891	706	2009	664	449	1074
1960	417	376	347	287	989	4382	3144	2238	1323	1111	787	487	1325
1961	448	425	386	366	1262	4153	3087	2310	2038	1097	486	396	1375
1962	379	373	359	359	678	4112	3995	1207	718	686	463	435	1150
1963	445	449	442	379	562	3620	2966	1492	2239	1071	478	571	1228
1964	474	406	314	255	339	4870	2908	1986	2039	1571	625	520	1358
1965	460	400	370	348	494	4702	3476	2132	4554	1576	569	460	1628
1966	400	350	300	260	367	3900	3226	2010	2300	2497	910	480	1421
1967	437	407	386	375	404	2699	2209	1059	1164	987	438	382	914
1968	357	348	344	344	708	2659	1429	1689	1016	477	418	397	849
1969	378	359	351	351	771	6650	4145	1167	805	2781	1858	489	1678
1970	402	378	366	359	790	3915	3279	2209	1852	593	442	391	1251
1971	368	354	348	346	559	3618	4935	3523	1377	1095	552	441	1468
1972	403	374	351	346	412	2987	4211	1687	1390	1258	974	472	1241
1973	421	389	367	354	563	3697	4242	1574	1691	1284	472	408	1293
1974	375	355	351	352	657	2907	2274	840	1097	1255	573	426	957
1975	390	373	364	363	549	3521	3709	1322	1164	1614	611	425	1205
1976	372	339	307	299	434	2616	2614	1857	2329	2770	1037	489	1291
1977	450	423	387	361	446	5117	7611	6897	2281	902	473	416	2162
1978	406	391	379	379	2716	3826	4018	1975	1926	938	706	527	1523
1979	455	405	378	404	1356	5006	3722	3708	2007	2963	2092	654	1937
1980	431	424	414	414	1400	5523	5026	2476	885	1486	1031	440	1666
1981	428	433	421	415	1452	4934	3073	1935	1096	526	530	444	1310
1982	404	419	401	384	626	4829	5152	1800	2772	2959	584	454	1738
1983	432	408	380	381	1278	5216	3537	1348	494	496	481	1108	1300
1984	494	428	392	374	697	3283	3450	1106	503	640	437	402	1019
1985	398	416	374	339	367	3564	4426	2714	1748	1798	594	465	1440
1986	431	399	385	374	433	2565	3919	2666	2489	2159	1544	458	1491
1987	425	398	389	381	500	4623	6438	3210	1181	1698	862	453	1723
1988	420	412	398	384	877	5638	5131	3031	2750	1765	1076	480	1865
1989	429	388	386	373	499	4214	3434	2154	4519	3273	1038	452	1766
1990	428	400	378	395	533	3273	1793	1448	1540	1536	529	430	1058
1991	410	397	389	404	749	3778	2159	1374	2185	3390	1162	426	1405
1992	386	377	368	373	1015	3744	3388	2450	2323	587	434	398	1321
1993	381	373	374	422	2182	5274	3200	1935	2490	2394	744	467	1691
1994	438	418	391	402	881	4910	3975	2492	1475	2722	948	498	1636
1995	448	409	384	406	2171	4891	3181	1933	2759	2727	1253	459	1756
1996	405	390	402	394	1254	2541	2018	1090	612				
Avg	**419**	**391**	**373**	**365**	**864**	**4071**	**3450**	**2032**	**1705**	**1559**	**842**	**516**	**1386**
Min	**303**	**322**	**300**	**255**	**339**	**2469**	**1239**	**477**	**485**	**477**	**418**	**382**	**781**
Max	**743**	**486**	**451**	**422**	**2716**	**6650**	**7611**	**6897**	**4554**	**3390**	**3294**	**2696**	**2162**

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Table 4 Estimated average monthly flows on Allen River, post-project conditions (regulated flows)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1954										1275	1362	1323	
1955	1473	1414	1382	1357	1298	1305	1312	2062	1662	1329	1354	1317	**1439**
1956	1468	1363	1379	1355	1397	1268	1335	1283	1266	1191	1395	1359	**1338**
1957	1518	1461	1432	1409	1340	1330	1443	1412	1379	1392	1472	1426	**1418**
1958	1597	1540	1513	386	1298	1314	1306	1992	1487	1262	1358	1321	**1365**
1959	1472	1414	1383	1359	1300	1291	1368	1323	1341	1340	1450	1414	**1371**
1960	1583	1475	1500	283	1476	1333	1398	1320	1322	1243	1450	1413	**1316**
1961	1580	1522	1494	366	1372	1336	1403	1324	1309	1329	1442	1407	**1324**
1962	1575	1519	1492	50	1382	1347	1389	1336	1353	1388	1516	1483	**1319**
1963	1665	449	440	379	50	1359	1430	1371	1350	1374	1498	1459	**1069**
1964	1635	1526	280	260	704	1327	1398	1327	1313	1221	1428	1389	**1151**
1965	1551	1493	1465	1444	1382	1331	1387	1312	1258	1343	1351	1313	**1386**
1966	1462	1405	1374	1352	1298	1281	1343	1274	1255	1795	1337	1298	**1373**
1967	1444	1385	1352	1326	1270	1283	1369	1322	1328	1352	1472	1439	**1362**
1968	1615	1508	344	344	1481	1384	1503	1438	1451	1401	404	386	**1105**
1969	366	351	351	351	1379	1283	1321	1270	1283	1267	1432	1293	**996**
1970	1439	1381	1348	1322	1258	1244	1304	1612	1697	1266	1365	1328	**1380**
1971	1481	1424	1393	1369	1311	1299	1322	2070	1509	1293	1354	1315	**1428**
1972	1466	1360	1375	1351	1396	1301	1339	1277	1275	1192	1382	1344	**1338**
1973	1499	1440	1410	1386	1328	1312	1348	1287	1282	1296	1401	1365	**1363**
1974	1525	1468	1439	1417	1357	1355	1446	1404	1414	1437	1574	1544	**1448**
1975	379	366	359	379	1095	1363	1413	1357	1365	1375	1494	1460	**1034**
1976	1640	1534	303	303	825	1386	1469	1398	1375	1255	1457	1419	**1197**
1977	1588	1531	1503	362	751	1325	1796	5935	2478	1372	1353	1315	**1776**
1978	1465	1406	1374	1349	1235	1225	2330	1918	1940	1308	1349	1309	**1517**
1979	1456	1397	1365	1338	1260	1223	2153	3848	2136	2841	2166	1281	**1872**
1980	1424	1318	1329	1302	1324	1676	4387	2472	1379	1376	1339	1300	**1719**
1981	1447	1387	1353	1326	1246	1212	1961	1870	1347	1273	1371	1333	**1427**
1982	1486	1427	1395	1370	1310	1270	1545	1585	3075	2422	1338	1299	**1627**
1983	1446	1387	1354	1328	1251	1212	2338	1497	1254	1286	1389	1334	**1423**
1984	1485	1377	1393	1368	1406	1301	1357	1308	1328	1262	1485	1451	**1377**
1985	1629	1572	359	320	497	1362	1391	1303	1295	1298	1400	1362	**1149**
1986	1520	1462	1432	1409	1354	1364	1409	1320	1295	1291	1366	1328	**1379**
1987	1480	1421	1389	1364	1307	1274	2829	2851	1550	1696	1339	1301	**1650**
1988	1448	1342	1355	1329	1362	1214	3631	3201	2729	1898	1412	1294	**1851**
1989	1439	1381	1347	1321	1264	1244	1300	1695	4206	2986	1485	1292	**1747**
1990	1438	1379	1346	1319	1261	1260	1356	1299	1296	1306	1411	1375	**1337**
1991	1536	1478	1448	1425	1362	1336	1429	1372	1357	1320	1411	1374	**1404**
1992	1536	1429	1449	1427	1455	1333	1391	1310	1287	1219	1431	1396	**1389**
1993	1562	1505	1477	1455	1349	1287	1349	1282	1258	1615	1342	1303	**1399**
1994	1450	1390	1357	1331	1264	1229	2178	2190	1783	2328	1412	1293	**1600**
1995	1438	1379	1346	1319	1222	1244	2564	1970	2989	2413	1519	1292	**1725**
1996	1437	1332	1344	1318	1342	1258	1349	1300	1317				
Avg	**1456**	**1360**	**1227**	**1063**	**1234**	**1307**	**1676**	**1745**	**1609**	**1503**	**1406**	**1334**	**1410**
Min	**366**	**351**	**280**	**50**	**50**	**1212**	**1300**	**1270**	**1254**	**1191**	**404**	**386**	**676**
Max	**1665**	**1572**	**1513**	**1455**	**1481**	**1676**	**4387**	**5935**	**4206**	**2986**	**2166**	**1544**	**2549**

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4. Project Impact on Lake Chauekuktuli and Tikchik/Nuyakuk Lake

The total flow out of each lake can be determined based on estimated runoff into each lake and any additional inflow, regulated or unregulated, from upstream lakes. The water level in each lake can then be calculated based on estimated lake outlet rating curves.

The analysis of the Project impact on Lake Chauekuktuli and Tikchik/Nuyakuk Lake presented herein was performed using the long term average monthly flow records available from the Nuyakuk River stream gage (Table 2) and the corresponding unregulated (pre-project) and regulated (post-project) estimated monthly flow records on Allen River (Tables 3 and 4). Daily flow records were not considered necessary based on the expectation that daily flow and water level fluctuations would be very small.

The runoff characteristics of each drainage basin must be determined so that a simplified routing of the incremental flow contributions (basin runoff and inflow from upstream basin) on each basin can be determined. Estimated lake outlet rating curves facilitates the translation of outlet flows into lake levels.

4.1 Lake Chikuminuk Drainage Basin Runoff

The Lake Chikuminuk drainage basin is the most upstream drainage basin and the runoff is equal to the flows estimated at the lake outlet on the Allen River shown in Table 2.

4.2 Lake Chauekuktuli Drainage Basin Runoff

The Lake Chauekuktuli drainage basin is the middle drainage basin and there are no reliable long term lake outlet flow data available to calculate the contribution of runoff from this basin to the total lake outflow, which would also include the inflow from the Lake Chikuminuk drainage basin.

Therefore, a long term record of Lake Chauekuktuli average monthly runoff volumes had to be estimated by assuming runoff characteristics similar to those for Tikchik/Nuyakuk Lake. That assumption is reasonable considering the elevation and orientation of both drainage basins. The monthly runoff volumes were then estimated by scaling Tikchik/Nuyakuk Lake basin unit runoff (cfs/mi^2) to the drainage area of Lake Chauekuktuli.

The average monthly Lake Chauekuktuli outflows were estimated by adding the inflow from Lake Chikuminuk to the estimated basin runoff.

4.3 Tikchik/Nuyakuk Lake Drainage Basin Runoff

The average monthly unit runoff for Tikchik/Nuyakuk Lake was estimated by subtracting the inflows from Lake Chauekuktuli from the monthly record at the Nuyakuk Lake stream gage.

4.4 Lake Outlet Rating Curves

The water surface elevation in each lake is a function of the rating curve of the outlet from each lake. The outlet from Lake Chauekuktuli is represented by the NW Passage, a stream channel with very consistent width and depth characteristics. The stream slope is consistently very flat for most of the channel, except towards the downstream end where the slope increases. Assuming the same cross-sectional shape of the channel at the lake outlet as for the NW Passage gage, the outflow from Lake Chauekuktuli is subcritical and therefore normal depth controlled. A rating curve for the lake outlet was estimated by shifting the normal depth rating curve from the gage to the lake outlet by assuming the total energy should match the lake elevation for any flow. The slope of the channel at the outlet was assumed to be the same as at the gage, which was calculated from the measured cross section, flow, and water level of the gage calibration data. The resulting outlet rating curve for Lake Chauekuktuli is presented in Equation 1 below, in which *z* is the lake water level (ft) and *Q* is the flow (cfs).

$$z = 306.31 + 0.1860Q^{0.4772} \qquad \text{Eq. 1}$$

The water surface elevation of Tikchik/Nuyakuk Lake was derived in a similar fashion using the Nuyakuk River gage rating data available from the USGS. The resulting outlet rating curve for Tikchik/Nuyakuk Lake is presented in Equation 2 below.

$$z = 301.59 + 0.1102Q^{0.4638} \qquad \text{Eq. 2}$$

4.5 Analysis and Results

Detailed tabular results are presented in Attachment A, based on the estimated runoff volumes and the lake outlet rating curves.

Figures 1 and 2 show the estimated pre- and post-Project water levels for Lake Chauekuktuli and Tikchick/Nuyakuk Lake, respectively, during the average hydrologic year (1987) of the record. The results indicate that the water levels would likely increase in both lakes during winter and spring as the Project would release more water for generation. The water level in Lake Chauekuktuli may increase as much as 2.5 feet in the spring, whereas the water level of Tikchik/Nuyakuk Lake may increase only about 1 foot. The results for the specific periods shown in Figures 1 and 2 are indicative of the overall results that the lake water levels would increase slightly in late fall through spring (October through May) and be reduced in the summer through early fall (June through September) as the reservoir stores the runoff from snow melt and early fall precipitation. The magnitude of the change in average monthly water levels in Lake Chauekuktuli is greater than in Tikchik/Nuyakuk Lake, since the regulated outflow from the Project affects Lake Chauekuktuli directly.

The estimated effect on water level of Lake Chauekuktuli due to the Project should be fairly accurate, since impact is primarily a function of the relative change in flows from Lake Chikuminuk. The accuracy of the lake outlet rating curve would likely have a greater effect on the results than any inaccuracy of the estimated average monthly flow record on Allen River.

Figures 3 and 4 show the estimated pre- and post-Project water levels for Lake Chauekuktuli during an average hydrologic year (1987) and the wettest hydrologic year (1977) of the record for fish spawning in August and eggs hatching in November. These results are indicative of the overall results that the water level variations from the time of spawning (in June through August) to the eggs hatch (in September through November) would generally be reduced in both lakes if the Project is constructed.

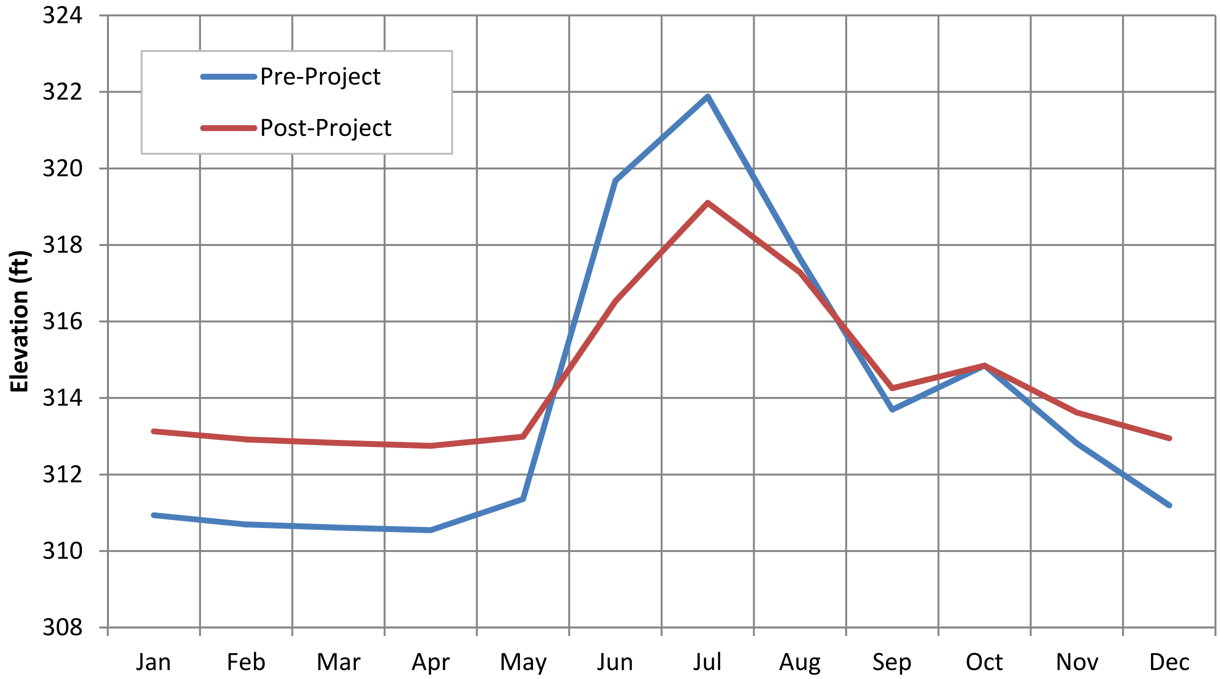

Figure 1 Estimated average monthly water level for Lake Chauekuktuli during the average hydrologic year of record (1987) of the available record (1954-1996)

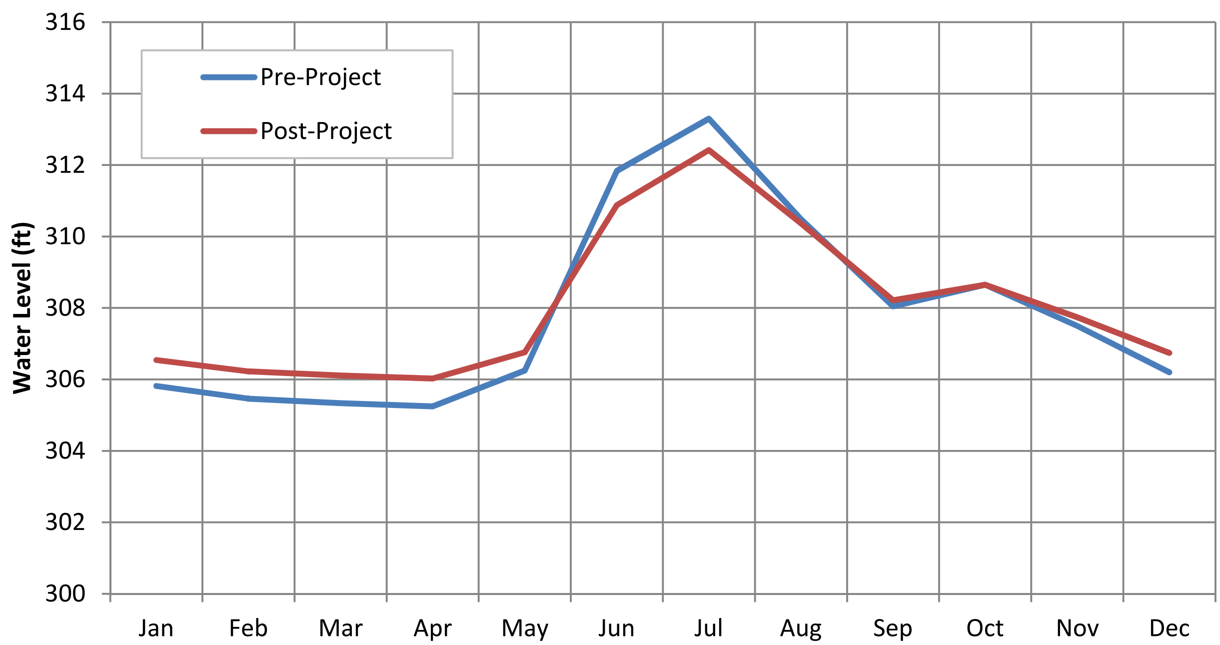

Figure 2 Estimated average monthly water level for Tikchick/Nuyakuk Lake during the average hydrologic year of record (1987) of the available record (1954-1996)

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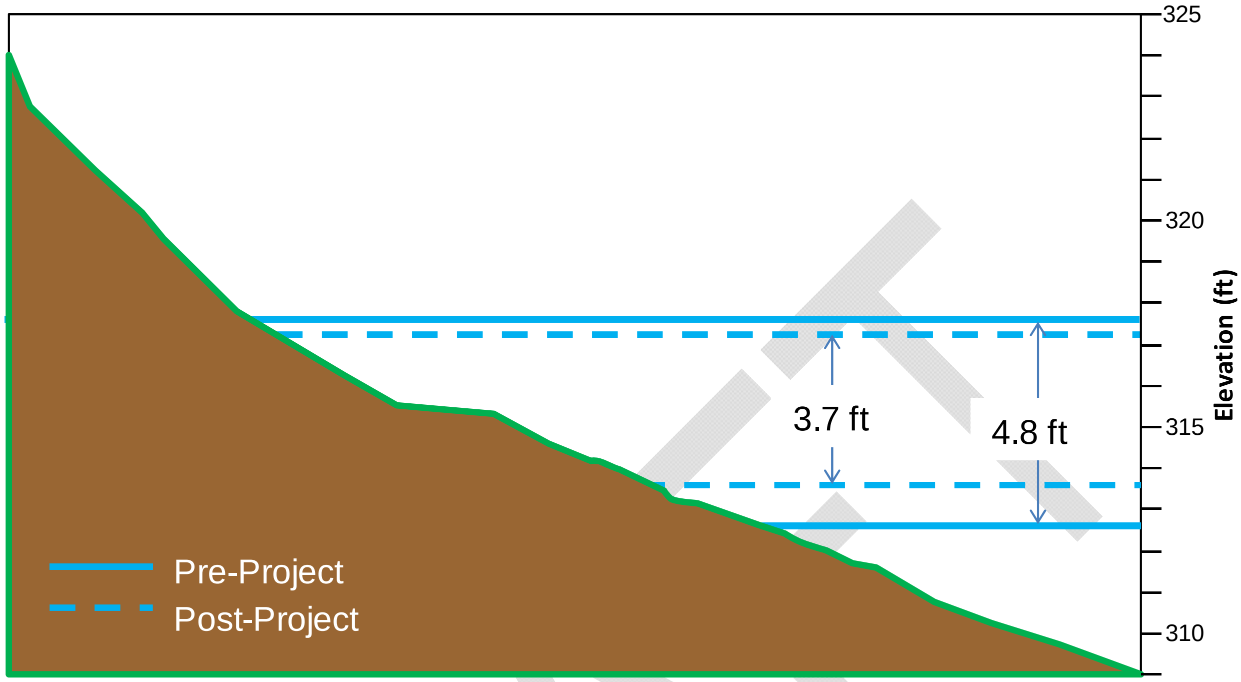

Figure 3 Estimated impact of Project on Lake Chauekuktuli water levels for an average hydrologic year (1987) with spawning in August and eggs hatching in November

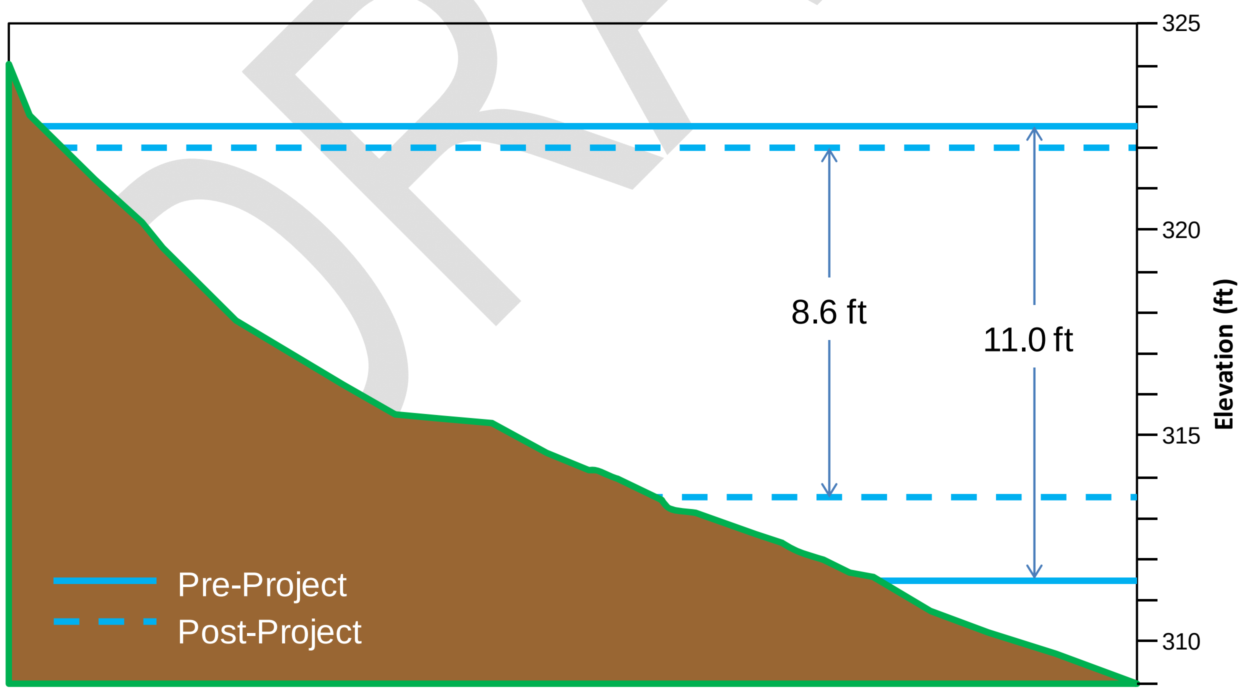

Figure 4 Estimated impact of Project on Lake Chauekuktuli water levels for <u>wettest</u> hydrologic year (1977) with spawning in August and eggs hatching in November

Development of lake outlet rating curves by concurrently measuring lake levels and outlet flows would significantly improve these estimates of lake level fluctuations.

One drawback of the methodology used to perform the analysis is that the estimated average monthly flows from Lake Chikuminuk and Lake Chauekuktuli are both based on correlated flows from the Nuyakuk River stream gage record. The estimated runoff and lake outflows from Lake Chikuminuk and Lake Chauekuktuli are therefore not independent. Reestablishment of the destroyed stream gage in the NW Passage and the continuation of flow measurements in the Allen River would allow a more refined analysis to be performed during a later design phase, should the Project proceed.

5. Summary and Conclusions

The regulated Project outflow from the project operations model were used to estimate the impact of the Project on water levels in the two downstream lakes, Lake Chauekuktuli and Tikchik/Nuyakuk Lake. Estimates of pre-project (unregulated) and post-project (regulated) lake water levels were calculated based on estimated basin runoff characteristics from the unregulated stream flow data. Detailed tabular results are included in Attachment A. The following is a summary of the results and conclusions:

- The water levels in the downstream lakes will likely increase in the winter and decrease in the summer. Lake Chauekuktuli may experience an increase of about 2.5 feet in the winter and spring and a decrease of up to 3.5 ft in the early summer. Tikchik/Nuyakuk Lake will likely only experience a modest increase of about 1 ft in the winter and spring and a modest decrease of about 1 ft in the early summer.
- Reestablishment of the stream gage in the NW Passage is recommended to facilitate a more detailed and accurate routing analysis of flows to Lake Chauekuktuli and Tikchik/Nuyakuk Lake.
- Development of lake outlet rating curves at both Lake Chauekuktuli and Tikchik/Nuyakuk Lake are recommended to facilitate more accurate estimates of lake levels.

6. References

Hatch. (2014a). *Draft Interim Feasibility Report, Chikuminuk Lake Hydroelectric Project.*
Hatch. (2014b). *Draft Project Operations Memorandum.*

Carl Mannheim

CM:cm
Attachment(s)/Enclosure

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Attachment A

Detailed Tabular Results

				Unregulated Monthly Flow		Estimated Monthly Runoff	Estimated Monthly Runoff Coefficient		Estimated Basin Runoff (cfs)			Estimated Lake Outflow - Pre-Project (cfs)			Estimated Lake Outflow - Post-Project (cfs)			Estimated Lake Level - Pre-Project (ft)		Estimated Lake Level - Post-Project (ft)		Pre- and Post-Project Lake Water Level Differential From Time of Spawning to Eggs Hatch (3-Month Spawning Period: June-Aug) (ft)			
Date	Year	Month	WY	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs)	NUYAKUK R less ALLEN R (cfs)	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs/mi^2)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs/mi^2)	Lake Chikuminuk (USGS 15301500 ALLEN R NR ALEKNAGIK AK) (cfs)	Lake Chauekuktuli (NW Passage gage) (cfs)	Tikchik/Nuyakuk Lake (USGS 15302000 NUYAKUK R NR DILLINGHAM AK) (cfs)	Lake Chikuminuk Outflow - Pre-Project (cfs)	Lake Chauekuktuli Outflow - Pre-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Pre-Project (cfs)	Lake Chikuminuk Outflow - Post-Project (cfs)	Lake Chauekuktuli Outflow - Post-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Post-Project (cfs)	Lake Chauekuktuli (pre): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (pre): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli (post): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (post): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli - Pre-Project	Tikchik/Nuyakuk Lake Pre-Project	Lake Chauekuktuli - Post-Project	Tikchik/Nuyakuk Lake - Post-Project
Jan-54	1954	1	1954	2100	392	1708	1.5	1.1	392	355	1303	392	747	2050											
Feb-54	1954	2	1954	1700	366	1334	1.2	1.1	366	301	1017	366	667	1684											
Mar-54	1954	3	1954	1400	344	1056	0.9	1.0	344	259	805	344	603	1409											
Apr-54	1954	4	1954	1300	335	965	0.8	1.0	335	245	736	335	580	1316											
May-54	1954	5	1954	3919	677	3242	2.8	1.9	677	648	2473	677	1325	3798											
Jun-54	1954	6	1954	10360	2469	7891	6.9	7.1	2469	1898	6018	2469	4367	10385											
Jul-54	1954	7	1954	6794	1239	5555	4.9	3.6	1239	1141	4237	1239	2380	6617											
Aug-54	1954	8	1954	5191	679	4512	4.0	2.0	679	800	3442	679	1478	4920											
Sep-54	1954	9	1954	5589	788	4801	4.2	2.3	788	877	3661	788	1665	5326											
Oct-54	1954	10	1955	5058	631	4427	3.9	1.8	631	771	3376	631	1402	4778	1275	2046	5422	312.2	307.2	313.4	307.5				
Nov-54	1954	11	1955	6111	968	5143	4.5	2.8	968	987	3923	968	1955	5877	1362	2349	6272	313.2	307.8	313.9	307.9				
Dec-54	1954	12	1955	4029	486	3543	3.1	1.4	486	610	2702	486	1096	3798	1323	1932	4635	311.6	306.6	313.2	307.1				
Jan-55	1955	1	1955	3000	440	2560	2.2	1.3	440	475	1953	440	915	2868	1473	1948	3901	311.1	306.0	313.2	306.7				
Feb-55	1955	2	1955	2400	409	1991	1.7	1.2	409	395	1519	409	804	2323	1414	1810	3328	310.8	305.6	313.0	306.3				
Mar-55	1955	3	1955	2100	392	1708	1.5	1.1	392	355	1303	392	747	2050	1382	1737	3040	310.7	305.4	312.8	306.1				
Apr-55	1955	4	1955	2000	386	1614	1.4	1.1	386	342	1231	386	728	1959	1357	1698	2929	310.6	305.3	312.8	306.1				
May-55	1955	5	1955	3359	531	2828	2.5	1.5	531	542	2157	531	1073	3230	1298	1841	3997	311.5	306.3	313.0	306.8				
Jun-55	1955	6	1955	11790	2894	8896	7.8	8.3	2894	2182	6785	2894	5076	11861	1305	3487	10272	317.2	310.1	315.4	309.6	-2.7	-1.7	-0.7	-1.1
Jul-55	1955	7	1955	20420	5609	14811	13.0	16.1	5609	3941	11296	5609	9550	20847	1312	5253	16550	321.1	312.7	317.4	311.6	-7.3	-4.7	-3.4	-3.5
Aug-55	1955	8	1955	12730	3187	9543	8.4	9.2	3187	2373	7278	3187	5560	12839	2062	4435	11713	317.7	310.5	316.5	310.1	-6.2	-4.0	-3.3	-3.1
Sep-55	1955	9	1955	7485	1510	5975	5.2	4.3	1510	1297	4557	1510	2807	7364	1662	2959	7516	314.5	308.4	314.7	308.5				
Oct-55	1955	10	1956	6592	1163	5429	4.8	3.3	1163	1097	4141	1163	2260	6401	1329	2426	6566	313.7	308.0	314.0	308.1				
Nov-55	1955	11	1956	3800	475	3325	2.9	1.4	475	579	2536	475	1054	3590	1354	1933	4469	311.5	306.5	313.2	307.0				
Dec-55	1955	12	1956	2400	409	1991	1.7	1.2	409	395	1519	409	804	2323	1317	1712	3231	310.8	305.6	312.8	306.3				
Jan-56	1956	1	1956	1800	373	1427	1.2	1.1	373	315	1088	373	688	1776	1468	1782	2871	310.5	305.1	312.9	306.0				
Feb-56	1956	2	1956	1400	344	1056	0.9	1.0	344	259	805	344	603	1409	1363	1623	2428	310.3	304.8	312.6	305.7				
Mar-56	1956	3	1956	1300	335	965	0.8	1.0	335	245	736	335	580	1316	1379	1624	2360	310.2	304.7	312.6	305.6				
Apr-56	1956	4	1956	1400	344	1056	0.9	1.0	344	259	805	344	603	1409	1355	1614	2420	310.3	304.8	312.6	305.7				
May-56	1956	5	1956	3298	546	2752	2.4	1.6	546	539	2099	546	1086	3184	1397	1936	4035	311.5	306.2	313.2	306.8				
Jun-56	1956	6	1956	16680	4407	12273	10.7	12.7	4407	3172	9361	4407	7579	16940	1268	4440	13801	319.5	311.7	316.5	310.8	-3.7	-2.5	-1.8	-1.9
Jul-56	1956	7	1956	11880	2901	8979	7.9	8.3	2901	2195	6848	2901	5096	11944	1335	3530	10378	317.2	310.2	315.5	309.6	-4.5	-2.8	-2.1	-2.0
Aug-56	1956	8	1956	7006	1302	5704	5.0	3.7	1302	1184	4351	1302	2485	6836	1283	2467	6817	314.1	308.2	314.0	308.2	-2.8	-2.0	-0.9	-1.4
Sep-56	1956	9	1956	9277	2154	7123	6.2	6.2	2154	1684	5433	2154	3838	9270	1266	2950	8383	315.9	309.2	314.7	308.9				
Oct-56	1956	10	1957	5395	808	4587	4.0	2.3	808	859	3499	808	1666	5165	1191	2050	5549	312.7	307.4	313.4	307.6				
Nov-56	1956	11	1957	3333	455	2878	2.5	1.3	455	519	2195	455	974	3169	1395	1914	4109	311.3	306.2	313.2	306.8				
Dec-56	1956	12	1957	2732	425	2307	2.0	1.2	425	439	1759	425	864	2624	1359	1798	3557	311.0	305.8	313.0	306.5				
Jan-57	1957	1	1957	1800	373	1427	1.2	1.1	373	315	1088	373	688	1776	1518	1832	2921	310.5	305.1	313.0	306.1				
Feb-57	1957	2	1957	1400	344	1056	0.9	1.0	344	259	805	344	603	1409	1461	1720	2526	310.3	304.8	312.8	305.8				
Mar-57	1957	3	1957	1400	344	1056	0.9	1.0	344	259	805	344	603	1409	1432	1691	2496	310.3	304.8	312.8	305.7				
Apr-57	1957	4	1957	1700	366	1334	1.2	1.1	366	301	1017	366	667	1684	1409	1710	2728	310.5	305.0	312.8	305.9				
May-57	1957	5	1957	4806	939	3867	3.4	2.7	939	825	2949	939	1764	4713	1340	2165	5114	312.9	307.2	313.6	307.4				
Jun-57	1957	6	1957	13080	3271	9809	8.6	9.4	3271	2438	7481	3271	5709	13190	1330	3767	11248	317.8	310.6	315.8	309.9	-0.8	-0.5	-0.3	-0.4
Jul-57	1957	7	1957	7232	1396	5836	5.1	4.0	1396	1236	4451	1396	2632	7083	1443	2679	7130	314.3	308.3	314.4	308.3	0.2	0.1	0.0	0.1
Aug-57	1957	8	1957	3855	477	3378	3.0	1.4	477	587	2576	477	1064	3640	1412	1999	4575	311.5	306.5	313.3	307.1	4.1	2.5	1.6	1.7
Sep-57	1957	9	1957	11540	2780	8760	7.7	8.0	2780	2122	6681	2780	4902	11583	1379	3501	10182	317.0	310.0	315.4	309.6				
Oct-57	1957	10	1958	7500	1499	6001	5.3	4.3	1499	1296	4577	1499	2795	7372	1392	2688	7264	314.5	308.4	314.4	308.4				
Nov-57	1957	11	1958	8886	2037	6849	6.0	5.9	2037	1606	5224	2037	3643	8866	1472	3078	8301	315.6	309.1	314.9	308.8				
Dec-57	1957	12	1958	4887	738	4149	3.6	2.1	738	780	3164	738	1518	4682	1426	2206	5370	312.4	307.1	313.6	307.5				
Jan-58	1958	1	1958	3097	444	2653	2.3	1.3	444	488	2023	444	932	2955	1597	2085	4108	311.2	306.1	313.4	306.8				
Feb-58	1958	2	1958	2354	407	1947	1.7	1.2	407	389	1485	407	796	2281	1540	1929	3415	310.8	305.6	313.2	306.4				
Mar-58	1958	3	1958	2100	392	1708	1.5	1.1	392	355	1303	392	747	2050	1513	1868	3171	310.7	305.4	313.1	306.2				
Apr-58	1958	4	1958	2050	389	1661	1.5	1.1	389	349	1267	389	738	2004	386	735	2001	310.7	305.3	310.6	305.3				
May-58	1958	5	1958	3854	559	3295	2.9	1.6	559	609	2513	559	1167	3681	1298	1907	4420	311.7	306.6	313.1	307.0				
Jun-58	1958	6	1958	19900	5520	14380	12.6	15.9	5520	3856	10967	5520	9376	20343	1314	5170	16137	320.9	312.6	317.3	311.4	-6.8	-4.3	-2.9	-3.1
Jul-58	1958	7	1958	21850	6106	15744	13.8	17.5	6106	4246	12008	6106	10352	22360	1306	5552	17560	321.6	313.1	317.7	311.8	-8.2	-5.2	-3.9	-3.9
Aug-58	1958	8	1958	11460	2789	8671	7.6	8.0	2789	2115	6613	2789	4904	11517	1992	4107	10720	317.0	310.0	316.2	309.7	-5.7	-3.7	-3.0	-2.9
Sep-58	1958	9	1958	7098	1343	5755	5.0	3.9	1343	1206	4389	1343	2549	6938	1487	2692	7082	314.2	308.3	314.4	308.3				
Oct-58	1958	10	1959	6255	1034	5221	4.6	3.0	1034	1022	3982	1034	2057	6038	1262	2284	6266	313.4	307.8	313.8	307.9				
Nov-58	1958	11	1959	3450	459	2991	2.6	1.3	459	534	2281	459	993	3274	1358	1892	4173	311.3	306.3	313.1	306.9				
Dec-58	1958	12	1959	2600	420	2180	1.9	1.2	420	422	1663	420	842	2505	1321	1743	3405	310.9	305.7	312.9	306.4				
Jan-59	1959	1	1959	2300	404	1896	1.7	1.2	404	382	1446	404	786	2232	1472	1854	3300	310.8	305.5	313.1	306.3				
Feb-59	1959	2	1959	1700	366	1334	1.2	1.1	366	301	1017	366	667	1684	1414	1715	2732	310.5	305.0	312.8	305.9				
Mar-59	1959	3	1959	1300	335	965	0.8	1.0	335	245	736	335	580	1316	1383	1628	2364	310.2	304.7	312.6	305.6				
Apr-59	1959	4	1959	1400	344	1056	0.9	1.0	344	259	805	344	603	1409	1359	1618	2424	310.3	304.8	312.6	305.7				
May-59	1959	5	1959	3415	571	2844	2.5	1.6	571	560	2169	571	1131	3300	1300	1860	4029	311.6	306.3	313.1	306.8				
Jun-59	1959	6	1959	13680	3466	10214	8.9	10.0	3466	2562	7790	3466	6028	13818	1291	3853	11643	318.2	310.8	315.9	310.1	-5.7	-3.4	-2.3	-2.4
Jul-59	1959	7	1959	10910	2639	8271	7.2	7.6	2639	2009	6308	2639	4648	10956	1368	3376	9685	316.8	309.8	315.3	309.4	-1.2	-0.7	-0.5	-0.5
Aug-59	1959	8	1959	5836	891	4945	4.3	2.6	891	934	3771	891	1825	5596	1323	2257	6028	313.0	307.6	313.7	307.8	-0.7	-0.4	0.0	-0.2
Sep-59	1959	9	1959	5271	706	4565	4.0	2.0	706	817	3482	706	1523	5004	1341	2158	5639	312.5	307.3	313.6	307.6				
Oct-59	1959	10	1960	9049	2009	7040	6.2	5.8	2009	1618	5369	2009	3627	8996	1340	2958	8327	315.6	309.1	314.7	308.8				
Nov-59	1959	11	1960	5092	664	4428	3.9	1.9	664	784	3377	664	1448	4825	1450	2234	5611	312.3	307.2	313.7	307.6				
Dec-59	1959	12	1960	3190	449	2741	2.4	1.3	449	500	2091	449	948	3039	1414	1914	4005	311.2	306.1	313.2	306.8				
Jan-60	1960	1	1960	2545	417	2128	1.9	1.2	417	415	1623	417	832	2455	1583	1997	3621	310.9	305.7	313.3	306.5				
Feb-60	1960	2	1960	1855	376	1479	1.3	1.1	376	322	1128	376	698	1826	1475	1797	2925	310.5	305.2	313.0	306.1				
Mar-60	1960	3	1960	1448	347	1101	1.0	1.0	347	266	839	347	613	1453	1500	1765	2605	310.3	304.8	312.9	305.8				
Apr-60	1960	4	1960	800	287	514	0.4	0.8	287	172	392	287	459	851	283	455	847	309.8	304.1	309.8	304.1				
May-60	1960	5	1960	5084	989	4095	3.6	2.8	989	871	3123	989	1860	4983	1476	2347	5470	313.1	307.3	313.9	307.6				
Jun-60	1960	6	1960	16650	4382	12268	10.7	12.6	4382	3162	9357	4382	7543	16900	1333	4494	13852	319.5	311.7	316.6	310.8	-5.4	-3.4	-2.5	-2.5
Jul-60	1960	7	1960	12630	3144	9486	8.3	9.0	3144	2350	7235	3144	5494	12729	1398	3747	10982	317.6	310.4	315.7	309.8	-4.0	-2.4	-1.9	-1.8
Aug-60	1960	8	1960	9579	2238	7341	6.4	6.4	2238	1743	5599	2238	3981	9580	1320	3062	8661	316.0	309.3	314.9	309.0	-3.3	-1.8	-1.1	-1.2
Sep-60	1960	9	1960	7068	1323	5745	5.0	3.8	1323	1197	4382	1323	2520	6902	1322	2518	6900	314.1	308.2	314.1	308.2				
Oct-60	1960	10	1961	6531	1111	5420	4.7	3.2	1111	1076	4134	1111	2187	6321	1243	2319	6452	313.6	308.0	313.8	308.0				
Nov-60	1960	11	1961	5586	787	4799	4.2	2.3	787	876	3660	787	1663	5323	1450	2326	5986	312.7	307.5	313.8	307.8				
Dec-60	1960	12	1961	4100	487	3613	3.2	1.4	487	618	2756	487	1105	3861	1413	2031	4787	311.6	306.7	313.4	307.2				
Jan-61	1961	1	1961	3176	448	2728	2.4	1.3	448	498	2081	448	946	3027	1580	2078	4159	311.2	306.1	313.4	306.8				
Feb-61	1961	2	1961	2700	425	2275	2.0	1.2	425	435	1735	425	860	2596	1522	1958	3693	311.0	305.8	313.2	306.6				
Mar-61	1961	3	1961	2000	386	1614	1.4	1.1	386	342	1231	386	728	1959	1494	1836	3067	310.6	305.3	313.0	306.2				
Apr-61	1961	4	1961	1700	366	1334	1.2	1.1	366	301	1017	366	667	1684	366	667	1684	310.5	305.0	310.5	305.0				
May-61	1961	5	1961	5890	1262	4628	4.1	3.6	1262	1041	3530	1262	2303	5832	1372	2413	5942	313.8	307.7	314.0	307.8				

				Unregulated Monthly Flow		Estimated Monthly Runoff	Estimated Monthly Runoff Coefficient		Estimated Basin Runoff (cfs)			Estimated Lake Outflow - Pre-Project (cfs)			Estimated Lake Outflow - Post-Project (cfs)			Estimated Lake Level - Pre-Project (ft)		Estimated Lake Level - Post-Project (ft)		Pre- and Post-Project Lake Water Level Differential From Time of Spawning to Eggs Hatch (3-Month Spawning Period: June-Aug) (ft)			
Date	Year	Month	WY	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs)	NUYAKUK R less ALLEN R (cfs)	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs/mi^2)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs/mi^2)	Lake Chikuminuk (USGS 15301500 ALLEN R NR ALEKNAGIK AK) (cfs)	Lake Chauekuktuli (NW Passage gage) (cfs)	Tikchik/Nuyakuk Lake (USGS 15302000 NUYAKUK R NR DILLINGHAM AK) (cfs)	Lake Chikuminuk Outflow - Pre-Project (cfs)	Lake Chauekuktuli Outflow - Pre-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Pre-Project (cfs)	Lake Chikuminuk Outflow - Post-Project (cfs)	Lake Chauekuktuli Outflow - Post-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Post-Project (cfs)	Lake Chauekuktuli (pre): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (pre): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli (post): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (post): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli - Pre-Project	Tikchik/Nuyakuk Lake Pre-Project	Lake Chauekuktuli - Post-Project	Tikchik/Nuyakuk Lake - Post-Project
Jun-61	1961	6	1961	15930	4153	11777	10.3	11.9	4153	3014	8982	4153	7168	16150	1336	4351	13333	319.2	311.5	316.4	310.6	-3.6	-2.4	-1.8	-1.9
Jul-61	1961	7	1961	12460	3087	9373	8.2	8.9	3087	2314	7148	3087	5402	12550	1403	3718	10866	317.5	310.4	315.7	309.8	-4.0	-2.4	-1.8	-1.8
Aug-61	1961	8	1961	9820	2310	7510	6.6	6.6	2310	1790	5728	2310	4100	9828	1324	3114	8842	316.2	309.4	315.0	309.0	-4.6	-2.8	-1.6	-1.9
Sep-61	1961	9	1961	8813	2038	6775	5.9	5.9	2038	1597	5167	2038	3635	8803	1309	2906	8073	315.6	309.0	314.7	308.7				
Oct-61	1961	10	1962	6402	1097	5305	4.6	3.2	1097	1057	4046	1097	2153	6200	1329	2386	6432	313.6	307.9	313.9	308.0				
Nov-61	1961	11	1962	4010	486	3524	3.1	1.4	486	607	2687	486	1094	3781	1442	2049	4737	311.6	306.6	313.4	307.2				
Dec-61	1961	12	1962	2187	396	1791	1.6	1.1	396	367	1366	396	762	2129	1407	1773	3140	310.7	305.4	312.9	306.2				
Jan-62	1962	1	1962	1897	379	1518	1.3	1.1	379	328	1158	379	707	1865	1575	1903	3061	310.6	305.2	313.1	306.1				
Feb-62	1962	2	1962	1800	373	1427	1.2	1.1	373	315	1088	373	688	1776	1519	1834	2922	310.5	305.1	313.0	306.1				
Mar-62	1962	3	1962	1600	359	1241	1.1	1.0	359	287	947	359	646	1593	1492	1779	2726	310.4	305.0	312.9	305.9				
Apr-62	1962	4	1962	1600	359	1241	1.1	1.0	359	287	947	359	646	1593	50	337	1284	310.4	305.0	309.3	304.6				
May-62	1962	5	1962	4161	678	3483	3.0	1.9	678	677	2656	678	1356	4012	1382	2059	4715	312.1	306.8	313.4	307.2				
Jun-62	1962	6	1962	15640	4112	11528	10.1	11.8	4112	2969	8793	4112	7081	15873	1347	4316	13109	319.1	311.4	316.4	310.5	-6.6	-4.0	-2.8	-2.9
Jul-62	1962	7	1962	15370	3995	11375	10.0	11.5	3995	2905	8676	3995	6900	15576	1389	4294	12969	318.9	311.3	316.4	310.5	-6.5	-4.0	-2.8	-2.8
Aug-62	1962	8	1962	6707	1207	5500	4.8	3.5	1207	1122	4195	1207	2329	6524	1336	2458	6653	313.8	308.1	314.0	308.1	-2.5	-1.7	-0.6	-1.2
Sep-62	1962	9	1962	5351	718	4633	4.1	2.1	718	829	3533	718	1548	5081	1353	2182	5716	312.5	307.4	313.6	307.7				
Oct-62	1962	10	1963	5228	686	4542	4.0	2.0	686	806	3464	686	1492	4956	1388	2194	5658	312.4	307.3	313.6	307.7				
Nov-62	1962	11	1963	3500	463	3037	2.7	1.3	463	541	2316	463	1004	3320	1516	2056	4373	311.3	306.3	313.4	307.0				
Dec-62	1962	12	1963	2900	435	2465	2.2	1.3	435	462	1880	435	897	2777	1483	1944	3824	311.1	305.9	313.2	306.6				
Jan-63	1963	1	1963	3100	445	2655	2.3	1.3	445	488	2025	445	933	2958	1665	2153	4178	311.2	306.1	313.6	306.9				
Feb-63	1963	2	1963	3200	449	2751	2.4	1.3	449	501	2098	449	950	3048	449	950	3048	311.2	306.1	311.2	306.1				
Mar-63	1963	3	1963	3041	442	2599	2.3	1.3	442	480	1982	442	922	2905	440	920	2903	311.1	306.0	311.1	306.0				
Apr-63	1963	4	1963	1900	379	1521	1.3	1.1	379	328	1160	379	707	1867	379	707	1867	310.6	305.2	310.6	305.2				
May-63	1963	5	1963	3550	562	2988	2.6	1.6	562	573	2279	562	1136	3414	50	623	2902	311.6	306.4	310.3	306.0				
Jun-63	1963	6	1963	14230	3620	10610	9.3	10.4	3620	2668	8092	3620	6288	14380	1359	4028	12120	318.4	310.9	316.1	310.2	-2.2	-1.2	-1.0	-0.8
Jul-63	1963	7	1963	11480	2966	8514	7.5	8.5	2966	2165	6494	2966	5131	11625	1430	3595	10089	317.3	310.1	315.6	309.5	-3.7	-2.0	-1.5	-1.3
Aug-63	1963	8	1963	6306	1492	4814	4.2	4.3	1492	1152	3671	1492	2644	6316	1371	2523	6195	314.3	308.0	314.1	307.9	-3.0	-1.9	-0.8	-1.2
Sep-63	1963	9	1963	10770	2239	8531	7.5	6.4	2239	1884	6506	2239	4123	10630	1350	3234	9740	316.2	309.7	315.1	309.4				
Oct-63	1963	10	1964	6702	1071	5631	4.9	3.1	1071	1085	4295	1071	2156	6451	1374	2459	6754	313.6	308.0	314.0	308.2				
Nov-63	1963	11	1964	3057	478	2579	2.3	1.4	478	492	1967	478	970	2937	1498	1990	3957	311.3	306.1	313.3	306.7				
Dec-63	1963	12	1964	1848	571	1277	1.1	1.6	571	374	974	571	945	1919	1459	1833	2807	311.2	305.3	313.0	306.0				
Jan-64	1964	1	1964	1397	474	923	0.8	1.4	474	294	704	474	768	1472	1635	1930	2633	310.7	304.8	313.2	305.8				
Feb-64	1964	2	1964	1252	406	846	0.7	1.2	406	258	645	406	664	1310	1526	1785	2430	310.4	304.7	312.9	305.7				
Mar-64	1964	3	1964	1097	314	783	0.7	0.9	314	215	597	314	529	1126	280	495	1092	310.0	304.5	309.9	304.4				
Apr-64	1964	4	1964	1100	255	845	0.7	0.7	255	200	644	255	455	1099	260	460	1104	309.8	304.4	309.8	304.4				
May-64	1964	5	1964	1719	339	1380	1.2	1.0	339	296	1053	339	635	1687	704	1000	2052	310.4	305.0	311.3	305.4				
Jun-64	1964	6	1964	16370	4870	11500	10.1	14.0	4870	3261	8771	4870	8130	16902	1327	4587	13359	320.0	311.7	316.7	310.6	-4.5	-3.1	-2.2	-2.3
Jul-64	1964	7	1964	13740	2908	10832	9.5	8.4	2908	2418	8261	2908	5326	13587	1398	3815	12076	317.5	310.7	315.8	310.2	-2.9	-2.3	-1.7	-2.0
Aug-64	1964	8	1964	7720	1986	5734	5.0	5.7	1986	1454	4373	1986	3439	7813	1327	2781	7154	315.4	308.6	314.5	308.3	-3.4	-1.9	-1.0	-1.1
Sep-64	1964	9	1964	7620	2039	5581	4.9	5.9	2039	1456	4256	2039	3496	7752	1313	2769	7025	315.4	308.6	314.5	308.3				
Oct-64	1964	10	1965	7364	1571	5793	5.1	4.5	1571	1299	4419	1571	2870	7288	1221	2520	6938	314.6	308.4	314.1	308.3				
Nov-64	1964	11	1965	4225	625	3600	3.2	1.8	625	671	2746	625	1296	4041	1428	2098	4844	312.0	306.8	313.5	307.2				
Dec-64	1964	12	1965	2700	520	2180	1.9	1.5	520	461	1663	520	981	2644	1389	1850	3513	311.3	305.9	313.0	306.5				
Jan-65	1965	1	1965	2000	460	1540	1.3	1.3	460	362	1175	460	822	1996	1551	1913	3087	310.9	305.3	313.2	306.2				
Feb-65	1965	2	1965	1600	400	1200	1.1	1.1	400	298	915	400	698	1613	1493	1791	2707	310.5	305.0	312.9	305.9				
Mar-65	1965	3	1965	1700	370	1330	1.2	1.1	370	302	1014	370	672	1686	1465	1766	2781	310.5	305.0	312.9	306.0				
Apr-65	1965	4	1965	2300	348	1952	1.7	1.0	348	367	1489	348	715	2204	1444	1811	3300	310.6	305.5	313.0	306.3				
May-65	1965	5	1965	3247	494	2753	2.4	1.4	494	519	2100	494	1013	3113	1382	1901	4001	311.4	306.2	313.1	306.8				
Jun-65	1965	6	1965	18910	4702	14208	12.4	13.5	4702	3517	10837	4702	8218	19055	1331	4847	15684	320.0	312.2	317.0	311.3	-0.6	-1.1	-0.7	-1.2
Jul-65	1965	7	1965	14940	3476	11464	10.0	10.0	3476	2714	8743	3476	6190	14933	1387	4101	12844	318.3	311.1	316.2	310.5	-3.0	-1.3	-1.2	-0.7
Aug-65	1965	8	1965	9255	2132	7123	6.2	6.1	2132	1675	5432	2132	3808	9240	1312	2987	8420	315.8	309.2	314.8	308.9	-3.7	-1.9	-1.3	-1.2
Sep-65	1965	9	1965	14370	4554	9816	8.6	13.1	4554	2938	7487	4554	7491	14978	1258	4196	11683	319.4	311.1	316.3	310.1				
Oct-65	1965	10	1966	11520	1576	9944	8.7	4.5	1576	1793	7585	1576	3369	10954	1343	3136	10721	315.3	309.8	315.0	309.7				
Nov-65	1965	11	1966	5300	569	4731	4.1	1.6	569	783	3608	569	1352	4960	1351	2134	5743	312.1	307.3	313.5	307.7				
Dec-65	1965	12	1966	3100	460	2640	2.3	1.3	460	492	2014	460	952	2966	1313	1805	3818	311.2	306.1	313.0	306.6				
Jan-66	1966	1	1966	2000	400	1600	1.4	1.1	400	346	1220	400	746	1966	1462	1808	3028	310.7	305.3	313.0	306.1				
Feb-66	1966	2	1966	1700	350	1350	1.2	1.0	350	296	1030	350	646	1676	1405	1701	2731	310.4	305.0	312.8	305.9				
Mar-66	1966	3	1966	1600	300	1300	1.1	0.9	300	271	992	300	571	1563	1374	1645	2637	310.2	304.9	312.7	305.8				
Apr-66	1966	4	1966	1500	260	1240	1.1	0.7	260	248	946	260	508	1454	1352	1601	2547	309.9	304.8	312.6	305.8				
May-66	1966	5	1966	2010	367	1643	1.4	1.1	367	338	1253	367	705	1958	1298	1636	2889	310.6	305.3	312.7	306.0				
Jun-66	1966	6	1966	10900	3900	7000	6.1	11.2	3900	2349	5339	3900	6249	11588	1281	3630	8969	318.4	310.0	315.6	309.1	-2.4	-1.0	-0.9	-0.5
Jul-66	1966	7	1966	12870	3226	9644	8.4	9.3	3226	2400	7356	3226	5626	12982	1343	3743	11099	317.8	310.5	315.7	309.9	-1.3	-0.8	0.0	-0.5
Aug-66	1966	8	1966	9103	2010	7093	6.2	5.8	2010	1624	5410	2010	3634	9044	1274	2898	8308	315.6	309.1	314.7	308.8	-2.6	-1.5	-0.9	-1.0
Sep-66	1966	9	1966	8684	2300	6384	5.6	6.6	2300	1653	4869	2300	3953	8822	1255	2908	7777	316.0	309.0	314.7	308.6				
Oct-66	1966	10	1967	10470	2497	7973	7.0	7.2	2497	1918	6081	2497	4415	10496	1795	3713	9795	316.5	309.7	315.7	309.4				
Nov-66	1966	11	1967	5900	910	4990	4.4	2.6	910	946	3806	910	1856	5662	1337	2284	6090	313.1	307.7	313.8	307.9				
Dec-66	1966	12	1967	3916	480	3436	3.0	1.4	480	594	2621	480	1074	3695	1298	1892	4513	311.5	306.6	313.1	307.0				
Jan-67	1967	1	1967	2939	437	2502	2.2	1.3	437	467	1909	437	904	2812	1444	1911	3819	311.1	306.0	313.2	306.6				
Feb-67	1967	2	1967	2371	407	1964	1.7	1.2	407	392	1498	407	799	2297	1385	1776	3274	310.8	305.6	312.9	306.3				
Mar-67	1967	3	1967	2003	386	1617	1.4	1.1	386	342	1233	386	728	1961	1352	1694	2927	310.6	305.3	312.8	306.1				
Apr-67	1967	4	1967	1833	375	1458	1.3	1.1	375	319	1112	375	694	1806	1326	1645	2757	310.5	305.2	312.7	305.9				
May-67	1967	5	1967	2323	404	1919	1.7	1.2	404	385	1464	404	789	2252	1270	1655	3119	310.8	305.5	312.7	306.2				
Jun-67	1967	6	1967	11280	2699	8581	7.5	7.8	2699	2069	6544	2699	4768	11313	1283	3352	9896	316.9	310.0	315.3	309.4	-3.2	-1.9	-1.3	-1.4
Jul-67	1967	7	1967	9625	2209	7416	6.5	6.3	2209	1740	5656	2209	3949	9605	1369	3109	8766	316.0	309.3	314.9	309.0	-2.7	-1.6	-1.1	-1.1
Aug-67	1967	8	1967	6397	1059	5338	4.7	3.0	1059	1046	4071	1059	2105	6176	1322	2367	6439	313.5	307.9	313.9	308.0	-2.4	-1.9	-0.7	-1.3
Sep-67	1967	9	1967	6573	1164	5409	4.7	3.3	1164	1095	4125	1164	2260	6385	1328	2423	6548	313.7	308.0	314.0	308.1				
Oct-67	1967	10	1968	6015	987	5028	4.4	2.8	987	981	3835	987	1968	5803	1352	2333	6168	313.3	307.7	313.8	307.9				
Nov-67	1967	11	1968	2976	438	2538	2.2	1.3	438	472	1936	438	909	2845	1472	1944	3880	311.1	306.0	313.2	306.7				
Dec-67	1967	12	1968	1939	382	1557	1.4	1.1	382	333	1188	382	715	1903	1439	1772	2960	310.6	305.2	312.9	306.1				
Jan-68	1968	1	1968	1574	357	1217	1.1	1.0	357	283	928	357	640	1569	1615	1898	2827	310.4	304.9	313.1	306.0				
Feb-68	1968	2	1968	1462	348	1114	1.0	1.0	348	268	849	348	616	1465	1508	1776	2625	310.3	304.8	312.9	305.8				
Mar-68	1968	3	1968	1400	344	1056	0.9	1.0	344	259	805	344	603	1409	344	603	1409	310.3	304.8	310.3	304.8				
Apr-68	1968	4	1968	1400	344	1056	0.9	1.0	344	259	805	344	603	1409	344	603	1409	310.3	304.8	310.3	304.8				
May-68	1968	5	1968	3942	708	3234	2.8	2.0	708	660	2466	708	1368	3834	1481	2141	4607	312.1	306.7	313.5	307.1				
Jun-68	1968	6	1968	11030	2659	8371	7.3	7.6	2659	2029	6384	2659	4688	11072	1384	3412	9797	316.8	309.9	315.3	309.4	-3.5	-2.1	-1.3	-1.4
Jul-68	1968	7	1968	7297	1429	5868	5.1	4.1	1429	1253	4475	1429	2682	7157	1503	2756	7231	314.4	308.4	314.5	308.4	-2.9	-1.8	-1.2	-1.3
Aug-68	1968	8	1968	8098	1689	6409	5.6	4.9	1689	1418	4888	1689	3107	7995	1438	2856	7744	314.9	308.7	314.6	308.6	-4.0	-3.0	-3.7	-2.9
Sep-68	1968	9	1968	6127	1016	5111	4.5	2.9	1016	1002	3898	1016	2018	5916	1451	2453	6351	313.3	307.8	314.0	308.0				
Oct-68	1968	10	1969	3816	477	3339	2.9	1.4	477	582	2546	477	1059	3606	1401	1983	4529	311.5	306.5	313.3	307.1				

				Unregulated Monthly Flow		Estimated Monthly Runoff	Estimated Monthly Runoff Coefficient		Estimated Basin Runoff (cfs)			Estimated Lake Outflow - Pre-Project (cfs)			Estimated Lake Outflow - Post-Project (cfs)			Estimated Lake Level - Pre-Project (ft)		Estimated Lake Level - Post-Project (ft)		Pre- and Post-Project Lake Water Level Differential From Time of Spawning to Eggs Hatch (3-Month Spawning Period: June-Aug) (ft)			
Date	Year	Month	WY	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs)	NUYAKUK R less ALLEN R (cfs)	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs/mi^2)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs/mi^2)	Lake Chikuminuk (USGS 15301500 ALLEN R NR ALEKNAGIK AK) (cfs)	Lake Chauekuktuli (NW Passage gage) (cfs)	Tikchik/Nuyakuk Lake (USGS 15302000 NUYAKUK R NR DILLINGHAM AK) (cfs)	Lake Chikuminuk Outflow - Pre-Project (cfs)	Lake Chauekuktuli Outflow - Pre-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Pre-Project (cfs)	Lake Chikuminuk Outflow - Post-Project (cfs)	Lake Chauekuktuli Outflow - Post-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Post-Project (cfs)	Lake Chauekuktuli (pre): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (pre): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli (post): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (post): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli - Pre-Project	Tikchik/Nuyakuk Lake Pre-Project	Lake Chauekuktuli - Post-Project	Tikchik/Nuyakuk Lake - Post-Project
Nov-68	1968	11	1969	2570	418	2152	1.9	1.2	418	418	1641	418	836	2478	404	822	2463	310.9	305.7	310.9	305.7				
Dec-68	1968	12	1969	2187	397	1790	1.6	1.1	397	367	1365	397	764	2129	386	753	2118	310.7	305.4	310.7	305.4				
Jan-69	1969	1	1969	1887	378	1509	1.3	1.1	378	326	1151	378	705	1855	366	692	1843	310.6	305.2	310.5	305.2				
Feb-69	1969	2	1969	1600	359	1241	1.1	1.0	359	287	947	359	646	1592	351	638	1585	310.4	305.0	310.4	304.9				
Mar-69	1969	3	1969	1500	351	1149	1.0	1.0	351	273	876	351	624	1500	351	624	1500	310.3	304.9	310.3	304.9				
Apr-69	1969	4	1969	1500	351	1149	1.0	1.0	351	273	876	351	624	1500	351	624	1500	310.3	304.9	310.3	304.9				
May-69	1969	5	1969	4090	771	3319	2.9	2.2	771	694	2531	771	1465	3996	1379	2073	4605	312.3	306.7	313.4	307.1				
Jun-69	1969	6	1969	23290	6650	16640	14.6	19.1	6650	4564	12691	6650	11214	23905	1283	5847	18538	322.2	313.4	318.0	312.1	-9.5	-5.9	-4.4	-4.4
Jul-69	1969	7	1969	15760	4145	11615	10.2	11.9	4145	2992	8859	4145	7137	15996	1321	4313	13172	319.1	311.4	316.4	310.6	-2.1	-1.4	-1.1	-1.1
Aug-69	1969	8	1969	6564	1167	5397	4.7	3.4	1167	1095	4116	1167	2262	6378	1270	2365	6481	313.7	308.0	313.9	308.0	1.6	0.9	0.8	0.7
Sep-69	1969	9	1969	5633	805	4828	4.2	2.3	805	886	3682	805	1691	5374	1283	2169	5851	312.8	307.5	313.6	307.7				
Oct-69	1969	10	1970	11470	2781	8689	7.6	8.0	2781	2114	6627	2781	4895	11522	1267	3381	10008	317.0	310.0	315.3	309.5				
Nov-69	1969	11	1970	8567	1858	6709	5.9	5.3	1858	1519	5117	1858	3377	8494	1432	2951	8069	315.3	308.9	314.7	308.7				
Dec-69	1969	12	1970	3806	489	3317	2.9	1.4	489	584	2530	489	1072	3603	1293	1877	4407	311.5	306.5	313.1	307.0				
Jan-70	1970	1	1970	2284	402	1882	1.6	1.2	402	380	1435	402	782	2217	1439	1819	3254	310.8	305.5	313.0	306.3				
Feb-70	1970	2	1970	1871	378	1493	1.3	1.1	378	324	1139	378	702	1841	1381	1705	2844	310.6	305.2	312.8	306.0				
Mar-70	1970	3	1970	1700	366	1334	1.2	1.1	366	301	1017	366	667	1684	1348	1649	2666	310.5	305.0	312.7	305.9				
Apr-70	1970	4	1970	1600	359	1241	1.1	1.0	359	287	947	359	646	1593	1322	1609	2556	310.4	305.0	312.6	305.8				
May-70	1970	5	1970	4360	790	3570	3.1	2.3	790	731	2723	790	1521	4244	1258	1989	4712	312.4	306.9	313.3	307.2				
Jun-70	1970	6	1970	15130	3915	11215	9.8	11.2	3915	2855	8554	3915	6770	15324	1244	4099	12653	318.8	311.2	316.2	310.4	-3.6	-2.4	-1.1	-1.6
Jul-70	1970	7	1970	13100	3279	9821	8.6	9.4	3279	2442	7490	3279	5721	13212	1304	3746	11236	317.9	310.6	315.7	309.9	-5.8	-3.6	-2.5	-2.6
Aug-70	1970	8	1970	9471	2209	7262	6.4	6.3	2209	1722	5539	2209	3931	9469	1612	3333	8872	316.0	309.3	315.2	309.1	-4.8	-3.2	-2.2	-2.4
Sep-70	1970	9	1970	8407	1852	6555	5.7	5.3	1852	1499	5000	1852	3350	8350	1697	3196	8196	315.3	308.9	315.1	308.8				
Oct-70	1970	10	1971	4636	593	4043	3.5	1.7	593	711	3084	593	1303	4387	1266	1976	5060	312.0	307.0	313.3	307.3				
Nov-70	1970	11	1971	3057	442	2615	2.3	1.3	442	482	1994	442	924	2919	1365	1847	3841	311.1	306.1	313.0	306.7				
Dec-70	1970	12	1971	2094	391	1703	1.5	1.1	391	354	1299	391	746	2044	1328	1682	2981	310.7	305.4	312.8	306.1				
Jan-71	1971	1	1971	1726	368	1358	1.2	1.1	368	304	1036	368	672	1708	1481	1786	2822	310.5	305.1	312.9	306.0				
Feb-71	1971	2	1971	1532	354	1178	1.0	1.0	354	277	899	354	631	1530	1424	1701	2600	310.3	304.9	312.8	305.8				
Mar-71	1971	3	1971	1461	348	1113	1.0	1.0	348	268	849	348	616	1465	1393	1661	2509	310.3	304.8	312.7	305.7				
Apr-71	1971	4	1971	1423	346	1077	0.9	1.0	346	262	822	346	608	1430	1369	1632	2453	310.3	304.8	312.7	305.7				
May-71	1971	5	1971	3519	559	2960	2.6	1.6	559	569	2258	559	1127	3385	1311	1879	4137	311.6	306.4	313.1	306.8				
Jun-71	1971	6	1971	14130	3618	10512	9.2	10.4	3618	2656	8017	3618	6274	14292	1299	3955	11972	318.4	310.9	316.0	310.2	-4.1	-2.6	-1.6	-1.8
Jul-71	1971	7	1971	18350	4935	13415	11.7	14.2	4935	3513	10232	4935	8448	18680	1322	4835	15067	320.2	312.1	317.0	311.1	-6.7	-4.2	-3.1	-3.1
Aug-71	1971	8	1971	13830	3523	10307	9.0	10.1	3523	2595	7861	3523	6117	13979	2070	4664	12526	318.2	310.8	316.8	310.4	-6.3	-3.9	-3.4	-3.0
Sep-71	1971	9	1971	7192	1377	5815	5.1	4.0	1377	1226	4435	1377	2603	7038	1509	2735	7170	314.2	308.3	314.4	308.4				
Oct-71	1971	10	1972	6490	1095	5395	4.7	3.1	1095	1066	4115	1095	2161	6276	1293	2360	6475	313.6	308.0	313.9	308.0				
Nov-71	1971	11	1972	4572	552	4020	3.5	1.6	552	692	3066	552	1244	4310	1354	2045	5112	311.9	306.9	313.4	307.4				
Dec-71	1971	12	1972	3026	441	2585	2.3	1.3	441	478	1972	441	919	2891	1315	1794	3765	311.1	306.0	313.0	306.6				
Jan-72	1972	1	1972	2290	403	1887	1.7	1.2	403	381	1439	403	784	2223	1466	1846	3286	310.8	305.5	313.0	306.3				
Feb-72	1972	2	1972	1814	374	1440	1.3	1.1	374	316	1099	374	690	1789	1360	1677	2775	310.5	305.1	312.7	305.9				
Mar-72	1972	3	1972	1497	351	1146	1.0	1.0	351	273	874	351	624	1498	1375	1648	2522	310.3	304.9	312.7	305.8				
Apr-72	1972	4	1972	1433	346	1087	1.0	1.0	346	264	829	346	610	1439	1351	1615	2444	310.3	304.8	312.6	305.7				
May-72	1972	5	1972	2496	412	2084	1.8	1.2	412	408	1590	412	819	2409	1396	1803	3393	310.9	305.7	313.0	306.4				
Jun-72	1972	6	1972	12220	2987	9233	8.1	8.6	2987	2259	7042	2987	5246	12288	1301	3559	10601	317.4	310.3	315.5	309.7	-3.1	-2.0	-1.4	-1.5
Jul-72	1972	7	1972	16070	4211	11859	10.4	12.1	4211	3047	9045	4211	7258	16303	1339	4385	13430	319.2	311.5	316.5	310.6	-5.3	-3.4	-2.6	-2.6
Aug-72	1972	8	1972	7980	1687	6293	5.5	4.8	1687	1404	4799	1687	3091	7890	1277	2680	7480	314.9	308.7	314.4	308.5	-1.7	-0.9	-0.5	-0.6
Sep-72	1972	9	1972	7187	1390	5797	5.1	4.0	1390	1229	4422	1390	2619	7040	1275	2504	6926	314.3	308.3	314.1	308.2				
Oct-72	1972	10	1973	6755	1258	5497	4.8	3.6	1258	1142	4193	1258	2400	6592	1192	2334	6527	313.9	308.1	313.8	308.1				
Nov-72	1972	11	1973	6065	974	5091	4.5	2.8	974	983	3883	974	1958	5840	1382	2366	6248	313.2	307.7	313.9	307.9				
Dec-72	1972	12	1973	3727	472	3255	2.9	1.4	472	570	2483	472	1042	3524	1344	1914	4397	311.4	306.5	313.2	307.0				
Jan-73	1973	1	1973	2629	421	2208	1.9	1.2	421	426	1684	421	847	2531	1499	1925	3609	311.0	305.8	313.2	306.5				
Feb-73	1973	2	1973	2050	389	1661	1.5	1.1	389	348	1267	389	737	2004	1440	1789	3056	310.7	305.3	312.9	306.1				
Mar-73	1973	3	1973	1713	367	1346	1.2	1.1	367	303	1027	367	669	1696	1410	1712	2739	310.5	305.1	312.8	305.9				
Apr-73	1973	4	1973	1533	354	1179	1.0	1.0	354	278	899	354	631	1531	1386	1664	2564	310.3	304.9	312.7	305.8				
May-73	1973	5	1973	3567	563	3004	2.6	1.6	563	576	2291	563	1138	3430	1328	1903	4195	311.7	306.4	313.1	306.9				
Jun-73	1973	6	1973	14350	3697	10653	9.3	10.6	3697	2704	8125	3697	6401	14526	1312	4015	12140	318.5	311.0	316.1	310.2	-3.5	-2.2	-1.7	-1.7
Jul-73	1973	7	1973	16130	4242	11888	10.4	12.2	4242	3062	9067	4242	7304	16371	1348	4410	13477	319.3	311.5	316.5	310.7	-5.3	-3.4	-2.5	-2.5
Aug-73	1973	8	1973	7718	1574	6144	5.4	4.5	1574	1342	4686	1574	2916	7602	1287	2629	7315	314.7	308.5	314.3	308.4	-3.3	-2.1	-1.0	-1.4
Sep-73	1973	9	1973	8201	1691	6510	5.7	4.9	1691	1431	4965	1691	3122	8087	1282	2712	7678	315.0	308.7	314.4	308.6				
Oct-73	1973	10	1974	6901	1284	5617	4.9	3.7	1284	1167	4284	1284	2451	6735	1296	2463	6746	314.0	308.2	314.0	308.2				
Nov-73	1973	11	1974	3680	472	3208	2.8	1.4	472	564	2447	472	1037	3483	1401	1966	4412	311.4	306.4	313.2	307.0				
Dec-73	1973	12	1974	2377	408	1969	1.7	1.2	408	392	1502	408	800	2302	1365	1757	3259	310.8	305.6	312.9	306.3				
Jan-74	1974	1	1974	1832	375	1457	1.3	1.1	375	319	1111	375	694	1805	1525	1844	2956	310.5	305.2	313.0	306.1				
Feb-74	1974	2	1974	1554	355	1199	1.0	1.0	355	281	914	355	636	1550	1468	1749	2663	310.4	304.9	312.9	305.9				
Mar-74	1974	3	1974	1500	351	1149	1.0	1.0	351	273	876	351	624	1500	1439	1712	2589	310.3	304.9	312.8	305.8				
Apr-74	1974	4	1974	1510	352	1158	1.0	1.0	352	274	883	352	626	1510	1417	1692	2575	310.3	304.9	312.8	305.8				
May-74	1974	5	1974	4162	657	3505	3.1	1.9	657	672	2674	657	1328	4002	1357	2028	4702	312.1	306.8	313.4	307.2				
Jun-74	1974	6	1974	11850	2907	8943	7.8	8.4	2907	2193	6821	2907	5099	11921	1355	3548	10369	317.2	310.2	315.5	309.6	-3.7	-2.2	-1.4	-1.5
Jul-74	1974	7	1974	9749	2274	7475	6.5	6.5	2274	1772	5701	2274	4047	9748	1446	3218	8919	316.1	309.4	315.1	309.1	-2.1	-1.3	-0.9	-0.9
Aug-74	1974	8	1974	5721	840	4881	4.3	2.4	840	906	3723	840	1746	5469	1404	2310	6033	312.9	307.6	313.8	307.8	-0.9	-0.6	-0.1	-0.4
Sep-74	1974	9	1974	6497	1097	5400	4.7	3.2	1097	1068	4119	1097	2165	6283	1414	2482	6601	313.6	308.0	314.1	308.1				
Oct-74	1974	10	1975	6863	1255	5608	4.9	3.6	1255	1154	4278	1255	2408	6686	1437	2591	6868	314.0	308.1	314.2	308.2				
Nov-74	1974	11	1975	4573	573	4000	3.5	1.6	573	698	3050	573	1271	4322	1574	2272	5322	311.9	306.9	313.7	307.5				
Dec-74	1974	12	1975	2723	426	2297	2.0	1.2	426	438	1752	426	864	2616	1544	1982	3734	311.0	305.8	313.3	306.6				
Jan-75	1975	1	1975	2068	390	1678	1.5	1.1	390	351	1280	390	741	2021	379	730	2010	310.7	305.4	310.6	305.3				
Feb-75	1975	2	1975	1804	373	1431	1.3	1.1	373	315	1091	373	688	1779	366	681	1772	310.5	305.1	310.5	305.1				
Mar-75	1975	3	1975	1665	364	1301	1.1	1.0	364	296	993	364	659	1652	359	655	1648	310.4	305.0	310.4	305.0				
Apr-75	1975	4	1975	1653	363	1290	1.1	1.0	363	294	984	363	657	1641	379	673	1657	310.4	305.0	310.5	305.0				
May-75	1975	5	1975	3774	549	3225	2.8	1.6	549	596	2460	549	1145	3605	1095	1691	4151	311.7	306.5	312.8	306.8				
Jun-75	1975	6	1975	13860	3521	10339	9.1	10.1	3521	2598	7886	3521	6118	14004	1363	3961	11847	318.2	310.8	316.0	310.1	-4.5	-2.8	-2.0	-2.1
Jul-75	1975	7	1975	14470	3709	10761	9.4	10.7	3709	2721	8207	3709	6430	14638	1413	4134	12341	318.5	311.0	316.2	310.3	-3.8	-2.5	-1.8	-1.8
Aug-75	1975	8	1975	7034	1322	5712	5.0	3.8	1322	1192	4357	1322	2514	6871	1357	2549	6906	314.1	308.2	314.2	308.2	-2.0	-1.2	-0.5	-0.7
Sep-75	1975	9	1975	6526	1164	5362	4.7	3.3	1164	1089	4090	1164	2253	6343	1365	2454	6544	313.7	308.0	314.0	308.1				
Oct-75	1975	10	1976	7734	1614	6120	5.4	4.6	1614	1355	4668	1614	2969	7636	1375	2729	7397	314.8	308.6	314.4	308.5				
Nov-75	1975	11	1976	4807	611	4196	3.7	1.8	611	736	3201	611	1346	4547	1494	2230	5430	312.1	307.1	313.7	307.5				
Dec-75	1975	12	1976	2710	425	2285	2.0	1.2	425	436	1743	425	861	2604	1460	1897	3640	311.0	305.8	313.1	306.5				
Jan-76	1976	1	1976	1787	372	1415	1.2	1.1	372	313	1079	372	684	1764	1640	1953	3032	310.5	305.1	313.2	306.1				
Feb-76	1976	2	1976	1348	339	1009	0.9	1.0	339	252	770	339	590	1360	1534	1785	2555	310.2	304.7	312.9	305.8				
Mar-76	1976	3	1976	990	307	683	0.6	0.9	307	201	521	307	508	1029	303	504	1025	309.9	304.3	309.9	304.3				

				Unregulated Monthly Flow		Estimated Monthly Runoff	Estimated Monthly Runoff Coefficient		Estimated Basin Runoff (cfs)			Estimated Lake Outflow - Pre-Project (cfs)			Estimated Lake Outflow - Post-Project (cfs)			Estimated Lake Level - Pre-Project (ft)		Estimated Lake Level - Post-Project (ft)		Pre- and Post-Project Lake Water Level Differential From Time of Spawning to Eggs Hatch (3-Month Spawning Period: June-Aug) (ft)			
Date	Year	Month	WY	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs)	NUYAKUK R less ALLEN R (cfs)	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs/mi^2)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs/mi^2)	Lake Chikuminuk (USGS 15301500 ALLEN R NR ALEKNAGIK AK) (cfs)	Lake Chauekuktuli (NW Passage gage) (cfs)	Tikchik/Nuyakuk Lake (USGS 15302000 NUYAKUK R NR DILLINGHAM AK) (cfs)	Lake Chikuminuk Outflow - Pre-Project (cfs)	Lake Chauekuktuli Outflow - Pre-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Pre-Project (cfs)	Lake Chikuminuk Outflow - Post-Project (cfs)	Lake Chauekuktuli Outflow - Post-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Post-Project (cfs)	Lake Chauekuktuli (pre): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (pre): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli (post): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (post): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli - Pre-Project	Tikchik/Nuyakuk Lake Pre-Project	Lake Chauekuktuli - Post-Project	Tikchik/Nuyakuk Lake - Post-Project
Apr-76	1976	4	1976	905	299	607	0.5	0.9	299	188	463	299	487	949	303	491	954	309.9	304.2	309.9	304.2				
May-76	1976	5	1976	2565	434	2131	1.9	1.2	434	422	1625	434	856	2481	825	1247	2872	311.0	305.7	311.9	306.0				
Jun-76	1976	6	1976	10990	2616	8374	7.3	7.5	2616	2012	6387	2616	4628	11015	1386	3398	9785	316.7	309.8	315.3	309.4	-0.6	-0.4	-0.3	-0.3
Jul-76	1976	7	1976	10860	2614	8246	7.2	7.5	2614	1996	6289	2614	4610	10899	1469	3465	9755	316.7	309.8	315.4	309.4	0.3	0.2	-0.1	0.1
Aug-76	1976	8	1976	8261	1857	6404	5.6	5.3	1857	1483	4884	1857	3340	8224	1398	2881	7765	315.2	308.8	314.6	308.6	-1.8	-1.0	-0.6	-0.6
Sep-76	1976	9	1976	9851	2329	7522	6.6	6.7	2329	1799	5737	2329	4128	9865	1375	3175	8912	316.2	309.4	315.0	309.1				
Oct-76	1976	10	1977	11400	2770	8630	7.6	8.0	2770	2103	6582	2770	4873	11455	1255	3358	9940	317.0	310.0	315.3	309.5				
Nov-76	1976	11	1977	6249	1037	5212	4.6	3.0	1037	1022	3975	1037	2059	6034	1457	2479	6454	313.4	307.8	314.1	308.0				
Dec-76	1976	12	1977	3983	489	3494	3.1	1.4	489	605	2665	489	1094	3759	1419	2024	4689	311.6	306.6	313.3	307.1				
Jan-77	1977	1	1977	3216	450	2766	2.4	1.3	450	503	2110	450	953	3063	1588	2092	4201	311.2	306.2	313.5	306.9				
Feb-77	1977	2	1977	2654	423	2231	2.0	1.2	423	429	1702	423	852	2554	1531	1960	3662	311.0	305.8	313.2	306.5				
Mar-77	1977	3	1977	2026	387	1639	1.4	1.1	387	345	1250	387	732	1982	1503	1848	3098	310.6	305.3	313.0	306.2				
Apr-77	1977	4	1977	1623	361	1262	1.1	1.0	361	290	963	361	651	1614	362	652	1615	310.4	305.0	310.4	305.0				
May-77	1977	5	1977	2894	446	2448	2.1	1.3	446	464	1867	446	910	2777	751	1215	3082	311.1	305.9	311.8	306.2				
Jun-77	1977	6	1977	18620	5117	13503	11.8	14.7	5117	3594	10299	5117	8711	19010	1325	4919	15218	320.4	312.2	317.1	311.2	-4.3	-2.8	-0.7	-1.7
Jul-77	1977	7	1977	26220	7611	18609	16.3	21.9	7611	5171	14193	7611	12782	26975	1796	6968	21161	323.3	314.1	319.0	312.8	-10.2	-6.4	-5.2	-4.9
Aug-77	1977	8	1977	24190	6897	17293	15.1	19.8	6897	4737	13190	6897	11634	24823	5935	10672	23861	322.5	313.6	321.9	313.4	-11.1	-7.2	-8.7	-6.4
Sep-77	1977	9	1977	9861	2281	7581	6.6	6.6	2281	1787	5782	2281	4068	9850	2478	4265	10047	316.1	309.4	316.3	309.5				
Oct-77	1977	10	1978	5923	902	5021	4.4	2.6	902	947	3830	902	1848	5678	1372	2319	6149	313.0	307.7	313.8	307.9				
Nov-77	1977	11	1978	3747	473	3274	2.9	1.4	473	573	2497	473	1046	3543	1353	1925	4422	311.4	306.5	313.2	307.0				
Dec-77	1977	12	1978	2523	416	2107	1.8	1.2	416	412	1607	416	828	2435	1315	1727	3334	310.9	305.7	312.8	306.3				
Jan-78	1978	1	1978	2332	406	1926	1.7	1.2	406	386	1469	406	792	2261	1465	1852	3321	310.8	305.6	313.1	306.3				
Feb-78	1978	2	1978	2075	391	1685	1.5	1.1	391	352	1285	391	742	2027	1406	1758	3043	310.7	305.4	312.9	306.1				
Mar-78	1978	3	1978	1900	379	1521	1.3	1.1	379	328	1160	379	707	1867	1374	1702	2862	310.6	305.2	312.8	306.0				
Apr-78	1978	4	1978	1910	379	1531	1.3	1.1	379	329	1168	379	708	1876	1349	1678	2846	310.6	305.2	312.7	306.0				
May-78	1978	5	1978	11320	2716	8604	7.5	7.8	2716	2078	6562	2716	4795	11357	1235	3314	9876	316.9	310.0	315.2	309.4				
Jun-78	1978	6	1978	14890	3826	11064	9.7	11.0	3826	2802	8438	3826	6629	15067	1225	4027	12466	318.7	311.1	316.1	310.3	-3.3	-2.2	-0.7	-1.4
Jul-78	1978	7	1978	15490	4018	11472	10.0	11.5	4018	2926	8750	4018	6944	15693	2330	5255	14005	319.0	311.3	317.4	310.8	-5.8	-3.6	-3.6	-2.9
Aug-78	1978	8	1978	8829	1975	6854	6.0	5.7	1975	1582	5228	1975	3557	8785	1918	3500	8727	315.5	309.0	315.4	309.0	-3.1	-1.7	-1.9	-1.3
Sep-78	1978	9	1978	8593	1926	6667	5.8	5.5	1926	1541	5085	1926	3467	8552	1940	3481	8566	315.4	308.9	315.4	308.9				
Oct-78	1978	10	1979	6037	938	5099	4.5	2.7	938	970	3889	938	1908	5797	1308	2278	6167	313.1	307.7	313.8	307.9				
Nov-78	1978	11	1979	5325	706	4619	4.0	2.0	706	823	3523	706	1529	5052	1349	2172	5695	312.5	307.3	313.6	307.7				
Dec-78	1978	12	1979	4467	527	3940	3.5	1.5	527	673	3005	527	1199	4205	1309	1981	4987	311.8	306.9	313.3	307.3				
Jan-79	1979	1	1979	3333	455	2878	2.5	1.3	455	519	2195	455	973	3169	1456	1975	4170	311.3	306.2	313.3	306.9				
Feb-79	1979	2	1979	2336	405	1931	1.7	1.2	405	387	1473	405	792	2265	1397	1784	3257	310.8	305.6	312.9	306.3				
Mar-79	1979	3	1979	1881	378	1503	1.3	1.1	378	326	1146	378	703	1850	1365	1690	2837	310.6	305.2	312.8	306.0				
Apr-79	1979	4	1979	2309	404	1905	1.7	1.2	404	383	1453	404	787	2240	1338	1722	3175	310.8	305.5	312.8	306.2				
May-79	1979	5	1979	6930	1356	5574	4.9	3.9	1356	1189	4251	1356	2545	6797	1260	2449	6700	314.2	308.2	314.0	308.1				
Jun-79	1979	6	1979	18580	5006	13574	11.9	14.4	5006	3560	10353	5006	8566	18919	1223	4782	15135	320.3	312.2	316.9	311.2	-4.7	-3.1	-1.2	-2.0
Jul-79	1979	7	1979	14540	3722	10818	9.5	10.7	3722	2733	8251	3722	6455	14706	2153	4886	13137	318.5	311.0	317.0	310.6	-1.2	-0.8	0.2	-0.4
Aug-79	1979	8	1979	14420	3708	10712	9.4	10.7	3708	2715	8170	3708	6423	14593	3848	6562	14733	318.5	311.0	318.6	311.0	-2.8	-1.8	-2.8	-1.8
Sep-79	1979	9	1979	9039	2007	7032	6.2	5.8	2007	1616	5363	2007	3623	8986	2136	3752	9115	315.6	309.1	315.8	309.2				
Oct-79	1979	10	1980	12040	2963	9077	7.9	8.5	2963	2231	6923	2963	5194	12117	2841	5071	11994	317.3	310.2	317.2	310.2				
Nov-79	1979	11	1980	9192	2092	7100	6.2	6.0	2092	1657	5415	2092	3749	9164	2166	3823	9238	315.8	309.2	315.8	309.2				
Dec-79	1979	12	1980	4693	654	4039	3.5	1.9	654	734	3080	654	1388	4469	1281	2015	5095	312.2	307.0	313.3	307.4				
Jan-80	1980	1	1980	2820	431	2389	2.1	1.2	431	451	1822	431	882	2704	1424	1875	3697	311.0	305.9	313.1	306.6				
Feb-80	1980	2	1980	2678	424	2254	2.0	1.2	424	433	1719	424	857	2576	1318	1751	3470	311.0	305.8	312.9	306.4				
Mar-80	1980	3	1980	2495	414	2081	1.8	1.2	414	408	1587	414	823	2409	1329	1737	3324	310.9	305.7	312.9	306.3				
Apr-80	1980	4	1980	2496	414	2082	1.8	1.2	414	408	1588	414	823	2410	1302	1710	3298	310.9	305.7	312.8	306.3				
May-80	1980	5	1980	6748	1400	5348	4.7	4.0	1400	1180	4079	1400	2580	6659	1324	2504	6582	314.2	308.1	314.1	308.1				
Jun-80	1980	6	1980	20160	5523	14637	12.8	15.9	5523	3887	11164	5523	9410	20574	1676	5563	16726	321.0	312.6	317.7	311.6	-8.0	-5.0	-3.9	-3.7
Jul-80	1980	7	1980	18650	5026	13624	11.9	14.4	5026	3574	10391	5026	8600	18991	4387	7960	18351	320.3	312.2	319.8	312.1	-5.9	-3.8	-5.5	-3.7
Aug-80	1980	8	1980	10470	2476	7994	7.0	7.1	2476	1913	6097	2476	4389	10486	2472	4385	10482	316.5	309.7	316.5	309.7	-3.1	-1.9	-2.6	-1.7
Sep-80	1980	9	1980	5877	885	4992	4.4	2.5	885	937	3807	885	1822	5630	1379	2316	6123	313.0	307.6	313.8	307.9				
Oct-80	1980	10	1981	7480	1486	5994	5.2	4.3	1486	1290	4572	1486	2775	7347	1376	2666	7238	314.5	308.4	314.3	308.4				
Nov-80	1980	11	1981	6170	1031	5139	4.5	3.0	1031	1011	3920	1031	2042	5962	1339	2350	6270	313.4	307.8	313.9	307.9				
Dec-80	1980	12	1981	3045	440	2605	2.3	1.3	440	480	1987	440	921	2907	1300	1781	3768	311.1	306.0	312.9	306.6				
Jan-81	1981	1	1981	2756	428	2328	2.0	1.2	428	443	1776	428	871	2646	1447	1890	3666	311.0	305.9	313.1	306.5				
Feb-81	1981	2	1981	2850	433	2417	2.1	1.2	433	455	1844	433	888	2732	1387	1843	3687	311.1	305.9	313.0	306.6				
Mar-81	1981	3	1981	2615	421	2194	1.9	1.2	421	424	1673	421	845	2519	1353	1778	3451	310.9	305.8	312.9	306.4				
Apr-81	1981	4	1981	2497	415	2083	1.8	1.2	415	408	1588	415	823	2411	1326	1735	3323	310.9	305.7	312.8	306.3				
May-81	1981	5	1981	6988	1452	5536	4.8	4.2	1452	1222	4222	1452	2674	6897	1246	2469	6691	314.3	308.2	314.0	308.1				
Jun-81	1981	6	1981	18370	4934	13436	11.8	14.2	4934	3515	10247	4934	8450	18697	1212	4728	14975	320.2	312.1	316.9	311.1	-6.7	-4.2	-2.9	-3.1
Jul-81	1981	7	1981	12410	3073	9337	8.2	8.8	3073	2304	7122	3073	5377	12498	1961	4265	11387	317.5	310.3	316.3	310.0	-5.8	-3.6	-3.2	-2.8
Aug-81	1981	8	1981	8600	1935	6665	5.8	5.6	1935	1544	5083	1935	3480	8563	1870	3414	8497	315.4	308.9	315.3	308.9	-3.6	-2.1	-2.0	-1.6
Sep-81	1981	9	1981	6442	1096	5346	4.7	3.1	1096	1061	4077	1096	2157	6234	1347	2408	6485	313.6	307.9	314.0	308.0				
Oct-81	1981	10	1982	4268	526	3742	3.3	1.5	526	649	2854	526	1175	4029	1273	1921	4775	311.7	306.8	313.2	307.2				
Nov-81	1981	11	1982	4489	530	3959	3.5	1.5	530	676	3019	530	1206	4226	1371	2047	5066	311.8	306.9	313.4	307.3				
Dec-81	1981	12	1982	3095	444	2651	2.3	1.3	444	487	2022	444	931	2953	1333	1820	3842	311.2	306.1	313.0	306.7				
Jan-82	1982	1	1982	2303	404	1899	1.7	1.2	404	383	1448	404	786	2235	1486	1869	3317	310.8	305.5	313.1	306.3				
Feb-82	1982	2	1982	2604	419	2185	1.9	1.2	419	423	1666	419	842	2508	1427	1849	3516	310.9	305.7	313.0	306.5				
Mar-82	1982	3	1982	2248	401	1847	1.6	1.2	401	375	1409	401	776	2185	1395	1770	3179	310.8	305.5	312.9	306.2				
Apr-82	1982	4	1982	1977	384	1593	1.4	1.1	384	339	1215	384	723	1938	1370	1708	2923	310.6	305.3	312.8	306.1				
May-82	1982	5	1982	3706	626	3080	2.7	1.8	626	609	2349	626	1235	3584	1310	1919	4268	311.9	306.5	313.2	306.9				
Jun-82	1982	6	1982	17980	4829	13151	11.5	13.9	4829	3441	10030	4829	8270	18300	1270	4711	14741	320.1	312.0	316.8	311.0	-3.0	-2.0	0.5	-0.9
Jul-82	1982	7	1982	18950	5152	13798	12.1	14.8	5152	3643	10523	5152	8796	19319	1545	5188	15711	320.5	312.3	317.3	311.3	-3.2	-2.1	-0.6	-1.3
Aug-82	1982	8	1982	8398	1800	6598	5.8	5.2	1800	1484	5032	1800	3284	8316	1585	3069	8101	315.2	308.8	314.9	308.8	-3.1	-1.8	-1.5	-1.3
Sep-82	1982	9	1982	11660	2772	8888	7.8	8.0	2772	2134	6779	2772	4906	11685	3075	5209	11988	317.0	310.1	317.4	310.2				
Oct-82	1982	10	1983	12100	2959	9141	8.0	8.5	2959	2237	6972	2959	5195	12167	2422	4659	11631	317.3	310.2	316.8	310.1				
Nov-82	1982	11	1983	4815	584	4231	3.7	1.7	584	729	3227	584	1314	4541	1338	2068	5294	312.0	307.1	313.4	307.5				
Dec-82	1982	12	1983	3310	454	2856	2.5	1.3	454	516	2178	454	969	3148	1299	1815	3993	311.3	306.2	313.0	306.7				
Jan-83	1983	1	1983	2844	432	2412	2.1	1.2	432	454	1839	432	887	2726	1446	1900	3740	311.1	305.9	313.1	306.6				
Feb-83	1983	2	1983	2379	408	1971	1.7	1.2	408	393	1504	408	800	2304	1387	1779	3283	310.8	305.6	312.9	306.3				
Mar-83	1983	3	1983	1913	380	1533	1.3	1.1	380	330	1169	380	710	1879	1354	1683	2853	310.6	305.2	312.8	306.0				
Apr-83	1983	4	1983	1936	381	1555	1.4	1.1	381	333	1186	381	713	1900	1328	1660	2847	310.6	305.2	312.7	306.0				
May-83	1983	5	1983	6349	1278	5071	4.4	3.7	1278	1099	3867	1278	2378	6245	1251	2351	6218	313.9	307.9	313.9	307.9				
Jun-83	1983	6	1983	19230	5216	14014	12.3	15.0	5216	3694	10689	5216	8909	19598	1212	4905	15594	320.6	312.4	317.0	311.3	-9.0	-5.7	-3.9	-4.1
Jul-83	1983	7	1983	13920	3537	10383	9.1	10.2	3537	2609	7919	3537	6146	14065	2338	4947	12866	318.3	310.8	317.1	310.5	-6.6	-4.1	-3.9	-3.2
Aug-83	1983	8	1983	7060	1348	5712	5.0	3.9	1348	1203	4356	1348	2551	6907	1497	2700	7056	314.2	308.2	314.4	308.3	-2.7	-1.7	-1.1	-1.2

Date	Year	Month	WY	Unregulated Monthly Flow: USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs)	Unregulated Monthly Flow: USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs)	Estimated Monthly Runoff: NUYAKUK R less ALLEN R (cfs)	Estimated Monthly Runoff Coefficient: USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs/mi^2)	Estimated Monthly Runoff Coefficient: USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs/mi^2)	Estimated Basin Runoff (cfs): Lake Chikuminuk (USGS 15301500 ALLEN R NR ALEKNAGIK AK) (cfs)	Estimated Basin Runoff (cfs): Lake Chauekuktuli (NW Passage gage) (cfs)	Estimated Basin Runoff (cfs): Tikchik/Nuyakuk Lake (USGS 15302000 NUYAKUK R NR DILLINGHAM AK) (cfs)	Estimated Lake Outflow - Pre-Project (cfs): Lake Chikuminuk Outflow - Pre-Project (cfs)	Estimated Lake Outflow - Pre-Project (cfs): Lake Chauekuktuli Outflow - Pre-Project (cfs)	Estimated Lake Outflow - Pre-Project (cfs): Tikchik/Nuyakuk Lake Outflow - Pre-Project (cfs)	Estimated Lake Outflow - Post-Project (cfs): Lake Chikuminuk Outflow - Post-Project (cfs)	Estimated Lake Outflow - Post-Project (cfs): Lake Chauekuktuli Outflow - Post-Project (cfs)	Estimated Lake Outflow - Post-Project (cfs): Tikchik/Nuyakuk Lake Outflow - Post-Project (cfs)	Estimated Lake Level - Pre-Project (ft): Lake Chauekuktuli (pre): EL = 318.78-12.47+0.186*Q^0.4772	Estimated Lake Level - Pre-Project (ft): Tikchik/Nuyakuk Lake (pre): EL = 301.59+0.1102*Q^0.4638	Estimated Lake Level - Post-Project (ft): Lake Chauekuktuli (post): EL = 318.78-12.47+0.186*Q^0.4772	Estimated Lake Level - Post-Project (ft): Tikchik/Nuyakuk Lake (post): EL = 301.59+0.1102*Q^0.4638	Pre- and Post-Project Lake Water Level Differential From Time of Spawning to Eggs Hatch (3-Month Spawning Period: June-Aug) (ft): Lake Chauekuktuli - Pre-Project	Tikchik/Nuyakuk Lake Pre-Project	Lake Chauekuktuli - Post-Project	Tikchik/Nuyakuk Lake - Post-Project
Sep-83	1983	9	1983	4167	494	3673	3.2	1.4	494	628	2802	494	1122	3923	1254	1882	4684	311.6	306.7	313.1	307.1				
Oct-83	1983	10	1984	4282	496	3786	3.3	1.4	496	642	2887	496	1139	4026	1286	1928	4816	311.7	306.8	313.2	307.2				
Nov-83	1983	11	1984	3857	481	3376	3.0	1.4	481	588	2575	481	1069	3644	1389	1977	4552	311.5	306.5	313.3	307.1				
Dec-83	1983	12	1984	6500	1108	5392	4.7	3.2	1108	1071	4113	1108	2179	6292	1334	2405	6518	313.6	308.0	313.9	308.1				
Jan-84	1984	1	1984	4005	494	3511	3.1	1.4	494	609	2678	494	1103	3781	1485	2093	4771	311.6	306.6	313.5	307.2				
Feb-84	1984	2	1984	2759	428	2331	2.0	1.2	428	443	1778	428	871	2649	1377	1821	3599	311.0	305.9	313.0	306.5				
Mar-84	1984	3	1984	2097	392	1705	1.5	1.1	392	355	1301	392	746	2047	1393	1747	3048	310.7	305.4	312.9	306.1				
Apr-84	1984	4	1984	1817	374	1443	1.3	1.1	374	317	1101	374	691	1791	1368	1685	2786	310.5	305.1	312.8	306.0				
May-84	1984	5	1984	4085	697	3388	3.0	2.0	697	673	2584	697	1370	3954	1406	2079	4663	312.1	306.7	313.4	307.1				
Jun-84	1984	6	1984	13060	3283	9777	8.6	9.4	3283	2438	7457	3283	5721	13178	1301	3739	11196	317.9	310.6	315.7	309.9	-6.2	-3.9	-2.5	-2.8
Jul-84	1984	7	1984	13620	3450	10170	8.9	9.9	3450	2550	7756	3450	6000	13757	1357	3907	11664	318.1	310.7	315.9	310.1	-5.9	-3.6	-2.6	-2.6
Aug-84	1984	8	1984	6407	1106	5301	4.6	3.2	1106	1060	4043	1106	2166	6209	1308	2367	6410	313.6	307.9	313.9	308.0	-2.5	-1.9	-0.7	-1.3
Sep-84	1984	9	1984	4099	503	3596	3.1	1.4	503	622	2743	503	1125	3868	1328	1951	4694	311.6	306.7	313.2	307.1				
Oct-84	1984	10	1985	4933	640	4293	3.8	1.8	640	759	3274	640	1399	4673	1262	2021	5295	312.2	307.1	313.3	307.5				
Nov-84	1984	11	1985	2950	437	2513	2.2	1.3	437	468	1917	437	905	2822	1485	1953	3870	311.1	306.0	313.2	306.7				
Dec-84	1984	12	1985	2281	402	1879	1.6	1.2	402	379	1433	402	782	2215	1451	1831	3264	310.8	305.5	313.0	306.3				
Jan-85	1985	1	1985	2205	398	1807	1.6	1.1	398	369	1378	398	767	2145	1629	1998	3376	310.7	305.5	313.3	306.4				
Feb-85	1985	2	1985	2527	416	2111	1.8	1.2	416	412	1610	416	828	2438	1572	1985	3595	310.9	305.7	313.3	306.5				
Mar-85	1985	3	1985	1823	374	1449	1.3	1.1	374	318	1105	374	692	1797	359	677	1782	310.5	305.2	310.5	305.1				
Apr-85	1985	4	1985	1350	339	1011	0.9	1.0	339	252	771	339	591	1362	320	572	1343	310.2	304.7	310.2	304.7				
May-85	1985	5	1985	1817	367	1450	1.3	1.1	367	315	1106	367	682	1788	497	812	1918	310.5	305.1	310.9	305.3				
Jun-85	1985	6	1985	14040	3564	10476	9.2	10.2	3564	2631	7990	3564	6195	14185	1362	3993	11982	318.3	310.9	316.0	310.2	-3.3	-2.1	-1.6	-1.6
Jul-85	1985	7	1985	16710	4426	12284	10.8	12.7	4426	3181	9369	4426	7606	16976	1391	4572	13941	319.5	311.7	316.7	310.8	-4.4	-2.9	-2.2	-2.2
Aug-85	1985	8	1985	11210	2714	8496	7.4	7.8	2714	2065	6480	2714	4779	11259	1303	3368	9848	316.9	309.9	315.3	309.4	-4.9	-2.9	-1.8	-1.9
Sep-85	1985	9	1985	8146	1748	6398	5.6	5.0	1748	1440	4880	1748	3188	8068	1295	2734	7614	315.0	308.7	314.4	308.5				
Oct-85	1985	10	1986	8212	1798	6414	5.6	5.2	1798	1461	4892	1798	3259	8151	1298	2759	7651	315.1	308.8	314.5	308.6				
Nov-85	1985	11	1986	4790	594	4196	3.7	1.7	594	729	3201	594	1323	4523	1400	2129	5330	312.1	307.1	313.5	307.5				
Dec-85	1985	12	1986	3555	465	3090	2.7	1.3	465	548	2357	465	1012	3369	1362	1910	4267	311.4	306.4	313.2	306.9				
Jan-86	1986	1	1986	2823	431	2392	2.1	1.2	431	452	1824	431	883	2707	1520	1972	3796	311.0	305.9	313.3	306.6				
Feb-86	1986	2	1986	2221	399	1822	1.6	1.1	399	372	1390	399	771	2160	1462	1834	3223	310.7	305.5	313.0	306.3				
Mar-86	1986	3	1986	1981	385	1596	1.4	1.1	385	339	1218	385	724	1941	1432	1771	2988	310.6	305.3	312.9	306.1				
Apr-86	1986	4	1986	1823	374	1449	1.3	1.1	374	318	1105	374	692	1797	1409	1726	2831	310.5	305.2	312.8	306.0				
May-86	1986	5	1986	2708	433	2275	2.0	1.2	433	439	1735	433	872	2607	1354	1792	3527	311.0	305.8	312.9	306.5				
Jun-86	1986	6	1986	10760	2565	8195	7.2	7.4	2565	1971	6250	2565	4536	10786	1364	3335	9585	316.6	309.8	315.2	309.3	-0.1	-0.1	-0.2	-0.1
Jul-86	1986	7	1986	15170	3919	11251	9.9	11.3	3919	2861	8581	3919	6780	15361	1409	4270	12851	318.8	311.2	316.4	310.5	-3.0	-2.0	-1.6	-1.6
Aug-86	1986	8	1986	11050	2666	8384	7.3	7.7	2666	2033	6394	2666	4699	11093	1320	3353	9747	316.8	309.9	315.3	309.4	-2.2	-1.4	-0.9	-1.0
Sep-86	1986	9	1986	10440	2489	7951	7.0	7.2	2489	1913	6064	2489	4402	10466	1295	3207	9271	316.5	309.7	315.1	309.2				
Oct-86	1986	10	1987	9273	2159	7114	6.2	6.2	2159	1685	5426	2159	3843	9269	1291	2976	8402	315.9	309.2	314.8	308.9				
Nov-86	1986	11	1987	7477	1544	5933	5.2	4.4	1544	1305	4525	1544	2849	7374	1366	2671	7197	314.6	308.4	314.3	308.4				
Dec-86	1986	12	1987	3397	458	2939	2.6	1.3	458	527	2242	458	985	3226	1328	1855	4097	311.3	306.3	313.1	306.8				
Jan-87	1987	1	1987	2700	425	2275	2.0	1.2	425	435	1735	425	860	2595	1480	1915	3650	311.0	305.8	313.2	306.5				
Feb-87	1987	2	1987	2207	398	1809	1.6	1.1	398	370	1379	398	768	2148	1421	1791	3170	310.7	305.5	312.9	306.2				
Mar-87	1987	3	1987	2048	389	1659	1.5	1.1	389	348	1265	389	737	2003	1389	1737	3002	310.7	305.3	312.8	306.1				
Apr-87	1987	4	1987	1933	381	1552	1.4	1.1	381	333	1183	381	714	1897	1364	1697	2880	310.6	305.2	312.8	306.0				
May-87	1987	5	1987	3340	500	2840	2.5	1.4	500	532	2166	500	1032	3198	1307	1838	4004	311.4	306.2	313.0	306.8				
Jun-87	1987	6	1987	17260	4623	12637	11.1	13.3	4623	3299	9638	4623	7922	17561	1274	4573	14211	319.8	311.8	316.7	310.9	-6.0	-3.8	-2.4	-2.7
Jul-87	1987	7	1987	22850	6438	16412	14.4	18.5	6438	4454	12517	6438	10892	23410	2829	7283	19800	322.0	313.3	319.3	312.4	-7.1	-4.7	-4.3	-3.8
Aug-87	1987	8	1987	12830	3210	9620	8.4	9.2	3210	2391	7337	3210	5601	12938	2851	5242	12580	317.7	310.5	317.4	310.4	-4.9	-3.0	-3.7	-2.6
Sep-87	1987	9	1987	6660	1181	5479	4.8	3.4	1181	1110	4179	1181	2290	6470	1550	2659	6839	313.8	308.0	314.3	308.2				
Oct-87	1987	10	1988	7928	1698	6230	5.5	4.9	1698	1400	4752	1698	3098	7850	1696	3096	7848	314.9	308.6	314.9	308.6				
Nov-87	1987	11	1988	5567	862	4705	4.1	2.5	862	894	3589	862	1756	5344	1339	2233	5822	312.9	307.5	313.7	307.7				
Dec-87	1987	12	1988	3284	453	2831	2.5	1.3	453	512	2159	453	965	3124	1301	1813	3972	311.2	306.2	313.0	306.7				
Jan-88	1988	1	1988	2603	420	2183	1.9	1.2	420	423	1665	420	843	2508	1448	1870	3535	310.9	305.7	313.1	306.5				
Feb-88	1988	2	1988	2452	412	2040	1.8	1.2	412	402	1556	412	815	2370	1342	1744	3300	310.9	305.6	312.9	306.3				
Mar-88	1988	3	1988	2197	398	1799	1.6	1.1	398	368	1372	398	766	2138	1355	1723	3095	310.7	305.5	312.8	306.2				
Apr-88	1988	4	1988	1967	384	1583	1.4	1.1	384	337	1208	384	721	1929	1329	1666	2873	310.6	305.3	312.7	306.0				
May-88	1988	5	1988	4958	877	4081	3.6	2.5	877	826	3112	877	1703	4815	1362	2188	5300	312.8	307.2	313.6	307.5				
Jun-88	1988	6	1988	20400	5638	14762	12.9	16.2	5638	3947	11259	5638	9585	20844	1214	5161	16419	321.1	312.7	317.3	311.5	-4.1	-2.7	-0.4	-1.6
Jul-88	1988	7	1988	18920	5131	13789	12.1	14.7	5131	3634	10517	5131	8765	19282	3631	7265	17782	320.5	312.3	319.3	311.9	-5.4	-3.6	-4.0	-3.1
Aug-88	1988	8	1988	12280	3031	9249	8.1	8.7	3031	2277	7055	3031	5308	12363	3201	5479	12533	317.5	310.3	317.6	310.4	-3.9	-2.4	-3.6	-2.3
Sep-88	1988	9	1988	11320	2750	8570	7.5	7.9	2750	2088	6536	2750	4837	11374	2729	4817	11353	317.0	310.0	316.9	310.0				
Oct-88	1988	10	1989	8065	1765	6300	5.5	5.1	1765	1435	4805	1765	3200	8005	1898	3333	8138	315.1	308.7	315.2	308.8				
Nov-88	1988	11	1989	6400	1076	5324	4.7	3.1	1076	1051	4061	1076	2127	6187	1412	2463	6523	313.5	307.9	314.0	308.1				
Dec-88	1988	12	1989	3719	480	3239	2.8	1.4	480	571	2471	480	1051	3521	1294	1865	4336	311.5	306.5	313.1	306.9				
Jan-89	1989	1	1989	2781	429	2352	2.1	1.2	429	446	1794	429	875	2669	1439	1885	3679	311.0	305.9	313.1	306.6				
Feb-89	1989	2	1989	2036	388	1648	1.4	1.1	388	347	1257	388	735	1992	1381	1727	2984	310.6	305.3	312.8	306.1				
Mar-89	1989	3	1989	2000	386	1614	1.4	1.1	386	342	1231	386	728	1959	1347	1689	2920	310.6	305.3	312.8	306.1				
Apr-89	1989	4	1989	1797	373	1424	1.2	1.1	373	314	1086	373	687	1773	1321	1635	2722	310.5	305.1	312.7	305.9				
May-89	1989	5	1989	3410	499	2911	2.5	1.4	499	540	2221	499	1038	3259	1264	1803	4024	311.4	306.3	313.0	306.8				
Jun-89	1989	6	1989	16010	4214	11796	10.3	12.1	4214	3040	8997	4214	7254	16251	1244	4285	13282	319.2	311.5	316.4	310.6	0.4	0.3	3.0	1.1
Jul-89	1989	7	1989	13570	3434	10136	8.9	9.9	3434	2540	7730	3434	5974	13705	1300	3840	11570	318.1	310.7	315.9	310.0	-0.3	-0.2	1.7	0.4
Aug-89	1989	8	1989	9173	2154	7019	6.1	6.2	2154	1671	5354	2154	3825	9179	1695	3366	8720	315.8	309.2	315.3	309.0	-2.5	-1.5	-1.2	-1.1
Sep-89	1989	9	1989	17070	4519	12551	11.0	13.0	4519	3249	9572	4519	7768	17341	4206	7455	17027	319.7	311.8	319.4	311.7				
Oct-89	1989	10	1990	13010	3273	9737	8.5	9.4	3273	2430	7427	3273	5702	13129	2986	5416	12842	317.8	310.5	317.6	310.5				
Nov-89	1989	11	1990	5978	1038	4940	4.3	3.0	1038	990	3767	1038	2029	5796	1485	2475	6243	313.4	307.7	314.1	307.9				
Dec-89	1989	12	1990	3272	452	2820	2.5	1.3	452	511	2151	452	963	3114	1292	1803	3954	311.2	306.2	313.0	306.7				
Jan-90	1990	1	1990	2761	428	2333	2.0	1.2	428	443	1779	428	872	2651	1438	1881	3661	311.0	305.9	313.1	306.5				
Feb-90	1990	2	1990	2243	400	1843	1.6	1.1	400	374	1406	400	775	2180	1379	1753	3159	310.8	305.5	312.9	306.2				
Mar-90	1990	3	1990	1881	378	1503	1.3	1.1	378	326	1146	378	704	1850	1346	1671	2817	310.6	305.2	312.7	306.0				
Apr-90	1990	4	1990	2160	395	1765	1.5	1.1	395	363	1346	395	759	2105	1319	1682	3028	310.7	305.4	312.8	306.1				
May-90	1990	5	1990	3777	533	3244	2.8	1.5	533	593	2474	533	1126	3600	1261	1853	4327	311.6	306.5	313.1	306.9				
Jun-90	1990	6	1990	13030	3273	9757	8.5	9.4	3273	2432	7442	3273	5705	13147	1260	3692	11134	317.8	310.6	315.7	309.9	-3.2	-2.0	-1.4	-1.5
Jul-90	1990	7	1990	8359	1793	6566	5.7	5.2	1793	1477	5008	1793	3270	8278	1356	2833	7841	315.2	308.8	314.6	308.6	-0.6	-0.3	-0.3	-0.3
Aug-90	1990	8	1990	7373	1448	5925	5.2	4.2	1448	1267	4519	1448	2715	7234	1299	2566	7085	314.4	308.4	314.2	308.3	-2.7	-1.6	-0.8	-1.1
Sep-90	1990	9	1990	7651	1540	6111	5.4	4.4	1540	1325	4661	1540	2865	7526	1296	2621	7282	314.6	308.5	314.3	308.4				
Oct-90	1990	10	1991	7569	1536	6033	5.3	4.4	1536	1314	4602	1536	2849	7451	1306	2620	7221	314.6	308.5	314.3	308.4				
Nov-90	1990	11	1991	4247	529	3718	3.3	1.5	529	647	2835	529	1177	4012	1411	2059	4894	311.7	306.8	313.4	307.3				
Dec-90	1990	12	1991	2796	430	2366	2.1	1.2	430	448	1805	430	878	2683	1375	1823	3628	311.0	305.9	313.0	306.5				
Jan-91	1991	1	1991	2419	410	2009	1.8	1.2	410	398	1532	410	808	2340	1536	1934	3466	310.8	305.6	313.2	306.4				

				Unregulated Monthly Flow		Estimated Monthly Runoff	Estimated Monthly Runoff Coefficient		Estimated Basin Runoff (cfs)			Estimated Lake Outflow - Pre-Project (cfs)			Estimated Lake Outflow - Post-Project (cfs)			Estimated Lake Level - Pre-Project (ft)		Estimated Lake Level - Post-Project (ft)		Pre- and Post-Project Lake Water Level Differential From Time of Spawning to Eggs Hatch (3-Month Spawning Period: June-Aug) (ft)			
Date	Year	Month	WY	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs)	NUYAKUK R less ALLEN R (cfs)	USGS 15302000 NUYAKUK R NR DILLINGHAM AK (cfs/mi^2)	USGS 15301500 ALLEN R NR ALEKNAGIK AK (cfs/mi^2)	Lake Chikuminuk (USGS 15301500 ALLEN R NR ALEKNAGIK AK) (cfs)	Lake Chauekuktuli (NW Passage gage) (cfs)	Tikchik/Nuyakuk Lake (USGS 15302000 NUYAKUK R NR DILLINGHAM AK) (cfs)	Lake Chikuminuk Outflow - Pre-Project (cfs)	Lake Chauekuktuli Outflow - Pre-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Pre-Project (cfs)	Lake Chikuminuk Outflow - Post-Project (cfs)	Lake Chauekuktuli Outflow - Post-Project (cfs)	Tikchik/Nuyakuk Lake Outflow - Post-Project (cfs)	Lake Chauekuktuli (pre): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (pre): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli (post): EL = 318.78-12.47+0.186*Q^0.4772	Tikchik/Nuyakuk Lake (post): EL = 301.59+0.1102*Q^0.4638	Lake Chauekuktuli - Pre-Project	Tikchik/Nuyakuk Lake - Pre-Project	Lake Chauekuktuli - Post-Project	Tikchik/Nuyakuk Lake - Post-Project
Feb-91	1991	2	1991	2179	397	1783	1.6	1.1	397	366	1360	397	762	2122	1478	1844	3204	310.7	305.4	313.0	306.2				
Mar-91	1991	3	1991	2045	389	1656	1.5	1.1	389	348	1263	389	737	2000	1448	1796	3059	310.7	305.3	313.0	306.1				
Apr-91	1991	4	1991	2300	404	1897	1.7	1.2	404	382	1446	404	786	2232	1425	1807	3254	310.8	305.5	313.0	306.3				
May-91	1991	5	1991	4687	749	3938	3.4	2.2	749	759	3004	749	1508	4511	1362	2121	5124	312.4	307.0	313.5	307.4				
Jun-91	1991	6	1991	14700	3778	10922	9.6	10.9	3778	2767	8330	3778	6545	14875	1336	4103	12433	318.6	311.1	316.2	310.3	-2.6	-1.7	-1.2	-1.2
Jul-91	1991	7	1991	9258	2159	7099	6.2	6.2	2159	1683	5414	2159	3842	9256	1429	3112	8526	315.9	309.2	314.9	308.9	2.2	1.5	0.9	1.1
Aug-91	1991	8	1991	7184	1374	5810	5.1	3.9	1374	1224	4431	1374	2599	7030	1372	2596	7027	314.2	308.3	314.2	308.3	-0.5	-0.4	-0.2	-0.2
Sep-91	1991	9	1991	9811	2185	7626	6.7	6.3	2185	1756	5816	2185	3941	9757	1357	3112	8928	316.0	309.4	314.9	309.1				
Oct-91	1991	10	1992	13350	3390	9960	8.7	9.7	3390	2502	7597	3390	5891	13488	1320	3822	11418	318.0	310.7	315.8	310.0				
Nov-91	1991	11	1992	6399	1162	5237	4.6	3.3	1162	1074	3994	1162	2236	6230	1411	2484	6479	313.7	307.9	314.1	308.0				
Dec-91	1991	12	1992	2748	426	2322	2.0	1.2	426	441	1771	426	867	2638	1374	1815	3586	311.0	305.8	313.0	306.5				
Jan-92	1992	1	1992	2006	386	1620	1.4	1.1	386	343	1235	386	729	1964	1536	1879	3114	310.6	305.3	313.1	306.2				
Feb-92	1992	2	1992	1869	377	1492	1.3	1.1	377	324	1138	377	701	1839	1429	1753	2891	310.6	305.2	312.9	306.0				
Mar-92	1992	3	1992	1732	368	1364	1.2	1.1	368	305	1040	368	673	1714	1449	1754	2794	310.5	305.1	312.9	306.0				
Apr-92	1992	4	1992	1810	373	1437	1.3	1.1	373	316	1096	373	688	1785	1427	1743	2839	310.5	305.1	312.9	306.0				
May-92	1992	5	1992	5474	1015	4459	3.9	2.9	1015	924	3401	1015	1939	5340	1455	2379	5781	313.2	307.5	313.9	307.7				
Jun-92	1992	6	1992	14570	3744	10826	9.5	10.8	3744	2742	8257	3744	6486	14743	1333	4075	12333	318.6	311.0	316.1	310.3	-2.4	-1.5	-1.2	-1.2
Jul-92	1992	7	1992	13410	3388	10022	8.8	9.7	3388	2508	7644	3388	5896	13540	1391	3899	11543	318.0	310.7	315.9	310.0	-6.0	-3.7	-2.8	-2.7
Aug-92	1992	8	1992	10240	2450	7790	6.8	7.0	2450	1878	5942	2450	4328	10269	1310	3188	9130	316.4	309.6	315.0	309.2	-5.3	-3.6	-1.9	-2.5
Sep-92	1992	9	1992	10040	2323	7717	6.8	6.7	2323	1820	5886	2323	4143	10029	1287	3107	8993	316.2	309.5	314.9	309.1				
Oct-92	1992	10	1993	4583	587	3996	3.5	1.7	587	703	3048	587	1290	4338	1219	1922	4970	312.0	306.9	313.2	307.3				
Nov-92	1992	11	1993	2893	434	2459	2.2	1.2	434	461	1875	434	895	2770	1431	1892	3767	311.1	305.9	313.1	306.6				
Dec-92	1992	12	1993	2213	398	1815	1.6	1.1	398	370	1384	398	769	2153	1396	1766	3150	310.7	305.5	312.9	306.2				
Jan-93	1993	1	1993	1932	381	1551	1.4	1.1	381	332	1183	381	714	1896	1562	1895	3077	310.6	305.2	313.1	306.2				
Feb-93	1993	2	1993	1804	373	1431	1.3	1.1	373	315	1091	373	688	1780	1505	1821	2912	310.5	305.1	313.0	306.0				
Mar-93	1993	3	1993	1816	374	1442	1.3	1.1	374	317	1100	374	691	1791	1477	1794	2894	310.5	305.1	313.0	306.0				
Apr-93	1993	4	1993	2692	422	2270	2.0	1.2	422	434	1731	422	856	2587	1455	1889	3620	311.0	305.8	313.1	306.5				
May-93	1993	5	1993	9715	2182	7533	6.6	6.3	2182	1743	5746	2182	3925	9671	1349	3092	8838	316.0	309.4	314.9	309.0				
Jun-93	1993	6	1993	19400	5274	14126	12.4	15.2	5274	3730	10774	5274	9004	19778	1287	5016	15790	320.7	312.4	317.2	311.3	-4.1	-2.8	-2.1	-2.1
Jul-93	1993	7	1993	12830	3200	9630	8.4	9.2	3200	2389	7345	3200	5589	12933	1349	3738	11083	317.7	310.5	315.7	309.9	-1.4	-0.9	-0.3	-0.6
Aug-93	1993	8	1993	8505	1935	6570	5.8	5.6	1935	1533	5011	1935	3468	8479	1282	2815	7826	315.4	308.9	314.5	308.6	-2.8	-1.5	-0.9	-1.0
Sep-93	1993	9	1993	10440	2490	7950	7.0	7.2	2490	1913	6064	2490	4403	10466	1258	3171	9234	316.5	309.7	315.0	309.2				
Oct-93	1993	10	1994	10130	2394	7736	6.8	6.9	2394	1850	5900	2394	4244	10144	1615	3465	9366	316.3	309.5	315.4	309.2				
Nov-93	1993	11	1994	5377	744	4633	4.1	2.1	744	839	3533	744	1584	5117	1342	2181	5715	312.6	307.4	313.6	307.7				
Dec-93	1993	12	1994	3600	467	3133	2.7	1.3	467	553	2390	467	1020	3410	1303	1856	4246	311.4	306.4	313.1	306.9				
Jan-94	1994	1	1994	2974	438	2536	2.2	1.3	438	472	1934	438	910	2844	1450	1921	3855	311.1	306.0	313.2	306.7				
Feb-94	1994	2	1994	2571	418	2153	1.9	1.2	418	418	1642	418	836	2478	1390	1809	3451	310.9	305.7	313.0	306.4				
Mar-94	1994	3	1994	2090	391	1699	1.5	1.1	391	354	1296	391	745	2041	1357	1711	3007	310.7	305.4	312.8	306.1				
Apr-94	1994	4	1994	2273	402	1871	1.6	1.2	402	378	1427	402	780	2207	1331	1709	3136	310.8	305.5	312.8	306.2				
May-94	1994	5	1994	5206	881	4325	3.8	2.5	881	856	3299	881	1737	5036	1264	2120	5419	312.9	307.3	313.5	307.5				
Jun-94	1994	6	1994	18230	4910	13320	11.7	14.1	4910	3492	10159	4910	8402	18561	1229	4721	14880	320.2	312.1	316.8	311.1	-5.7	-3.7	-1.9	-2.5
Jul-94	1994	7	1994	15370	3975	11395	10.0	11.4	3975	2900	8691	3975	6875	15566	2178	5077	13768	318.9	311.3	317.2	310.7	-2.0	-1.3	-0.7	-0.9
Aug-94	1994	8	1994	10520	2492	8028	7.0	7.2	2492	1923	6123	2492	4414	10538	2190	4113	10236	316.5	309.7	316.2	309.6	-3.3	-2.0	-2.3	-1.6
Sep-94	1994	9	1994	7543	1475	6068	5.3	4.2	1475	1294	4628	1475	2769	7397	1783	3077	7705	314.5	308.5	314.9	308.6				
Oct-94	1994	10	1995	11240	2722	8518	7.5	7.8	2722	2071	6497	2722	4792	11289	2328	4399	10896	316.9	309.9	316.5	309.8				
Nov-94	1994	11	1995	6050	948	5102	4.5	2.7	948	975	3891	948	1923	5814	1412	2387	6278	313.2	307.7	313.9	308.0				
Dec-94	1994	12	1995	4177	498	3679	3.2	1.4	498	631	2806	498	1129	3935	1293	1924	4730	311.6	306.7	313.2	307.2				
Jan-95	1995	1	1995	3177	448	2729	2.4	1.3	448	498	2081	448	946	3028	1438	1937	4018	311.2	306.1	313.2	306.8				
Feb-95	1995	2	1995	2393	409	1984	1.7	1.2	409	395	1513	409	803	2317	1379	1774	3287	310.8	305.6	312.9	306.3				
Mar-95	1995	3	1995	1965	384	1581	1.4	1.1	384	337	1206	384	720	1927	1346	1683	2889	310.6	305.3	312.8	306.0				
Apr-95	1995	4	1995	2365	406	1959	1.7	1.2	406	390	1494	406	796	2290	1319	1709	3204	310.8	305.6	312.8	306.2				
May-95	1995	5	1995	9564	2171	7393	6.5	6.2	2171	1723	5639	2171	3894	9532	1222	2945	8583	315.9	309.3	314.7	308.9				
Jun-95	1995	6	1995	18230	4891	13339	11.7	14.1	4891	3487	10174	4891	8378	18552	1244	4731	14904	320.2	312.1	316.9	311.1	-3.2	-2.1	0.4	-1.0
Jul-95	1995	7	1995	12770	3181	9589	8.4	9.1	3181	2376	7314	3181	5557	12871	2564	4940	12254	317.7	310.5	317.1	310.3	-0.8	-0.5	-0.5	-0.4
Aug-95	1995	8	1995	8641	1933	6708	5.9	5.6	1933	1549	5116	1933	3482	8598	1970	3519	8635	315.4	309.0	315.5	309.0	-1.5	-0.8	-1.1	-0.7
Sep-95	1995	9	1995	11420	2759	8661	7.6	7.9	2759	2102	6606	2759	4861	11466	2989	5091	11697	317.0	310.0	317.2	310.1				
Oct-95	1995	10	1996	11280	2727	8553	7.5	7.8	2727	2077	6523	2727	4804	11327	2413	4489	11013	316.9	310.0	316.6	309.8				
Nov-95	1995	11	1996	6793	1253	5541	4.9	3.6	1253	1145	4226	1253	2398	6623	1519	2664	6890	313.9	308.1	314.3	308.2				
Dec-95	1995	12	1996	3452	459	2993	2.6	1.3	459	534	2283	459	993	3276	1292	1825	4108	311.3	306.3	313.0	306.8				
Jan-96	1995	12	1996	2323	405	1918	1.7	1.2	405	385	1463	405	790	2253	1437	1822	3285	310.8	305.5	313.0	306.3				
Feb-96	1995	12	1996	2066	390	1676	1.5	1.1	390	351	1278	390	741	2019	1332	1683	2961	310.7	305.3	312.8	306.1				
Mar-96	1995	12	1996	2271	402	1869	1.6	1.2	402	378	1425	402	780	2206	1344	1723	3148	310.8	305.5	312.8	306.2				
Apr-96	1995	12	1996	2151	394	1757	1.5	1.1	394	362	1340	394	756	2096	1318	1680	3020	310.7	305.4	312.7	306.1				
May-96	1995	12	1996	6330	1254	5076	4.4	3.6	1254	1090	3871	1254	2344	6216	1342	2432	6303	313.9	307.9	314.0	308.0				
Jun-96	1995	12	1996	10623	2541	8083	7.1	7.3	2541	1948	6165	2541	4489	10654	1258	3207	9371	316.6	309.7	315.1	309.3				
Jul-96	1995	12	1996	8811	2018	6793	5.9	5.8	2018	1592	5181	2018	3610	8791	1349	2940	8122	315.6	309.0	314.7	308.8				
Aug-96	1995	12	1996	6420	1090	5330	4.7	3.1	1090	1057	4065	1090	2147	6212	1300	2357	6422	313.5	307.9	313.9	308.0				
Sep-96	1995	12	1996	4895	612	4283	3.8	1.8	612	747	3267	612	1359	4625	1317	2064	5330	312.1	307.1	313.4	307.5				

Chikuminuk Lake Hydroelectric Project
FERC No. 14369

Interim Feasibility Report
Volume I – Technical Studies

Appendix D – Probable Construction Cost

DRAFT April, 2014

Prepared By:

HATCH™

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D - Opinion of Probable Total Construction Cost, Summary

SUMMARY

ITEM			ESTIMATED COST
1. General			$35,000,000
2. Roads and Airstrip			$29,000,000
3. Roller Compacted Concrete Dam			$38,000,000
4. Waterways			
4.1	General Mobilization / Demobilization	$5,200,000	
4.2	Portal Construction	$9,600,000	
4.3	Tunnel Construction	$22,800,000	
4.4	Gate Shaft Construction	$7,600,000	
4.5	Penstock System	$4,300,000	
4.6	Intake Structure and Gate	$6,800,000	
			$56,000,000
5. Powerhouse			
5.1	Structure and Site Development	$23,700,000	
5.2	Mechanical and Electrical Equipment	$40,600,000	
			$64,000,000
6. Transmission Line			
6.1	Chikuminuk to Bethel	$114,400,000	
6.2	Chikuminuk to Dillingham	$30,800,000	
			$145,000,000
Subtotal - Direct Construction Cost			**$367,000,000**
7. Contingencies			$126,000,000
8. Administration and Management			$76,000,000
TOTAL CONSTRUCTION COST (2013 Dollars)			**$569,000,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D - Opinion of Probable Total Construction Cost, Detail

		Labor	Equip	Materials	Total	Quantity	Units	Unit Price	Price	Total Price
1	**General**									**$35,000,000**
1.1	Mobilization / Demobilization					1	Lump Sum	$13,800,000	$13,800,000	**$13,800,000**
1.2	Man Camp Construction					1	Lump Sum	$5,000,000	$5,000,000	**$5,000,000**
1.3	C-130 Flight Cost - Dam & Powerhouse, Equipment & materials delivery					1	Lump Sum	$3,718,500	$3,719,000	**$3,719,000**
1.4	C-130 Flight Cost - Fuel delivery					1	Lump Sum	$753,750	$754,000	**$754,000**
1.5	Allowance for Compensation, Mitigation and Enhancement					1	Lump Sum	$10,000,000	$10,000,000	**$10,000,000**
1.6	Equipment Rental During Non-use Period					1	Lump Sum	$2,100,000	$2,100,000	**$2,100,000**
2	**Roads and Airstrips**									**$29,000,000**
2.1	Airstrip					1	Lump Sum	$21,575,400	$21,575,000	**$21,575,000**
2.2	Roadway 1 - Airstrip to Camp					1	Lump Sum	$1,126,500	$1,127,000	**$1,127,000**
2.3	Roadway 2 - Camp to Float Plane					1	Lump Sum	$815,500	$816,000	**$816,000**
2.3	Roadway 3 - Camp to Powerhouse					1	Lump Sum	$1,859,800	$1,860,000	**$1,860,000**
2.3	Roadway 4 - Roadway 3 to Dam					1	Lump Sum	$2,051,000	$2,051,000	**$2,051,000**
2.4	Camp Pad					1	Lump Sum	$1,330,600	$1,331,000	**$1,331,000**
2.5	Float Plane and Boat Ramp					1	Lump Sum	$292,700	$293,000	**$293,000**
3	**Roller Compacted Concrete Dam**				**$37,710,000**					**$38,000,000**
3.1	Prep area / laydown	$432,000	$138,800	$61,900	$633,000					**$633,000**
3.2	Excavate dam foundation	$600,000	$173,000	$60,000	$833,000					**$833,000**
3.3	Erect batch plant	$1,200,000	$145,500	$240,000	$1,586,000					**$1,586,000**
3.4	Stockpile cement/ trial mixes	$432,000	$106,700	$86,400	$625,000					**$625,000**
3.5	RCC convential concrete	$10,080,000	$1,415,000	$17,001,300	$28,496,000					**$28,496,000**
3.6	Conveyor systems	$72,000	$273,600	$27,400	$373,000					**$373,000**
3.7	Cofferdams u/s & d/s and dewater	$360,000	$137,400	$1,864,000	$2,361,000					**$2,361,000**
3.8	Consolidation Grouting	$1,080,000	$118,500	$37,200	$1,236,000					**$1,236,000**
3.9	Curtain Grouting	$1,296,000	$142,200	$128,700	$1,567,000					**$1,567,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D - Opinion of Probable Total Construction Cost, Detail

		Labor	Equip	Materials	Total	Quantity	Units	Unit Price	Price	Total Price
4	**Waterways**									**$56,000,000**
4.1	General Mobilization / Demobilization								$5,190,000	**$5,190,000**
4.1.1	Mobilization - Lower 48 to Dillingham					1	Lump Sum	$1,129,659	$1,130,000	**$1,130,000**
4.1.2	Mobilization - Dillingham to Lower 48					1	Lump Sum	$1,588,582	$1,589,000	**$1,589,000**
4.1.3	Demobilization - Lower 48 to Dillingham					1	Lump Sum	$1,482,677	$1,483,000	**$1,483,000**
4.1.4	Demobilization - Dillingham to Lower 48					1	Lump Sum	$988,451	$988,000	**$988,000**
4.2	Portal Construction								$9,622,000	**$9,622,000**
4.2.1	Diversion / Power Tunnel - Upper Portal					1	Lump Sum	$6,471,783	$6,472,000	**$6,472,000**
4.2.2	Diversion / Power Tunnel - Lower Portal					1	Lump Sum	$3,149,983	$3,150,000	**$3,150,000**
4.3	Tunnel Construction								$22,776,000	**$22,776,000**
4.3.1	Tunnel Excavation					930	Feet	$18,349	$17,065,000	**$17,065,000**
4.3.2	Tunnel Concrete Work					645	Feet	$8,855	$5,711,000	**$5,711,000**
4.4	Gate Shaft Construction								$7,615,000	**$7,615,000**
4.4.1	Shaft Excavation					110	Feet	$40,581	$4,464,000	**$4,464,000**
4.4.2	Shaft Lining					110	Feet	$28,646	$3,151,000	**$3,151,000**
4.5	Penstock System								$4,300,000	**$4,300,000**
4.5.1	Penstock Supply - Tunnel Section					308,900	Pounds	$3.00	$927,000	**$927,000**
4.5.2	Penstock Supply - Manifold Section Section					54,700	Pounds	$6.00	$328,000	**$328,000**
4.5.3	Penstock Supply - Powerhouse Section					82,500	Pounds	$6.00	$495,000	**$495,000**
4.5.4	Penstock / Manifold Installation					1	Lump Sum	$1,500,000	$1,500,000	**$1,500,000**
4.5.5	Tunnel Plug					700	Cubic Yard	$1,500	$1,050,000	**$1,050,000**
4.6	Intake Structure and Gate House				**$6,778,000**					**$6,778,000**
4.6.1	Intake Structure - Crane Pad	$192,000	$51,800	$61,200	$305,000					**$305,000**
4.6.2	Intake Structure - Reinforced Concrete	$408,000	$100,600	$289,900	$799,000					**$799,000**
4.6.3	Intake Structure - Stoplogs and Guides	$132,000	$36,200	$432,500	$601,000					**$601,000**
4.6.4	Intake Structure - Trashracks	$156,000	$37,400	$510,000	$703,000					**$703,000**
4.6.5	Gate House - Excavation and Surface Prep	$192,000	$51,800	$21,200	$265,000					**$265,000**
4.6.6	Gate House - Gates, Stoplogs and Guides	$360,000	$87,400	$1,614,000	$2,061,000					**$2,061,000**
4.6.7	Gate House - Reinforced Concrete Structure	$276,000	$77,000	$181,800	$535,000					**$535,000**
4.6.8	Gate House - Steel Superstructure	$216,000	$46,000	$556,200	$818,000					**$818,000**
4.6.9	Gate House - Architectural, Mechanical and Electrical	$312,000	$42,600	$336,200	$691,000					**$691,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D - Opinion of Probable Total Construction Cost, Detail

		Labor	Equip	Materials	Total	Quantity	Units	Unit Price	Price	Total Price
5	**Powerhouse**									**$64,000,000**
5.1	Structure	$10,140,000	$1,377,500	$12,195,260	$23,713,000					**$23,713,000**
5.1.1	Prep area / laydown	$288,000	$73,600	$141,500	$503,000					**$503,000**
5.1.2	Excavate overburden/rock foundation	$480,000	$159,900	$72,000	$712,000					**$712,000**
5.1.3	Foundation prep	$144,000	$16,600	$19,740	$180,000					**$180,000**
5.1.4	Concrete for substructure	$2,016,000	$260,600	$9,428,000	$11,705,000					**$11,705,000**
5.1.5	Steel frame superstructure	$2,640,000	$273,000	$2,370,500	$5,284,000					**$5,284,000**
5.1.6	Mechanical / Electrical Installation	$3,300,000	$444,400	$70,000	$3,814,000					**$3,814,000**
5.1.7	Archectural / paint / trim	$720,000	$57,000	$72,000	$849,000					**$849,000**
5.1.8	Pre-operation system testing	$168,000	$67,200	$10,000	$245,000					**$245,000**
5.1.9	Trial operation	$384,000	$25,200	$11,520	$421,000					**$421,000**
5.2	Mechanical / Electrical Equipment								$40,613,000	**$40,613,000**
5.2.1	Turbine, Generator, Switchgear, Governor (Each)					4	each	$4,974,200	$19,897,000	**$19,897,000**
5.2.2	Turbine, Generator, Switchgear, Governor Installation					4	each	$2,984,520	$11,938,000	**$11,938,000**
5.2.3	Turbine Isolation Valve					4	each	$150,000	$600,000	**$600,000**
5.2.4	Flywheel					8	each	$55,500	$444,000	**$444,000**
5.2.5	Air Compressors and Appurtenances (S&I)					1	each	$30,000	$30,000	**$30,000**
5.2.6	Unwatering, Drainage, & Cooling Water Pumps (S&I)					1	each	$40,000	$40,000	**$40,000**
5.2.7	Fire Protection System (S&I)					4	each	$25,000	$100,000	**$100,000**
5.2.8	Oil Filtration System (S&I)					1	each	$30,000	$30,000	**$30,000**
5.2.9	Potable Water System					1	each	$30,000	$30,000	**$30,000**
5.2.10	Piping, Valves and Fittings (S&I)					1	each	$300,000	$300,000	**$300,000**
5.2.11	Maintenance Equipment (S&I)					1	each	$20,000	$20,000	**$20,000**
5.2.12	Ventilation Equipment (S&I)					1	each	$60,000	$60,000	**$60,000**
5.2.13	Sanitary System (S&I)					1	each	$25,000	$25,000	**$25,000**
5.2.14	Miscellaneous Equipment (S&I)					1	each	$50,000	$50,000	**$50,000**
5.2.15	Station Service Transformer 500 kVA, 12.47 kV/480-877V					2	each	$25,000	$50,000	**$50,000**
5.2.16	Station Batteries, Controls, installation					1	each	$198,968	$199,000	**$199,000**
5.2.17	Station Service Switchgear, Incl. 10 C.B.'s 480 V					1	each	$200,000	$200,000	**$200,000**
5.2.18	Unit Protection					4	each	$137,500	$550,000	**$550,000**
5.2.19	Electrical Services					1	each	$650,000	$650,000	**$650,000**
5.2.26	SCADA					4	each	$137,500	$550,000	**$550,000**
5.2.27	Crane (S&I)					1	each	$300,000	$300,000	**$300,000**
5.2.28	300 KW Standby Generator and 2000 gal Fuel Tank (S&I)					4	each	$137,500	$550,000	**$550,000**
5.2.29	Switchyard					1	each	$4,000,000	$4,000,000	**$4,000,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D - Opinion of Probable Total Construction Cost, Detail

		Labor	Equip	Materials	Total	Quantity	Units	Unit Price	Price	Total Price
6	**Transmission Line**									**$145,000,000**
6.1	Chikuminuk to Bethel								$114,386,000	**$114,386,000**
6.1.1	Air (helicopter) construction = 30 miles					1	Lump Sum	$45,631,000	$45,631,000	**$45,631,000**
6.1.2	Overland summer construction = 43 miles					1	Lump Sum	$28,338,100	$28,338,000	**$28,338,000**
6.1.3	Overland winter construction = 46 miles					1	Lump Sum	$40,417,300	$40,417,000	**$40,417,000**
6.2	Chikuminuk to Dillingham								$30,803,000	**$30,803,000**
6.2.1	Air (helicopter) construction = 4 miles					1	Lump Sum	$3,164,900	$3,165,000	**$3,165,000**
6.2.2	Overland summer construction = 96 miles					1	Lump Sum	$24,381,900	$24,382,000	**$24,382,000**
6.2.3	Road summer construction = 19 miles					1	Lump Sum	$3,256,200	$3,256,000	**$3,256,000**
	DIRECT CONSTRUCTION COST									**$367,000,000**
7	**Contingencies**									**$126,276,000**
7.1	Pricing							15.0%	$55,050,000	**$55,050,000**
7.2	Scope - Roads and Airstrip							40.0%	$11,600,000	**$11,600,000**
7.2	Scope - Dam, Tunnel Concrete, Penstock, Intake Gate, and PH Civil							30.0%	$24,496,000	**$24,496,000**
7.3	Scope - PH Equipment							15.0%	$6,092,000	**$6,092,000**
7.4	Scope - Transmission							20.0%	$29,038,000	**$29,038,000**
	SUBTOTAL: DIRECT + CONTINGENCIES									**$493,000,000**
8	**Administration and Management**									**$76,415,000**
8.1	Planning and Licensing							1.5%	$7,395,000	**$7,395,000**
8.2	Engineering							3.0%	$14,790,000	**$14,790,000**
8.3	Engineering During Construction							2.0%	$9,860,000	**$9,860,000**
8.4	Construction Oversight & Mgt							5.0%	$24,650,000	**$24,650,000**
8.5	Misc Owner's soft costs							2.0%	$9,860,000	**$9,860,000**
8.6	Land Acquisistions, Rights and Mitigation							2.0%	$9,860,000	**$9,860,000**
	TOTAL CONSTRUCTION COST									**$569,000,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.1 - Estimated Labor Rates

Dick Freeman

Chikuminuk Labor Rate Estimate			
Average Equipment Operator Wage (Means 2012 - rear cover)		$46.55	
Factor for Fairbanks 115.0 = +15% (Means 2012, page 588)		$6.98	
	Subtotal		$53.53
Escalation @ 2.1% (ENR)		$1.12	
			$54.65
Overtime Allowance for 6-10s = 70 pay/60 work = 0.167 x Means		$9.13	
	Subtotal		$63.78
Workmans' Comp @ 9%		$5.74	
Average Fixed Overhead (home office) @ 17.9%		$11.42	
Overhead at site @ 14%		$8.93	
			$26.09
	Subtotal		$89.87
Supervision, maintenance, safety, non-production personnel etc. @ 25%		$22.47	
Subsistence (food/shelter/camp) @ $500/day		$62.50	
			$84.97
	Subtotal		$174.83
Risk / inefficiencies / turnover @ 7%		$12.24	
	Subtotal		$187.07
Profit @ 10%		$18.71	
	TOTAL		**$210.00**

Jim Peregoy

Chikuminuk Labor Rate Estimate			
Base Rate - Operator		$46.55	
Tax @13.5%		$6.28	
Fringes		$41.00	
	Subtotal		$93.83
Workman's comp @13.38%		$12.37	
	Subtotal		$106.20
Overtime @ 40.18%		$42.67	
	Subtotal		$148.87
Camp cost @ $500/day		$62.50	
	TOTAL		**$210.00**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.1 - Estimated Labor Rates

R & M Consultants

Chikuminuk Labor Rate Estimate		
Operator Group IA - A1602 Davis Bacon	$46.55	
Total Fringe Benefit Rate	$19.95	
Total Hourly Burden Rate (Davis Bacon Rate 2013)		$66.50
Workmans' Comp @ 8%	$3.72	
Subtotal		$70.22
Estimate a 70 Work Week (Seven Ten Hour Shifts) (50% OT premium)	$5,613.93	
35% markup for overhead cost	$1,754.67	
Subtotal Operator cost		$7,368.60
Camp cost @ 866.67 per day	$6,066.69	
Subtotal		$13,435.29
Contractor's hourly cost @ 70 hours/week	$191.93	
Profit @ 10%	$19.19	
TOTAL		**$210.00**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.1.1 - RCC Dam and Powerhouse Demobilization

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks Hours / Week = 60

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
Demobe incl Restoration													
Labor:													
Superintendent	1	3 weeks	180	$200	$36,000							$36,000	
Equip Operators	6	3 weeks	1,080	$200	$216,000							$216,000	
Truck drivers	2	3 weeks	360	$200	$72,000							$72,000	
Carpenters	2	3 weeks	360	$200	$72,000							$72,000	
Electrician	2	3 weeks	360	$200	$72,000							$72,000	
Mechanic	2	3 weeks	360	$200	$72,000							$72,000	
Laborers	6	3 weeks	1,080	$200	$216,000							$216,000	
Subtotal	**21**												$756,000
Equipment:													
Cat D7	2	3 weeks				$7,000	$42,000					$42,000	
966 loader	2	3 weeks				$5,500	$33,000					$33,000	
E/D trucks	2	3 weeks				$5,500	$33,000					$33,000	
Mobile Crane	2	3 weeks				$8,600	$51,600					$51,600	
Tractor/Trailer	2	3 weeks				$2,800	$16,800					$16,800	
Flights to demobe equipment							$1,507,500					$1,507,500	
Subtotal													$1,683,900
Materials:													
Cleanup/Restoration, % of labor								50%	%		$378,000	$378,000	
Misc gravel, plantings, small tools, etc.								1.00	LS		$1,000,000	$1,000,000	
Subtotal													$1,378,000
ITEM TOTAL					**$756,000**		**$1,683,900**				**$1,378,000**		**$3,800,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D1.3 and D1.4 - C 130 Flight Costs

Equipment	Qty Req'd	Total Weight (48,000 lbs max)	Length (55' max)	Width (9' max)	Height (9' max)	Disassemble ??	Re-Assembly Time	Flight No.	Comments - Demobilize or stay on-site post construction
--	(ea)	(lbs)	(ft)	(ft)	(ft)	(Y/N)	(hrs)	(#)	
Modular Batch Plant (Aran Modumix II or simila	1	48,000	55	8	8	N	NA	1	Assume 5 trips (Hoppers, Mixer, Operations Room), Steel Structure
Modular Batch Plant (Aran Modumix II or simila	1	48,000	55	8	8	N	NA	2	Assume 5 trips (Hoppers, Mixer, Operations Room), Steel Structure
Modular Batch Plant (Aran Modumix II or simila	1	48,000	55	8	8	N	NA	3	Assume 5 trips (Hoppers, Mixer, Operations Room), Steel Structure
Modular Batch Plant (Aran Modumix II or simila	1	48,000	55	8	8	N	NA	4	Assume 5 trips (Hoppers, Mixer, Operations Room), Steel Structure
Modular Batch Plant (Aran Modumix II or simila	1	48,000	55	8	8	N	NA	5	Assume 5 trips (Hoppers, Mixer, Operations Room), Steel Structure
Kenworth T470 (base truck only)	1	33,000	27.75	8	9.5	N	NA	6	Used as Dump Truck, Haul Low Boy, Mount a Cement Mixer, Attach a Plow. Probably have 3-4 that stay on site.
E/D trucks (dump attachment only)	1	10,000	20	8.5	8.5	N	NA	6	Assumed dimensions and weight
Kenworth T470 (base truck only)	1	33,000	27.75	8	9.5	N	NA	7	Used as Dump Truck, Haul Low Boy, Mount a Cement Mixer, Attach a Plow. Probably have 3-4 that stay on site.
E/D trucks (dump attachment only)	1	10,000	20	8.5	8.5	N	NA	7	Assumed dimensions and weight
Kenworth T470 (base truck only)	1	33,000	27.75	8	9.5	N	NA	8	Used as Dump Truck, Haul Low Boy, Mount a Cement Mixer, Attach a Plow. Probably have 3-4 that stay on site.
Light plants, Doosan L20-60Hz	1	2,540	15.2	6.6	7.4	N	NA	8	
Kenworth T470 (base truck only)	1	33,000	27.75	8	9.5	N	NA	9	Used as Dump Truck, Haul Low Boy, Mount a Cement Mixer, Attach a Plow. Probably have 3-4 that stay on site.
Light plants, Doosan L20-60Hz	1	2,540	15.2	6.6	7.4	N	NA	9	
Trailer, lowboy	1	18,800	50	8.5	8	N	NA	10	
Scaffolding	1	5,848	40	5	8	N	NA	10	5' x 5' frames stacked 8.5' high, 4 stacks
500 A Welder, Lincoln Electric K2325-2	1	1,730	5.25	2.75	4.08	N	NA	10	
Trailer, lowboy	1	18,800	50	8.5	8	N	NA	11	
Scaffolding	1	5,848	40	5	8	N	NA	11	5' x 5' frames stacked 8.5' high, 4 stacks
500 A Welder, Lincoln Electric K2325-2	1	1,730	5.25	2.75	4.08	N	NA	11	
Track Drill, Cat MD509	1	41,000	34	8.5	10.25	Y	4	12	
Track Drill, Cat MD509	1	41,000	34	8.5	10.25	Y	4	13	
Grove 540E Rough Terrain Crane	1	60,126	39	8.64	10.6	Y	16	14 & 15	Disassemble at Chasis. Keep 1 or 2 on site. In lieu of 60 ton crane?
67" Roller, Cat CB54	1	23,818	16	6.3	10.1	Y	4	15	Need to remove cab/roof
Grove 540E Rough Terrain Crane	1	60,126	39	8.64	10.6	Y	16	16 & 17	Disassemble at Chasis. Keep 1 or 2 on site. In lieu of 60 ton crane?
CAT D6 Dozer	1	29,690	15.3	7.7	9.67	Y	4	17	D7 is too heavy
4WD Forklift, Cat TL1055C	1	34,160	20.8	8.4	8.4	N	NA	18	
250 kW generator, Doosan G325WCU	1	13,595	19.3	6.9	9.4	N	NA	18	
Dragline setup for 60 ton crane	1	96,000	55	8	8	Y	32	19 & 20	Assumed 2 flights required
Silo, Diversified Storage System 1400	1	12,000	37	8.5	8.5	Y	6	21	Must remove wheels for this model
Misc diesel pumps, Godwin CD400M	1	13,575	15.0	7.2	6.0	N	NA	21	
Silo, Diversified Storage System 1400	1	12,000	37	8.5	8.5	Y	6	22	Must remove wheels for this model
Misc diesel pumps, Godwin CD400M	1	13,575	15.0	7.2	6.0	N	NA	22	
Silo, Diversified Storage System 1400	1	12,000	37	8.5	8.5	Y	6	23	Must remove wheels for this model
Mixer truck, drum only, London Series 60	1	10,000	13.92	8.5	8.333	N	NA	23	8.5 yd capacity, weight is assumed
Silo, Diversified Storage System 1400	1	12,000	37	8.5	8.5	Y	6	24	Must remove wheels for this model
Mixer truck, drum only, London Series 60	1	10,000	13.92	8.5	8.333	N	NA	24	8.5 yd capacity, weight is assumed
Silo, Diversified Storage System 1400	1	12,000	37	8.5	8.5	Y	6	25	Must remove wheels for this model
600 cfm compressor, Doosan P600	1	5,178	14.2	6.5	6.3	N	NA	25	
Silo, Diversified Storage System 1400	1	12,000	37	8.5	8.5	Y	6	26	Must remove wheels for this model
600 cfm compressor, Doosan P600	1	5,178	14.2	6.5	6.3	N	NA	26	
Conveyor, Putzmeister Telebelt 130	1	29,800	42	8	12	Y	24	27	
Mixer truck, drum only, London Series 60	1	10,000	13.92	8.5	8.333	N	NA	27	8.5 yd capacity, weight is assumed
Silo, Diversified Storage System 1400	1	12,000	37	8.5	8.5	Y	6	28	Must remove wheels for this model
CAT D6 Dozer	1	29,690	15.3	7.7	9.67	Y	4	28	D7 is too heavy

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D1.3 and D1.4 - C 130 Flight Costs

Equipment	Qty Req'd	Total Weight (48,000 lbs max)	Length (55' max)	Width (9' max)	Height (9' max)	Disassemble ??	Re-Assembly Time	Flight No.	Comments - Demobilize or stay on-site post construction
CAT Loader 938	1	35,104	25.1	8.75	11	Y	4	29	In lieu of 966 which is too heavy, 950 is too wide
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	29	
CAT Loader 938	1	35,104	25.1	8.75	11	Y	4	30	In lieu of 966 which is too heavy, 950 is too wide
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	30	
CAT Excavator 318	1	41,010	28	8.75	10	Y	8	31	
Concrete pump, Schwing SP 4800, 2020	1	17,637	23	6.25	8.1	N	NA	32	
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	32	
4WD Forklift, Cat TL1055C	1	34,160	20.8	8.4	8.4	N	NA	33	
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	33	
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	33	
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	34	
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	34	
Pick-up truck, 4WD	1	4,816	18.7	6.7	6.2	N	NA	34	
Fuel Tanks, 12,000 gal	1	24,000	25	9	9	N	NA	35	Weight unknown
Fuel Tanks, 12,000 gal	1	24,000	25	9	9	N	NA	35	Weight unknown
Tool shed, Conex, 40'	1	8,575	40	8	8.5	N	NA	36	
Tool shed, Conex, 15'	1	3,500	15	8	8.5	N	NA	36	Weights and dimensions approximate
Tool shed, Conex, 40'	1	8,575	40	8	8.5	N	NA	37	
Tool shed, Conex, 15'	1	3,500	15	8	8.5	N	NA	37	Weights and dimensions approximate

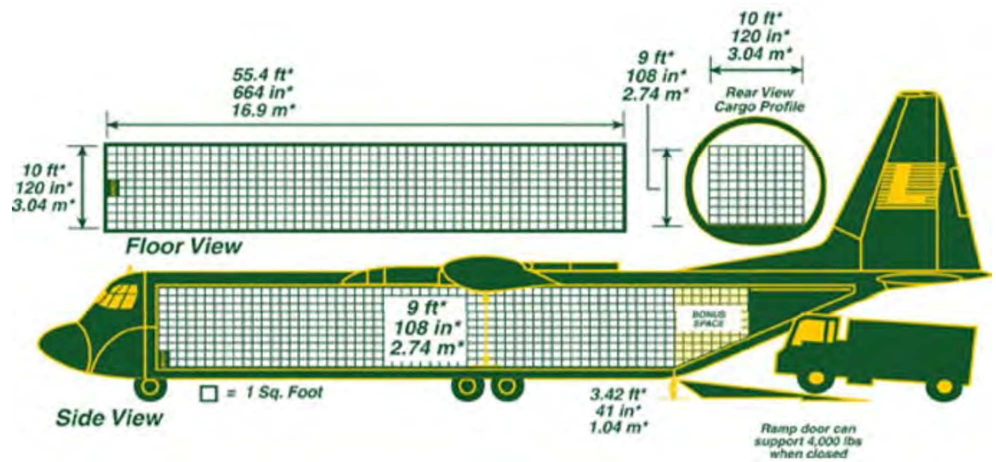
Total Flights: Material mob / demob — 74

Cost per Flight - Dillingham to Site =	$30,000
Cost per Flight - Fairbanks to Dillingham =	$35,000
Assume 10 Local Flights / Fairbanks Flight, Avg Cost / Flight (Dillingham to Site) =	$33,500
Applying a factor of 1.5 on mob/demob flights for labor, equip & materials: COST =	**$3,718,500**
Applying a factor of 1.5 on flights for fuel: COST =	**$753,750**

Total Flights: Fuel

Equipment	Gallons	Pounds	Flights
Track Drill	4800	35,280	1
Dozer	13500	99,225	2
Loader	918	6,747	0
Pickup	8237	60,542	1
Excavator	4200	30,870	1
Roller	2640	19,404	0
Mack Trucks	8160	59,976	1
Compressor	5175	38,036	1
Generator	19890	146,192	3
Crane	11160	82,026	2
Batch Plant	15120	111,132	2
Pump	1920	14,112	0
Light Plant	1800	13,230	0
Total =	**97,520**	**716,772**	**15**

All equipment must fit inside a C-130 Aircraft, payload 48,000 lbs



Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D1.6 - Equipment Standby Costs

Equipment	Weeks	Rate	Total Cost
Tractor/Trailer	50	$2,800	$140,000
Cat D7	94	$7,000	$658,000
966 Loader	58	$5,500	$319,000
600 cfm compressor	9	$3,750	$33,750
Batch plant	52	$5,250	$273,000
Concrete pump	52	$1,800	$93,600
60 ton crane, @ 50%	27	$12,900	$348,300
250 kW Generator	27	$6,900	$186,300
		Total =	**$2,100,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D2 - Roads and Airstrip

ITEM	UNIT	QTY	UNIT PRICE		AMOUNT
Airstrip					
Heavy Lift Copter Operations					
Heavy Lift Copter / Mob / Demob	Lump Sum	1	$400,000	$400,000	
Lift work	Hr	100	$15,000	$1,500,000	
Fuel	Gal	40,000	$12	$480,000	
Subsistence (10 for 10 days)	Each	100	$294	$29,400	
Subtotal					$2,409,400
Runway and Apron Construction					
Runway Mobe / Demobe	Lump sum	1	$2,460,000	$2,460,000	
Clear & Grub	Acre	29	$10,000	$290,000	
Unclassified excavation	Cu. Yd.	200,000	$22	$4,400,000	
Roadway structural sec tion	Cu. Yd.	120,000	$55	$6,600,000	
Borrow	Cu. Yd.	3,000	$35	$105,000	
Drainage	Lump sum	1	$570,000	$570,000	
Subsistence (30 person camp)	Lump sum	1	$4,381,000	$4,381,000	
Erosion control	Lump sum	1	$360,000	$360,000	
Subtotal					$19,166,000
Total					**$21,575,400**
Roadway 1 Construction (runway to camp)					
Clear & Grub	Acre	13	$10,000	$130,000	
Unclassified excavation	Cu. Yd.	19,000	$22	$418,000	
Borrow	Cu. Yd.	0	$35	$0	
Roadway structural sec tion	Cu. Yd.	9,000	$55	$495,000	
Subtotal					$1,043,000
Drainage @ 5%				$52,200	
Erosion Control @ 3%				$31,300	
Subtotal					$83,500
Total					**$1,126,500**
Roadway 2 construction (camp to float plane)					
Clear & Grub	Acre	4	$10,000	$40,000	
Unclassified excavation	Cu. Yd.	25,000	$22	$550,000	
Borrow	Cu. Yd.	0	$35	$0	
Roadway structural sec tion	Cu. Yd.	3,000	$55	$165,000	
Subtotal					$755,000
Drainage @ 5%				$37,800	
Erosion Control @ 3%				$22,700	
Subtotal					$60,500
Total					**$815,500**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D2 - Roads and Airstrip

Roadway 3 construction (camp to powerhouse)						
Clear & Grub		Acre	9	$10,000	$90,000	
Unclassified excavation		Cu. Yd.	51,000	$22	$1,122,000	
Borrow		Cu. Yd.	2,000	$35	$70,000	
Roadway structural sec tion		Cu. Yd.	8,000	$55	$440,000	
	Subtotal					$1,722,000
Drainage @ 5%					$86,100	
Erosion Control @ 3%					$51,700	
	Subtotal					$137,800
	Total					**$1,859,800**
Roadway 2 construction (roadway 3 to dam)						
Clear & Grub		Acre	6	$10,000	$60,000	
Unclassified excavation		Cu. Yd.	67,000	$22	$1,474,000	
Borrow		Cu. Yd.	1,000	$35	$35,000	
Roadway structural sec tion		Cu. Yd.	6,000	$55	$330,000	
	Subtotal					$1,899,000
Drainage @ 5%					$95,000	
Erosion Control @ 3%					$57,000	
	Subtotal					$152,000
	Total					**$2,051,000**
Camp Pad (permanent)						
Clear & Grub		Acre	5	$10,000	$50,000	
Unclassified excavation		Cu. Yd.	6,000	$22	$132,000	
Borrow		Cu. Yd.	8,000	$35	$280,000	
Roadway structural sec tion		Cu. Yd.	14,000	$55	$770,000	
	Subtotal					$1,232,000
Drainage @ 5%					$61,600	
Erosion Control @ 3%					$37,000	
	Subtotal					$98,600
	Total					**$1,330,600**
Float Plane & Boat Ramp Pad						
Clear & Grub		Acre	5	$10,000	$50,000	
Unclassified excavation		Cu. Yd.	3,000	$22	$66,000	
Borrow		Cu. Yd.	0	$35	$0	
Roadway structural sec tion		Cu. Yd.	1,000	$55	$55,000	
Dock, Ramp, Misc Items		Lump Sum	1	$100,000	$100,000	
	Subtotal					$271,000
Drainage @ 5%					$13,600	
Erosion Control @ 3%					$8,100	
	Subtotal					$21,700
	Total					**$292,700**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D3 - RCC Dam

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks Hours / Week = 60

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
3.1. Prepare laydown area - single shift (RF4.1)													
Labor:													
Superintendent	1	4 weeks	240	$200	$48,000							$48,000	
Equip Operators	4	4 weeks	960	$200	$192,000							$192,000	
Truck Drivers	2	4 weeks	480	$200	$96,000							$96,000	
Laborers	2	4 weeks	480	$200	$96,000							$96,000	
Subtotal	**9**												$432,000
Equipment:													
40 Ton crane	1	4 weeks				$8,600	$34,400					$34,400	
D7 Cat	2	4 weeks				$7,000	$56,000					$56,000	
E/D trucks	2	4 weeks				$4,300	$34,400					$34,400	
66" Roller	1	4 weeks				$3,500	$14,000					$14,000	
Subtotal													$138,800
Materials:													
Misc barricades @ 10% of labor											$43,000	$43,000	
Gravel Surfacing								420	CY	$45	$18,900	$18,900	
Subtotal													$61,900
ITEM TOTAL					**$432,000**		**$138,800**				**$61,900**		**$632,700**
3.2. Excavate dam foundation - single shift (RF4.2)													
Labor:													
Superintendent	1	5 weeks	300	$200	$60,000							$60,000	
Blasters	4	5 weeks	1,200	$200	$240,000							$240,000	
Dragline operator	1	5 weeks	300	$200	$60,000							$60,000	
Truck drivers	2	5 weeks	600	$200	$120,000							$120,000	
Operators	2	5 weeks	600	$200	$120,000							$120,000	
Subtotal	**10**												$600,000
Equipment:													
Cat D7	2	5 weeks				$7,000	$70,000					$70,000	
Dragline setup w/40 ton crane	1	5 weeks				$8,600	$43,000					$43,000	
E/D trucks	2	5 weeks				$4,300	$43,000					$43,000	
600 cfm (drill/shoot)	1	5 weeks				$3,400	$17,000					$17,000	
Subtotal													$173,000
Materials:													
Misc: safety, etc @ 10% of labor											$60,000	$60,000	
Subtotal													$60,000
ITEM TOTAL					**$600,000**		**$173,000**				**$60,000**		**$833,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D3 - RCC Dam

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks Hours / Week = 60

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
3.3. Erect Batch Plants - double shifts (RF4.3)													
Labor:													
Operators	4	5 weeks	1,200	$200	$240,000							$240,000	
Electrician	2	5 weeks	600	$200	$120,000							$120,000	
Ironworker	2	5 weeks	600	$200	$120,000							$120,000	
Carpenter	2	5 weeks	600	$200	$120,000							$120,000	
Truck drivers	2	5 weeks	600	$200	$120,000							$120,000	
Laborers	8	5 weeks	2,400	$200	$480,000							$480,000	
Subtotal	**20**												$1,200,000
Equipment:													
40 Ton crane	1	7.5 weeks				$8,600	$64,500					$64,500	
600 cfm	1	7.5 weeks				$3,400	$25,500					$25,500	
Tractor Trailer	1	7.5 weeks				$2,800	$21,000					$21,000	
250 kW Generator	1	7.5 weeks				$4,600	$34,500					$34,500	
Subtotal													$145,500
Materials:													
Misc @ 20% of labor											$240,000	$240,000	
Subtotal													$240,000
ITEM TOTAL					**$1,200,000**		**$145,500**				**$240,000**		**$1,585,500**
3.4. Stockpile cement / etc., trial mixes - double shifts (RF4.3)													
Labor:													
Equip Operators	2	3 weeks	360	$200	$72,000							$72,000	
Carpenter	4	3 weeks	720	$200	$144,000							$144,000	
Laborers	6	3 weeks	1,080	$200	$216,000							$216,000	
Subtotal	**12**												$432,000
Equipment:													
40 Ton crane	1	4.5 weeks				$8,600	$38,700					$38,700	
966 loader	1	4.5 weeks				$5,500	$24,800					$24,800	
Misc equip @ 10% labor							$43,200					$43,200	
Subtotal													$106,700
Materials:													
Misc @ 20% of labor											$86,400	$86,400	
Subtotal													$86,400
ITEM TOTAL					**$432,000**		**$106,700**				**$86,400**		**$625,100**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D3 - RCC Dam

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks Hours / Week = 60

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
3.5. RCC & conventional concrete - 7-10's, double shifts (44,300 cy) (RF4.5)													
Labor:													
Operators	4	20 weeks	5,600	$200	$1,120,000							$1,120,000	
40 Ton crane operator	2	20 weeks	2,800	$200	$560,000							$560,000	
Electrician	2	20 weeks	2,800	$200	$560,000							$560,000	
Laborers	4	20 weeks	5,600	$200	$1,120,000							$1,120,000	
Carpenters	8	20 weeks	11,200	$200	$2,240,000							$2,240,000	
D7 Dozer operator	2	20 weeks	2,800	$200	$560,000							$560,000	
Roller compactor operator	2	20 weeks	2,800	$200	$560,000							$560,000	
Vibrator operators	8	20 weeks	11,200	$200	$2,240,000							$2,240,000	
Mixer truck drivers	4	20 weeks	5,600	$200	$1,120,000							$1,120,000	
Subtotal	**36**												$10,080,000
Equipment:													
40 Ton crane	1	15 weeks				$8,600	$129,000					$129,000	
Concrete Mixer Trucks	2	20 weeks				$5,000	$200,000					$200,000	
E/D Trucks	1	20 weeks				$4,300	$86,000					$86,000	
D7 Dozer	1	20 weeks				$7,000	$140,000					$140,000	
66" Roller	2	20 weeks				$3,500	$140,000					$140,000	
Batch plants	4	30 weeks				$3,500	$420,000					$420,000	
Silos, conveyors, etc	4	30 weeks				$2,500	$300,000					$300,000	
Subtotal													$1,415,000
Materials:													
Form lumber - single use, 3/4 ply								215,000	sf	$1	$215,000	$215,000	
Roller Compacted Concrete								35,000	CY	$265	$9,275,000	$9,275,000	
Reinforced Conventional Concrete								8,330	CY	$610	$5,081,300	$5,081,300	
60" Dia Howell Bunger Valve								2	EA	$300,000	$600,000	$600,000	
24" Dia Howell Bunger Valve								1	EA	$50,000	$50,000	$50,000	
60" Steel Piping								440	LF	$1,440	$633,600	$633,600	
24" Steel Piping								220	LF	$580	$127,600	$127,600	
60" Butterfly Valve								2	EA	$200,000	$400,000	$400,000	
24" Butterfly Valve								1	EA	$40,000	$40,000	$40,000	
6'x6' Bulkhead Gate and Guides								2	EA	$50,000	$100,000	$100,000	
3'x3' Bulkhead Gate and Guides								1	EA	$15,000	$15,000	$15,000	
Misc: safety, etc @ 5% of cement	1							1	LS	$463,800	$463,800	$463,800	
Subtotal													$17,001,300
ITEM TOTAL					**$10,080,000**		**$1,415,000**				**$17,001,300**		**$28,496,300**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D3 - RCC Dam

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks Hours / Week = 60

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
3.6 Conveyor systems (RF4.6)													
Labor:													
Equip Operators	2	1 weeks	120	$200	$24,000							$24,000	
Laborers	4	1 weeks	240	$200	$48,000							$48,000	
Subtotal	**6**												$72,000
Equipment:													
76 foot setups	2	20 weeks				$2,680	$107,200					$107,200	
storage silos	3	20 weeks				$1,240	$74,400					$74,400	
250 kW generator	1	20 weeks				$4,600	$92,000					$92,000	
Subtotal													$273,600
Materials:													
Replacement Belts @ 10% of Equipment								1	LS	$27,360	$27,400	$27,400	
Subtotal													$27,400
ITEM TOTAL					**$72,000**		**$273,600**				**$27,400**		**$373,000**
3.7 U/S & D/S Cofferdams (RF4.7)													
Labor:													
40 Ton Crane Operator	2	3 weeks	360	$200	$72,000							$72,000	
D7 Cat operator	2	3 weeks	360	$200	$72,000							$72,000	
E/D truck drivers	2	3 weeks	360	$200	$72,000							$72,000	
Laborers	4	3 weeks	720	$200	$144,000							$144,000	
Subtotal	**10**												$360,000
Equipment:													
40 ton Crane	2	3 weeks				$8,600	$51,600					$51,600	
Cat D7	2	3 weeks				$7,000	$42,000					$42,000	
E/D trucks	2	3 weeks				$4,300	$25,800					$25,800	
Misc pumps - 6" diesels	2	30 weeks				$300	$18,000					$18,000	
Subtotal													$137,400
Materials:													
Rock Fill								10,700	CY	$40	$428,000	$428,000	
Cement Grout								2,000	CY	$700	$1,400,000	$1,400,000	
Misc @ 10% of Labor											$36,000	$36,000	
Subtotal													$1,864,000
ITEM TOTAL					**$360,000**		**$137,400**				**$1,864,000**		**$2,361,400**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D3 - RCC Dam

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks Hours / Week = 60

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
3.8 Consolidation Grouting (RF4.8)													
Labor:													
Superintendent	2	5 weeks	600	$200	$120,000							$120,000	
Laborers	16	5 weeks	4,800	$200	$960,000							$960,000	
Subtotal	**18**												$1,080,000
Equipment:													
Compressor, 600 cfm	2	5 weeks				$3,750	$37,500					$37,500	
Rotary Diamond Bits	2	5 weeks				$4,350	$43,500					$43,500	
Grout mix/pumps	2	5 weeks				$3,000	$30,000					$30,000	
Cement storage trailers	2	5 weeks				$750	$7,500					$7,500	
Subtotal													$118,500
Materials:													
Cement "take" for 2080' drilled, 1 sack/ft								2,080	bag	$15	$31,200	$31,200	
Replacement bits								6	ea	$1,000	$6,000	$6,000	
Subtotal													$37,200
ITEM TOTAL					**$1,080,000**		**$118,500**				**$37,200**		**$1,235,700**
3.9 Curtain Grouting and Drain Holes (RF4.9)													
Labor:													
Superintendent	2	6 weeks	720	$200	$144,000							$144,000	
Laborers	16	6 weeks	5,760	$200	$1,152,000							$1,152,000	
Subtotal	**18**												$1,296,000
Equipment:													
Compressor, 600 cfm	2	6 weeks				$3,750	$45,000					$45,000	
Rotary Diamond Bits	2	6 weeks				$4,350	$52,200					$52,200	
Grout mix/pumps	2	6 weeks				$3,000	$36,000					$36,000	
Cement storage trailers	2	6 weeks				$750	$9,000					$9,000	
Subtotal													$142,200
Materials:													
Cement "take" for 7300' drilled, 1 sack/ft								7,300	bag	$15	$109,500	$109,500	
Drain Hole Piping								4,380	LF	$3	$13,200	$13,200	
Replacement bits								6	ea	$1,000	$6,000	$6,000	
Subtotal													$128,700
ITEM TOTAL					**$1,296,000**		**$142,200**				**$128,700**		**$1,566,900**

Subtotals		
Labor	**$15,552,000**	
Equipment	**$2,650,700**	
Materials	**$19,506,900**	
TOTAL		**$37,709,600**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D4.2 and D4.3 - Tunnel System

Bid Item	Item Description	Qty	MHR	Lab	PM	XM	Equip	Direct	Indirect	Total	Margin	Bid	Quantity	Units	Unit	Total
10000	**General Mobilization/Demobilization**	**1**	**4,704**	**$462,368**		**$2,977,600**	**$196,258**	**$3,636,226**	**$1,553,143**	**$5,189,369**	**$0**	**$5,189,369**	**1**	**LS**	**$5,189,369**	**$5,189,369**
1000	Mob - Lower USA	1	1,024	$94,615		$130,400	$42,723	$267,738	$338,099	$1,129,659	$0	$1,129,659				$1,129,659
1010	Mob - Dillingham to Site	1	1,440	$147,396		$1,375,000	$60,079	$1,582,475	$475,452	$1,588,582	$0	$1,588,582				$1,588,582
1030	Demob - Site to Dillingham	1	1,344	$137,569		$1,375,000	$56,074	$1,568,643	$443,755	$1,482,677	$0	$1,482,677				$1,482,677
1040	Demob - Dillingham to Lower 48	1	896	$82,788		$97,200	$37,383	$217,371	$295,837	$988,451	$0	$988,451				$988,451
20000	**Portal Construction**	**2**	**16,128**	**$2,761,208**	**$695,846**	**$1,159,050**	**$2,544,824**	**$4,296,704**	**$5,325,062**	**$9,621,766**	**$0**	**$9,621,766**				**$9,621,766**
2010	*Diversion/PowerTunnel - Lower Portal*	*1*	*10,848*	*$1,110,379*	*$262,403*	*$468,079*	*$1,023,363*	*$2,864,224*	*$3,581,738*	*$6,471,783*	*$0*		*1*	*LS*	*$6,471,783*	*$6,471,783*
JP1000	Materials & Subs	1			$262,403	$468,079		$730,482	$0	$730,482	$0					
JP3000	Soil Excavation	877	576	$58,958			$54,338	$113,296	$190,181	$303,477	$0					
JP3010	Rock Excavation	16,364	6,624	$678,019			$624,886	$1,302,905	$2,187,079	$3,489,984	$0					
JP3020	Rock Support	1,200	2,496	$255,486			$235,464	$490,950	$824,117	$1,315,067	$0					
JP3030	Canopy Construction	16	1,152	$117,916			$108,676	$226,592	$380,362	$606,954	$0					
2020	*Diversion/Power Tunnel - Upper Portal*	*1*	*5,280*	*$540,450*	*$171,040*	*$222,893*	*$498,097*	*$1,432,480*	*$1,743,324*	*$3,149,983*	*$0*		*1*	*LS*	*$3,149,983*	*$3,149,983*
JP1000	Materials & Subs	1			$171,040	$222,893		$393,933	$0	$393,933	$0					
JP3001	Soil Excavation	544	480	$49,132			$45,281	$94,413	$158,484	$252,897	$0					
JP3011	Rock Excavation	6,993	2,592	$265,312			$244,521	$509,833	$855,814	$1,365,647	$0					
JP3021	Rock Support	5,050	1,056	$108,090			$99,620	$207,710	$348,665	$556,375	$0					
JP3031	Canopy Construction	16	1,152	$117,916			$108,676	$226,592	$380,362	$606,954	$0					
30000	**Tunnel Construction**	**1**	**39,240**	**$7,123,391**	**$3,191,455**	**$2,014,566**	**$4,253,672**	**$9,820,250**	**$12,956,067**	**$22,776,317**	**$0**	**$22,776,317**				**$22,776,317**
3010	*Tunnel Excavation*	*930*	*29,400*	*$3,060,712*	*$1,126,750*	*$757,393*	*$1,817,979*	*$6,762,834*	*$9,707,145*	*$17,064,824*	*$0*		*930*	*VF*	*$18,349*	*$17,064,824*
JP1000	Materials & Subs	1			$1,126,750	$757,393		$1,884,143	$0	$1,884,143	$0					
JP3110	Diversion Tunnel Excavation	870	27,240	$2,835,844			$1,684,412	$4,520,256	$8,993,967	$13,514,223	$0					
JP3111	Power Tunnel Excavation	60	2,160	$224,869			$133,566	$358,435	$713,178	$1,071,613	$0					
3020	*Tunnel Concrete Work*	*645*	*9,840*	*$1,001,966*	*$937,955*	*$499,780*	*$617,715*	*$3,057,416*	*$3,248,922*	*$5,711,492*	*$0*		*645*	*VF*	*$8,855*	*$5,711,492*
JP1000	Materials & Subs	1			$937,955	$499,780		$1,437,735	$0	$1,437,735	$0					
JP3112	Diversion Tunnel Lining	600	7,440	$757,584			$467,053	$1,224,637	$2,456,502	$3,681,139	$0					
JP3113	Diversion Tunnel Plug	5	960	$97,753			$60,265	$158,018	$316,968	$474,986	$0					
JP3114	Power Tunnel Plug	40	1,440	$146,629			$89,397	$236,026	$475,452	$711,478	$0					
40000	**Gate Shaft Construction**	**1**	**13,920**	**$2,285,525**	**$460,424**	**$436,600**	**$1,370,753**	**$3,018,900**	**$4,596,036**	**$7,614,936**	**$0**	**$7,614,936**				**$7,614,936**
4010	*Shaft Excavation*	*110*	*8,160*	*$849,504*	*$82,265*	*$98,050*	*$504,582*	*$1,534,401*	*$2,694,228*	*$4,463,928*	*$0*		*110*	*VF*	*$40,581*	*$4,463,928*
JP1000	Materials & Subs	1			$82,265	$98,050		$180,315	$0	$180,315	$0					
JP4010	Shaft Raise	110	3,000	$312,318			$185,508	$497,826	$990,525	$1,488,351	$0					
JP4011	Shaft Slash	110	5,160	$537,186			$319,074	$856,260	$1,703,703	$2,559,963	$0					
4020	*Shaft Lining*	*110*	*5,760*	*$586,517*	*$295,894*	*$240,500*	*$361,589*	*$1,484,499*	*$1,901,808*	*$3,151,008*	*$0*		*110*	*VF*	*$28,646*	*$3,151,008*
JP1000	Materials & Subs	1			$296,894	$240,500		$537,394	$0	$537,394	$0					
JP4012	Shaft Collar Section	5	600	$61,095			$37,665	$98,760	$198,105	$296,865	$0					
JP4013	Shaft Lining - First Stage	110	2,760	$281,039			$173,261	$454,300	$911,283	$1,365,583	$0					
JP4014	Shaft Lining - Second Stage	85	2,400	$244,384			$150,662	$395,046	$792,420	$1,187,466	$0					
	TOTALS =		**73,992**	**$12,632,492**	**$4,347,724**	**$6,587,816**	**$8,365,507**	**$20,772,079**	**$24,430,309**	**$45,202,388**	**$0**	**$45,202,388**				**$45,202,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.1. Intake Structure - Crane Pad, single shift													
Labor:													
Superintendent	1	2 weeks	120	$200	$24,000							$24,000	
Equipment Operators	3	2 weeks	360	$200	$72,000							$72,000	
Truck Drivers	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	2	2 weeks	240	$200	$48,000							$48,000	
Subtotal	**8**												$192,000
Equipment:													
D7 Dozer	1	2 weeks				$4,600	$9,200					$9,200	
966 Loader	1	2 weeks				$3,400	$6,800					$6,800	
316 Excavator	1	2 weeks				$4,500	$9,000					$9,000	
E/D Trucks	2	2 weeks				$4,300	$17,200					$17,200	
Misc. small tools, 5% of labor	1						$9,600					$9,600	
Subtotal													$51,800
Materials:													
Rock Fill								667	CY	$40	$26,700	$26,700	
Gravel Surfacing								100	CY	$45	$4,500	$4,500	
Ecology Blocks								200	CY	$150	$30,000	$30,000	
Subtotal													$61,200
ITEM TOTAL					**$192,000**		**$51,800**				**$61,200**		**$305,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.2. Intake Structure - Reinforced Concrete, single shift													
Labor:													
Superintendent	1	4 weeks	240	$200	$48,000							$48,000	
40 Ton crane operator	1	2 weeks	120	$200	$24,000							$24,000	
Carpenters	4	4 weeks	960	$200	$192,000							$192,000	
Mixer truck drivers	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	2	4 weeks	480	$200	$96,000							$96,000	
Subtotal	**10**												$408,000
Equipment:													
40 ton crane, @ 50%	1	2 weeks				$8,600	$17,200					$17,200	
Concrete Mixer Trucks	2	2 weeks				$5,000	$20,000					$20,000	
250 kW Generator	1	4 weeks				$4,600	$18,400					$18,400	
600 cfm compressor	1	4 weeks				$3,400	$13,600					$13,600	
Batch plants	1	2 weeks				$3,500	$7,000					$7,000	
Silos, conveyors, etc	1	2 weeks				$2,000	$4,000					$4,000	
Misc. small tools, 5% of labor	1						$20,400					$20,400	
Subtotal													$100,600
Materials:													
Form Lumber 3/4" Plywood								3,000	SF	$2	$6,000	$6,000	
Reinforced Concrete								340	CY	$835	$283,900	$283,900	
Subtotal													$289,900
ITEM TOTAL					**$408,000**		**$100,600**				**$289,900**		**$798,500**

Chikuminuk Hydroelectric Project
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Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.3. Intake Structure - Stoplog and Guides, single shift													
Labor:													
Superintendent	1	2 weeks	120	$200	$24,000							$24,000	
40 Ton crane operator	1	1 weeks	60	$200	$12,000							$12,000	
Carpenters	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	2	2 weeks	240	$200	$48,000							$48,000	
Subtotal	**6**												$132,000
Equipment:													
40 ton crane, @ 50%	1	1 weeks				$8,600	$8,600					$8,600	
250 kW Generator	1	2 weeks				$4,600	$9,200					$9,200	
600 cfm compressor	1	2 weeks				$3,400	$6,800					$6,800	
500 A Welder	1	2 weeks				$2,500	$5,000					$5,000	
Misc. small tools, 5% of labor	1						$6,600					$6,600	
Subtotal													$36,200
Materials:													
Form Bracing								150	LF	$5	$800	$800	
Cement Grout								5	CY	$700	$3,500	$3,500	
Stoplogs								34,000	lb	$9	$306,000	$306,000	
Stoplog Guides								8,930	lb	$12	$107,200	$107,200	
Roof Hatch								1	LS	$15,000	$15,000	$15,000	
Subtotal													$432,500
ITEM TOTAL					**$132,000**		**$36,200**				**$432,500**		**$600,700**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.4. Intake Structure - Trashrack, single shift													
Labor:													
Superintendent	1	2 weeks	120	$200	$24,000							$24,000	
40 Ton crane operator	1	1 weeks	60	$200	$12,000							$12,000	
Carpenters	3	2 weeks	360	$200	$72,000							$72,000	
Laborers	2	2 weeks	240	$200	$48,000							$48,000	
Subtotal	**7**												$156,000
Equipment:													
40 ton crane, @ 50%	1	1 weeks				$8,600	$8,600					$8,600	
250 kW Generator	1	2 weeks				$4,600	$9,200					$9,200	
600 cfm compressor	1	2 weeks				$3,400	$6,800					$6,800	
500 A Welder	1	2 weeks				$2,500	$5,000					$5,000	
Misc. small tools, 5% of labor	1						$7,800					$7,800	
Subtotal													$37,400
Materials:													
Trashracks								34,000	lb	$15	$510,000	$510,000	
Subtotal													$510,000
ITEM TOTAL					**$156,000**		**$37,400**				**$510,000**		**$703,400**

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Interim Feasibility Report
Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.5. Gate House - Excavation and Surface Prep, single shift													
Labor:													
Superintendent	1	2 weeks	120	$200	$24,000							$24,000	
Equipment Operators	3	2 weeks	360	$200	$72,000							$72,000	
Truck Drivers	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	2	2 weeks	240	$200	$48,000							$48,000	
Subtotal	**8**												$192,000
Equipment:													
D7 Dozer	1	2 weeks				$4,600	$9,200					$9,200	
966 Loader	1	2 weeks				$3,400	$6,800					$6,800	
316 Excavator	1	2 weeks				$4,500	$9,000					$9,000	
E/D Trucks	2	2 weeks				$4,300	$17,200					$17,200	
Misc. small tools, 5% of labor	1						$9,600					$9,600	
Subtotal													$51,800
Materials:													
Gravel Surfacing								44	CY	$45	$2,000	$2,000	
labor								1	LS	$19,200	$19,200	$19,200	
Subtotal													$21,200
ITEM TOTAL					**$192,000**		**$51,800**				**$21,200**		**$265,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.6. Gate House - Gates and Guides, single shift (Note: Supply and install of Gates and Guides only, concrete and shaft lining in tunnel estimate.)													
Labor:													
Superintendent	1	4 weeks	240	$200	$48,000							$48,000	
40 Ton crane operator	1	2 weeks	120	$200	$24,000							$24,000	
Carpenters	4	4 weeks	960	$200	$192,000							$192,000	
Laborers	2	4 weeks	480	$200	$96,000							$96,000	
Subtotal	**8**												$360,000
Equipment:													
40 ton crane, @ 50%	1	2 weeks				$8,600	$17,200					$17,200	
4WD Forklift	1	4 weeks				$3,800	$15,200					$15,200	
250 kW Generator	1	4 weeks				$4,600	$18,400					$18,400	
600 cfm compressor	1	4 weeks				$3,400	$13,600					$13,600	
500 A Welder	1	2 weeks				$2,500	$5,000					$5,000	
Misc. small tools, 5% of labor	1						$18,000					$18,000	
Subtotal													$87,400
Materials:													
Intake Gate								42,000	lb	$12	$504,000	$504,000	
Intake Gate Guides								36,000	lb	$14	$504,000	$504,000	
Gate Shaft Stoplogs								34,000	lb	$9	$306,000	$306,000	
Gate Shaft Stoplog Guides								25,000	lb	$12	$300,000	$300,000	
Subtotal													$1,614,000
ITEM TOTAL					**$360,000**		**$87,400**				**$1,614,000**		**$2,061,400**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.7. Gate House Reinforced Concrete Structure, single shift													
Labor:													
Superintendent	1	2 weeks	120	$200	$24,000							$24,000	
40 Ton crane operator	1	1 weeks	60	$200	$12,000							$12,000	
Carpenters	4	2 weeks	480	$200	$96,000							$96,000	
Mixer truck drivers	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	4	2 weeks	480	$200	$96,000							$96,000	
Subtotal	**12**												$276,000
Equipment:													
40 ton crane, @ 50%	1	1 weeks				$8,600	$8,600					$8,600	
Concrete Mixer Trucks	2	2 weeks				$5,000	$20,000					$20,000	
4WD Forklift	1	2 weeks				$3,800	$7,600					$7,600	
250 kW Generator	1	2 weeks				$4,600	$9,200					$9,200	
600 cfm compressor	1	2 weeks				$3,400	$6,800					$6,800	
Batch plants	1	2 weeks				$3,500	$7,000					$7,000	
Silos, conveyors, etc	1	2 weeks				$2,000	$4,000					$4,000	
Misc. small tools, 5% of labor	1						$13,800					$13,800	
Subtotal													$77,000
Materials:													
Form Lumber 3/4" Plywood								2,000	SF	$2	$4,000	$4,000	
Reinforced Concrete								225	CY	$790	$177,800	$177,800	
Subtotal													$181,800
ITEM TOTAL					**$276,000**		**$77,000**				**$181,800**		**$534,800**

Chikuminuk Hydroelectric Project
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Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.8. Gate House Superstructure Erection, single shift													
Labor:													
Superintendent	1	2 weeks	120	$200	$24,000							$24,000	
Operators	2	2 weeks	240	$200	$48,000							$48,000	
Ironworkers	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	2	2 weeks	240	$200	$48,000							$48,000	
Sheetmetal workers	2	1 weeks	120	$200	$24,000							$24,000	
Roofers	2	1 weeks	120	$200	$24,000							$24,000	
Subtotal	**11**												$216,000
Equipment:													
40 Ton crane	1	2 weeks				$8,600	$17,200					$17,200	
4WD Forklift	1	2 weeks				$3,800	$7,600					$7,600	
250 kW Generator	1	2 weeks				$4,600	$9,200					$9,200	
500 A Welder	2	2 weeks				$2,500	$10,000					$10,000	
Misc. light plants	1	2 weeks				$1,000	$2,000					$2,000	
Subtotal													$46,000
Materials:													
Steel Superstructure								27,500	LB	$3.90	$107,300	$107,300	
Pre-insulated Wall Panels								1,420	SF	$29.00	$41,200	$41,200	
Pre-insulated Roof Panels								1,140	SF	$33.00	$37,700	$37,700	
Bridge Crane								1	LS	$250,000.00	$250,000	$250,000	
Supplier Representatives								1	LS	$40,000.00	$40,000	$40,000	
Doors/louvers/hatches								1	LS	$75,000.00	$75,000	$75,000	
Paint								1	LS	$5,000.00	$5,000	$5,000	
Subtotal													$556,200
ITEM TOTAL					**$216,000**		**$46,000**				**$556,200**		**$818,200**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D.4.4 - Intake and Gate House

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
4.6.9. Architectural, Mechanical and Electrical, single shift													
Labor:													
Superintendent	1	4 weeks	240	$200	$48,000							$48,000	
Carpenters	2	2 weeks	240	$200	$48,000							$48,000	
Electricians	2	4 weeks	480	$200	$96,000							$96,000	
Pipefitters	1	2 weeks	120	$200	$24,000							$24,000	
Laborers	2	4 weeks	480	$200	$96,000							$96,000	
Subtotal	**8**												$312,000
Equipment:													
4WD Forklift	1	4 weeks				$3,800	$15,200					$15,200	
250 kW Generator	1	4 weeks				$4,600	$18,400					$18,400	
500 A Welder	1	2 weeks				$2,500	$5,000					$5,000	
Misc. light plants	1	4 weeks				$1,000	$4,000					$4,000	
Subtotal													$42,600
Materials:													
Labor								1	LS	$31,200.00	$31,200	$31,200	
Piping								1	LS	$40,000.00	$40,000	$40,000	
Lighting Accessories, HVAC								1	LS	$15,000.00	$15,000	$15,000	
Communications Equipment								1	LS	$250,000.00	$250,000	$250,000	
Subtotal													$336,200
ITEM TOTAL					**$312,000**		**$42,600**				**$336,200**		**$690,800**

Subtotals		
Labor	**$972,000**	
Equipment	**$199,000**	
Materials	**$1,205,400**	
TOTAL		**$2,376,400**

*Intake Structure Excavation and Slope Support is included in Jim Peregoy's Estimate. Do not include on this tab.

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks
Hours / Week = 60

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Appendix D4.5 - Penstock System

PENSTOCK THICKNESS & WEIGHT CALCULATIONS

Minimum Thickness: tmin = (D + 20)/400

Item	Tunnel Section	Manifold Section	Powerhouse Section
D (inch) =	198	171	99
t_{min} =	0.545	0.4775	0.2975
say =	9/16"	1/2"	5/16"
weight (lb) =	308,900		

Weight: W = 128*D*t*L

Item	Tunnel Section	Manifold Section	Powerhouse Section	TOTAL
D (feet) =	16.5	14.25	8.25	
t =	0.5625	0.5	0.3125	
L (feet) =	260	60	250	
W (lb) =	**308,900**	**54,700**	**82,500**	**446,100**

Internal Pressure: allowable stress = pr/t

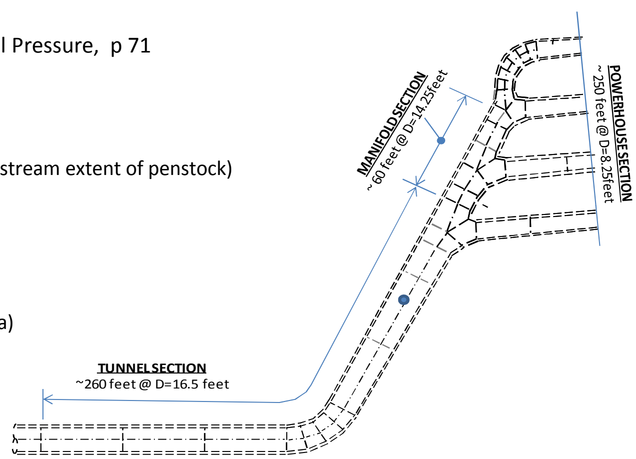
Item	Tunnel Section	Manifold Section	Powerhouse Section
p =	54.48	54.48	54.48
r =	99	85.5	49.5
stress =	15,000	15,000	15,000
t =	0.360	0.311	0.180

Note: minimum thickness controls over allowable stress

External Pressure (tunnel section only) - Amstutz Equation

see: Chapter 3 Buckling of Restrained Pipe under External Pressure, p 71

Head =	0.454*(660 - 540)		
Head =	54.48	psi	
Path =	850	feet	(total length of tunnel)
L =	550	feet	(distance from intake to upstream extent of penstock)
F.S. =	1.5		
p =	1.5*Head*L/Path		
p =	35	psi	
r =	99	inch	
t =	0.5625	inch	(Minimum thickness criteria)
i =	0.180421959		
σ =	28,800		
E =	30,000,000		
ε =	17		
Allowable P =	133	psi	(good to go!)



External Pressure (tunnel section only) - Amstutz, Jacobsen & Vaughan Formulas

see COE Engineering Monogram 110-2-2901, Table 9-2, p 9-19

Results for a 90 in radius

Formulas	Safety Factor	Shell Thickness 1/2	5/8	3/4	7/8	1
Amstutz	1.5	65	82	119	160	205
Jacobsen	1.5	51	65	116	153	173
Vaughan	1.5	97	135	175	217	260

Results for a 99 inch radius where Allowable Pressure varies by (t/r)^3 and t = 0.5625

Formulas	Safety Factor	9/16"	
Amstutz	1.5	69.5	
Jacobsen	1.5	54.6	(5/16" shell can support full head - headwater to tailwater)
Vaughan	1.5	103.8	

CONCLUSION: MINIMUM THICKNESS CRITERIA CONTROLS

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.1 Prepare laydown area - single shift													
Labor:													
Superintendent	1	2 weeks	120	$200	$24,000							$24,000	
Equip Operators	4	2 weeks	480	$200	$96,000							$96,000	
Truck drivers	3	2 weeks	360	$200	$72,000							$72,000	
Laborers	4	2 weeks	480	$200	$96,000							$96,000	
Subtotal	**12**												$288,000
Equipment:													
Cat D7	2	2 weeks				$7,000	$28,000					$28,000	
966 loader	1	2 weeks				$5,500	$11,000					$11,000	
E/D trucks	2	2 weeks				$5,500	$22,000					$22,000	
66" Roller	1	2 weeks				$3,500	$7,000					$7,000	
Tractor/Trailer	1	2 weeks				$2,800	$5,600					$5,600	
Subtotal													$73,600
Materials:													
Gravel Surfacing								2,500.00	CY	$45	$112,500	$112,500	
Geotextile, etc. @ 10% of labor											$29,000	$29,000	
Subtotal													$141,500
ITEM TOTAL					**$288,000**		**$73,600**				**$141,500**		**$503,100**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.2. Excavation - double shifts													
Labor:													
Superintendent	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	2	2 weeks	240	$200	$48,000							$48,000	
Truck drivers	4	2 weeks	480	$200	$96,000							$96,000	
Operators	12	2 weeks	1,440	$200	$288,000							$288,000	
Subtotal	**20**												$480,000
Equipment:													
Cat D7	2	2 weeks				$10,500	$42,000					$42,000	
966 Loader	2	2 weeks				$8,250	$33,000					$33,000	
316 Excavator	2	2 weeks				$6,750	$27,000					$27,000	
Track Drill	2	2 weeks				$4,350	$17,400					$17,400	
E/D trucks	2	2 weeks				$8,250	$33,000					$33,000	
600 cfm compressor	1	2 weeks				$3,750	$7,500					$7,500	
Subtotal													$159,900
Materials:													
Maint./drill steel, etc. @ 15% of labor											$72,000	$72,000	
Subtotal													$72,000
ITEM TOTAL					**$480,000**		**$159,900**				**$72,000**		**$711,900**
5.1.3. Foundation Prep - single shift													
Labor:													
Operators	1	2 weeks	120	$200	$24,000							$24,000	
Driller	2	2 weeks	240	$200	$48,000							$48,000	
Laborers	3	2 weeks	360	$200	$72,000							$72,000	
Subtotal	**6**												$144,000
Equipment:													
Track Drill	2	2 weeks				$2,900	$11,600					$11,600	
250 kW Generator	1	2 weeks				$2,500	$5,000					$5,000	
Subtotal													$16,600
Materials:													
Form lumber	2,670							$2,670	ft	$2	$5,340	$5,340	
Misc @ 10% of labor											$14,400	$14,400	
Subtotal													$19,740
ITEM TOTAL					**$144,000**		**$16,600**				**$19,740**		**$180,300**

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Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.4. Concrete construction for substructure - double shifts													
Labor:													
Superintendent	2	4 weeks	480	$200	$96,000							$96,000	
Equip Operators	4	4 weeks	960	$200	$192,000							$192,000	
Boilermakers	8	4 weeks	1,920	$200	$384,000							$384,000	
Ironworkers	4	4 weeks	960	$200	$192,000							$192,000	
Electrician	2	4 weeks	480	$200	$96,000							$96,000	
Mixer truck drivers	6	4 weeks	1,440	$200	$288,000							$288,000	
Carpenter	6	4 weeks	1,440	$200	$288,000							$288,000	
40 Ton crane operator	2	4 weeks	480	$200	$96,000							$96,000	
Laborers	8	4 weeks	1,920	$200	$384,000							$384,000	
Subtotal	**42**												$2,016,000
Equipment:													
40 Ton crane	1	4 weeks				$12,900	$51,600					$51,600	
4WD Forklift	1	4 weeks				$3,800	$15,200					$15,200	
Batch plant	1	4 weeks				$5,250	$21,000					$21,000	
Mixer truck	3	4 weeks				$7,500	$90,000					$90,000	
600 cfm compressor	1	4 weeks				$5,100	$20,400					$20,400	
Concrete pump	1	4 weeks				$1,800	$7,200					$7,200	
250 kW Generator	2	4 weeks				$6,900	$55,200					$55,200	
Subtotal													$260,600
Materials:													
Reinforced Concrete								7,800	CY	$690	$5,382,000	$5,382,000	
Inlet valves at wall								4	EA	$250,000	$1,000,000	$1,000,000	
Draft tube embedments								136,000	LBS	$14	$1,904,000	$1,904,000	
Draft tube gate / bulkhead guides								93,000	LBS	$12	$1,116,000	$1,116,000	
Form lumber for 20 pours, 15 sf/cy	0							13,000	SF	$2	$26,000	$26,000	
Subtotal													$9,428,000
ITEM TOTAL					**$2,016,000**		**$260,600**				**$9,428,000**		**$11,704,600**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.5. Superstructure Erection, double shifts													
Labor:													
Superintendent	2	5 weeks	600	$200	$120,000							$120,000	
Operators	4	5 weeks	1,200	$200	$240,000							$240,000	
Ironworkers	8	5 weeks	2,400	$200	$480,000							$480,000	
Electrician	4	5 weeks	1,200	$200	$240,000							$240,000	
Laborers	8	5 weeks	2,400	$200	$480,000							$480,000	
Carpenters	4	5 weeks	1,200	$200	$240,000							$240,000	
Sheetmetal workers	8	5 weeks	2,400	$200	$480,000							$480,000	
Roofers	6	5 weeks	1,800	$200	$360,000							$360,000	
Subtotal	**44**												$2,640,000
Equipment:													
40 Ton crane	2	5 weeks				$12,900	$129,000					$129,000	
4WD Forklift	2	5 weeks				$5,700	$57,000					$57,000	
250 kW Generator	1	5 weeks				$6,900	$34,500					$34,500	
500 A Welder	2	5 weeks				$3,750	$37,500					$37,500	
Misc. light plants	2	5 weeks				$1,500	$15,000					$15,000	
Subtotal													$273,000
Materials:													
Steel Superstructure								275,000	LB	$3.90	$1,072,500	$1,072,500	
Pre-insulated Wall Panels								14,200	SF	$29.00	$411,800	$411,800	
Pre-insulated Roof Panels								11,400	SF	$33.00	$376,200	$376,200	
Bridge Crane								1	LS	$300,000.00	$300,000	$300,000	
Supplier Representatives								1	LS	$40,000.00	$40,000	$40,000	
Doors/louvers/hatches								1	LS	$150,000.00	$150,000	$150,000	
Paint								1	LS	$20,000.00	$20,000	$20,000	
Subtotal													$2,370,500
ITEM TOTAL					**$2,640,000**		**$273,000**				**$2,370,500**		**$5,283,500**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.6. Mechanical / Electrical Installations - single shift													
Labor:													
Superintendent	1	11 weeks	660	$200	$132,000							$132,000	
Millrights	4	11 weeks	2,640	$200	$528,000							$528,000	
Boilermakers	2	11 weeks	1,320	$200	$264,000							$264,000	
Carpenters	2	11 weeks	1,320	$200	$264,000							$264,000	
Ironworkers	2	11 weeks	1,320	$200	$264,000							$264,000	
40 Ton crane operator	2	11 weeks	1,320	$200	$264,000							$264,000	
Pipefitters	2	11 weeks	1,320	$200	$264,000							$264,000	
Laborers	6	11 weeks	3,960	$200	$792,000							$792,000	
Electricians	<u>4</u>	11 weeks	2,640	$200	$528,000							<u>$528,000</u>	
Subtotal	**25**												$3,300,000
Equipment:													
40 ton crane, @ 50%	2	11 weeks				$4,300	$94,600					$94,600	
4WD Forklift	1	11 weeks				$3,800	$41,800					$41,800	
250 kW Generator	1	11 weeks				$4,600	$50,600					$50,600	
600 cfm compressor	1	11 weeks				$3,400	$37,400					$37,400	
500 A Welder	2	11 weeks				$2,500	$55,000					$55,000	
Misc. small tools, 5% of labor	1						$165,000					<u>$165,000</u>	
Subtotal													$444,400
Materials:													
Switchgear											$0		
In-house transformers											$0		
Lighting/accessory fixtures/HVAC								1	LS	$40,000.00	$40,000		
Small pumps/meters/piping								1	LS	$30,000.00	$30,000	<u>$30,000</u>	
Subtotal													$30,000
ITEM TOTAL					**$3,300,000**		**$444,400**				**$70,000**		**$3,774,400**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.7. Architectural - painting, office trim, flooring - single shift													
Labor:													
Carpenters	2	6 weeks	720	$200	$144,000							$144,000	
Laborers	6	6 weeks	2,160	$200	$432,000							$432,000	
Painters	2	6 weeks	720	$200	$144,000							$144,000	
Subtotal	**10**												$720,000
Equipment:													
Scaffolding	1	6 weeks				$100	$600					$600	
600 cfm compressor	1	6 weeks				$3,400	$20,400					$20,400	
Misc. fans, pumps, 5% of labor	1	6 weeks					$36,000					$36,000	
Subtotal													$57,000
Materials:													
Paint, 10% of labor											$72,000	$72,000	
Subtotal													$72,000
ITEM TOTAL					**$720,000**		**$57,000**				**$72,000**		**$849,000**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.8. Pre-Operational Systems Check - single shift													
Labor:													
Pipefitters	2	2 weeks	240	$200	$48,000							$48,000	
Electrician	1	2 weeks	120	$200	$24,000							$24,000	
Millrights	1	2 weeks	120	$200	$24,000							$24,000	
Start-up engineer	1	2 weeks	120	$200	$24,000							$24,000	
Factory reps	2	2 weeks	240	$200	$48,000							$48,000	
Subtotal	**7**												$168,000
Equipment:													
Misc. welders, oil flush, 40% of labor	1						$67,200					$67,200	
Subtotal													$67,200
Materials:													
Flushing oil / filters	1								LS	$10,000	$10,000	$10,000	
Subtotal													$10,000
ITEM TOTAL					**$168,000**		**$67,200**				**$10,000**		**$245,200**

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.1 - Powerhouse Structure

Item	No.	Duration	Labor Hours	Labor Rate	Labor Cost	Unit Cost	Equip Cost	Qty	Unit	Unit Cost	Materials Cost	Item Cost	
5.1.9. Commissioning/Trial Operation - single shift													
Labor:													
Superintendent, @80%	1	4 weeks	240	$160	$38,400							$38,400	
Pipefitters, @80%	1	4 weeks	240	$160	$38,400							$38,400	
Millrights, @80%	1	4 weeks	240	$160	$38,400							$38,400	
Electrician, @80%	1	4 weeks	240	$160	$38,400							$38,400	
Factory reps, @80%	2	4 weeks	480	$160	$76,800							$76,800	
Laborers, @80%	3	4 weeks	720	$160	$115,200							$115,200	
Boilermakers, @80%	1	4 weeks	240	$160	$38,400							$38,400	
Subtotal	**10**												$384,000
Equipment:													
250 kW Generator	1	4 weeks				$4,600	$18,400					$18,400	
600 cfm compressor, @ 50%	1	4 weeks				$1,700	$6,800					$6,800	
Subtotal													$25,200
Materials:													
Misc @ 3% of Labor											$11,520	$11,520	
Subtotal													$11,520
ITEM TOTAL					**$384,000**		**$25,200**				**$11,520**		**$420,700**

Subtotals		
Labor	**$10,140,000**	
Equipment	**$1,377,500**	
Materials	**$12,195,260**	
TOTAL		**$23,712,760**

Base Labor Rate / hour = $200 (includes directs, indirects, allowance for overtime & per diem)
Activity Duration Unit = Weeks Hours / Week = 60

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.2 - Powerhouse Equipment

Cost Estimate Summary

Item	Unit Cost	Quantity	Total	Total Weight	Notes
Turbine, Generator, Switchgear, Governor (Each)	$4,974,200	4	$19,896,800	440,000	5.5 MW Vertical Francis Units, 750 CFS at 100ft Head
Turbine, Generator, Switchgear, Governor Installation	$2,984,520	4	$11,938,080		
Turbine Isolation Valve	$150,000	4	$600,000	96,000	96" Weir Tricentric Butterfly Valve
Flywheel	$55,500	8	$444,000	296,000	9 ft diameter, two disc, each about two ft thick, weight 37,000 lb
Air Compressors and Appurtenances (S&I)	$30,000	1	$30,000	3,000	2 Ea 45 SCFM with 300Gal Recievers and dryer
Unwatering, Drainage, & Cooling Water Pumps (S&I)	$40,000	1	$40,000	5,000	4 Ea Vertical Turbine Pumps
Fire Protection System (S&I)	$25,000	4	$100,000	8,000	4 Ea CO2
Oil Filtration System (S&I)	$30,000	1	$30,000	2,000	Zurn 35GPM
Potable Water System	$30,000	1	$30,000	3,000	Dual supply, well and penstock, hyproclorinator, tank pumps
Piping, Valves and Fittings (S&I)	$300,000	1	$300,000	25,000	
Maintenance Equipment (S&I)	$20,000	1	$20,000	25,000	welders, lathe, drill press, gantry, hand tools etc
Ventilation Equipment (S&I)	$60,000	1	$60,000	12,000	Trane T17 Climate Changer (17,000 cfm)
Sanitary System (S&I)	$25,000	1	$25,000	20,000	Clow seage ejection system and septic system
Miscellaneous Equipment (S&I)	$50,000	1	$50,000	25,000	

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.2 - Powerhouse Equipment

Cost Estimate Summary

Item	Unit Cost	Quantity	Total	Total Weight	Notes
Station Service Transformer 500 kVA, 12.47 kV/480-877V	$25,000	2	$50,000	10,000	GE Dry Type
Station Batteries, Controls, installation	$198,968	1	$198,968	15,000	
Station Service Switchgear, Incl. 10 C.B.'s 480 V	$200,000	1	$200,000	12,000	
Unit Protection	$137,500	4	$550,000	12,000	
Electrical Services	$650,000	1	$650,000	89,000	
a. DC Load Centers		1	$0	1,000	
b. Conduit		1	$0	12,000	
c. Cable, Power, Control, Communications		1	$0	50,000	
d. Cable Tray System		1	$0	4,000	
e. Grounding System		1	$0	10,000	
f. Lighting		1	$0	12,000	
SCADA	$137,500	4	$550,000	20,000	
Crane (S&I)	$300,000	1	$300,000	50,000	48 Ton Bridge Crane
300 KW Standby Generator and 2000 gal Fuel Tank (S&I)	$137,500	4	$550,000	48,000	
Switchyard	$4,000,000	1	$4,000,000		
TOTALS			**$40,613,000**	**1,305,000**	

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D5.2 - Powerhouse Equipment

2009 Turbine Price

Item	Value
$/KW	$665
Escalation	0.16
Better Governor	0.05
Installation	0.6
Possible premium for European manufacture	0.15
Turbine size (kw)	5500
Turbine Generator Switchgear Governor ($2009)	$3,657,500
Unit Protection $/kw	$25

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D6.1 - Transmission to Bethel

Description	Qty	Unit	Estimated Cost Material	Estimated Cost Labor	Estimated Cost Total	
Air (helicopter) construction = 47 miles						
Structures	207	ea	$16,420	$45,665	$12,839,200	
Foundations	320	ea	$5,500	$15,600	$6,743,600	
Conductor	47	crkt mi	$26,136	$172,973	$9,358,100	
OPGW	0	crkt mi			$0	
Other*	47	mi	$20,318	$70,008	$4,245,300	
Clearing	0	mi			$0	
Subtotal						**$33,186,200**
Mob/Demob (10%)					$3,318,600	
Helicopter Construction (25%)					$9,126,200	
Contingency					$0	
Subtotal						**$12,444,800**
Estimated Total Construction Cost						**$45,631,000**
Overland summer construction = 43 miles						
Structures	346	ea	$15,152	$28,345	$15,050,000	
Foundations	294	ea	$3,600	$3,600	$2,116,800	
Conductor	43	crkt mi	$23,760	$95,040	$5,108,400	
OPGW	0	crkt mi			$0	
Other*	30	lump	$20,341	$70,135	$2,714,300	
Clearing	0	mi			$0	
Subtotal						**$24,989,500**
Mob/Demob (8%)					$1,999,200	
Helicopter Construction (5%)					$1,349,400	
Contingency					$0	
Subtotal						**$3,348,600**
Estimated Total Construction Cost						**$28,338,100**
Overland winter construction =	46	miles				
Structures	203	ea	$16,804	$43,834	$12,331,900	
Foundations	317	ea	$3,960	$5,760	$3,082,800	
Conductor	46	crkt mi	$26,136	$146,362	$7,934,900	
OPGW	0	crkt mi			$0	
Other*	46	lump	$20,344	$232,783	$11,643,800	
Clearing	0	mi			$0	
Subtotal						**$34,993,400**
Mob/Demob (10%)					$3,499,300	
Helicopter Construction (5%)					$1,924,600	
Contingency					$0	
Subtotal						**$5,423,900**
Estimated Total Construction Cost						**$40,417,300**

* Includes:dampers, aerial balls, bird diverters, signs

Chikuminuk Hydroelectric Project
Interim Feasibility Report
Appendix D6.2 - Transmission to Dillingham

Description	Qty	Unit	Estimated Cost: Material	Labor	Total	Subtotal
Air (helicopter) construction = 4 miles						
Structures	53	ea	$2,433	$8,683	$589,100	
Foundations	53	ea	$5,500	$12,480	$952,900	
Conductor	4	crkt mi	$8,712	$148,262	$627,900	
OPGW	4	crkt mi	$2,000	$20,000	$88,000	
Other*	1	lump			$33,800	
Clearing	1	mi	$0	$10,000	$10,000	
Subtotal						**$2,301,700**
Mob/Demob (10%)					$230,200	
Helicopter Construction (25%)					$633,000	
Contingency					$0	
Subtotal						**$863,200**
Estimated Total Construction Cost						**$3,164,900**
Overland summer construction = 96 miles						
Structures	1268	ea	$2,194	$4,548	$8,548,900	
Foundations	254	ea	$2,500	$3,600	$1,549,400	
Conductor	96	crkt mi	$7,920	$76,032	$8,059,400	
OPGW	96	crkt mi	$2,000	$15,000	$1,632,000	
Other*	4	lump			$33,800	
Clearing	70	mi	$0	$10,000	$700,000	
Subtotal						**$20,523,500**
Mob/Demob (8%)					$1,641,900	
Helicopter Construction (10%)					$2,216,500	
Contingency					$0	
Subtotal						**$3,858,400**
Estimated Total Construction Cost						**$24,381,900**
Road summer construction = 19 miles						
Structures	251	ea	$2,198	$2,237	$1,113,200	
Foundations	51	ea	$2,500	$3,600	$311,100	
Conductor	19	crkt mi	$7,920	$57,024	$1,233,900	
OPGW	19	crkt mi	$2,000	$12,000	$266,000	
Other*	1	lump			$104,900	
Clearing	12	mi	$0	$6,000	$72,000	
Subtotal						**$3,101,100**
Mob/Demob (5%)					$155,100	
Contingency					$0	
Subtotal						**$155,100**
Estimated Total Construction Cost						**$3,256,200**

* Includes:dampers, aerial balls, bird diverters, signs

Chikuminuk Lake Hydroelectric Project

Interim Feasibility Report
Volume I – Technical Studies

Appendix E – Economic Analysis

DRAFT April, 2014
Prepared By:

HATCH™

Alaska Fuel Price Projections 2013-2035

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Contents

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Introduction

The Alaska Fuel Price Projections are developed for the Alaska Energy Authority (AEA) for the purpose of *estimating the potential benefits and costs of renewable energy projects*. Project developers submit applications to AEA for grants awarded under the Alaska Renewable Energy Fund (REF) program process. These fuel price projections are used to evaluate the economic feasibility of project applications; economic feasibility is only one of many factors of the project evaluation process. In this report we present the methodology for the seventh fuel prices projection. In addition to their use for the REF review, the Institute of Social and Economic Research (ISER), University of Alaska Anchorage (UAA) uses the projections for other economic research and energy project evaluations.

Economists at ISER have completed six previous Alaska Fuel Price Projections since 2008 (all available at: http://www.iser.uaa.alaska.edu/). The fuel price projections fulfill an important need for price information and are used by many stakeholders in addition to AEA. As a result of their broad use among the public, we expanded what used to be cursory notes on methodology. Our intent is to provide more detailed information to the report's readers and users of the fuel price projections.

Projections vs. Forecasts

The fuel price projections are not price forecasts. Projections are statistical estimates based on a data sample that systematically adjusts the data using statistical estimation procedures. A projection provides an estimate of future values based on a statistical assessment of past relationships under specific assumptions, but they are not a prediction that these specific assumptions will happen. In contrast, forecasts speculate future values with a certain level of confidence, based on current and past values as a 'prediction' of what will happen in the future. In short, projections are based on assumptions but they do not imply the assumptions will happen, whereas forecasts are based on assumptions that represent expectations of actual future events. For example, in our rural fuel price projections for western Alaska villages, we assume that future sea ice patterns will remain similar to previous patterns and will have a similar effect on the cost and timing of fuel deliveries to the region. We do not attempt to forecast when seasonal ice patterns will change, and build that assumption into a forecast of fuel prices under diminished sea ice conditions.

The projections

The Alaska Fuel Price projections are a statistical estimation of potential utility avoided fuel prices from 2013 to 2035, based on historic relationships between utility fuel prices and crude oil prices reported by the U.S. Department of Energy, Energy Information Administration (EIA).[1] These statistically estimated relationships are used to project potential future fuel prices based on EIA's published *Annual Energy Outlook* crude oil and natural gas price forecasts. So in short, the Alaska fuel price projections are based on EIA forecasts. We use the historic relationships between actual crude oil and actual community utility fuel prices to project each community's future fuel prices based on the EIA forecast. The fuel price projections are limited in their applicability to the modeling of project benefits and costs and *should not be considered fuel price forecasts*.

[1] Avoided fuel costs are the marginal cost for a utility to produce one more unit of power. The projections presented in this report are based on the potential fuel prices a utility may have to pay if it needed to produce one more unit of power.

Based on the EIA low, medium and high forecasts, the projections also provide three possible scenarios: low, medium and high fuel price projections. In addition, estimates of the social cost of carbon (previously included as estimates of potential carbon taxes), and a price differential for home heating fuel are provided and are incorporated into the REF benefit-cost model for evaluating potential projects.[2] Previously, a five cents premium for low sulfur diesel was added to the fuel oil price projections in anticipation of the implementation of low sulfur diesel air quality requirements. However, the low sulfur diesel requirement was implemented in 2010; hence recent prices reflect the effects of the rule and a premium is no longer necessary.

The ranges of values between the low, medium (reference), and high projections are based on the assumptions implicit in the EIA oil price forecasts. Readers are encouraged to directly review the EIA *Annual Energy Outlook 2013* at: http://www.eia.doe.gov/oiaf/aeo/index.html

We generated low, medium, high case fuel price projections for the years 2013-2035 for the following fuels:

- Incremental (or next unit purchased) natural gas in Southcentral Alaska delivered to a utility-scale customer
- Incremental diesel delivered to a PCE community utility tank
- Incremental home heating oil/diesel purchased in a PCE community
- Incremental home heating oil/diesel purchased in Anchorage, Fairbanks, Juneau, Kenai, Ketchikan, Kodiak, Palmer, Petersburg, Sitka, Wasilla and Wrangell

This technical report provides documentation of the assumptions and methods used to develop these projections. A companion Excel workbook contains the detailed projections.

Methods and assumptions

Base year and time horizon

Our projections run from 2013 to 2035. They are computed and reported in inflation-adjusted year 2012 dollars. Because the projections are statistical estimates of annual prices, they may differ from actual prices. In addition, our sample data sets do not include pricing data for 2013. We recognize that a "projection" for 2013 is unlikely to match actual 2013 data. However, much of the data we rely on is published only through 2011 and 2012.

Ultra low sulfur diesel premium

We no longer include a five cent additional price premium for rural areas to account for the additional refining costs of ultra-low sulfur diesel. The low sulfur fuel requirement was implemented in 2010 and recent prices reflect this factor.

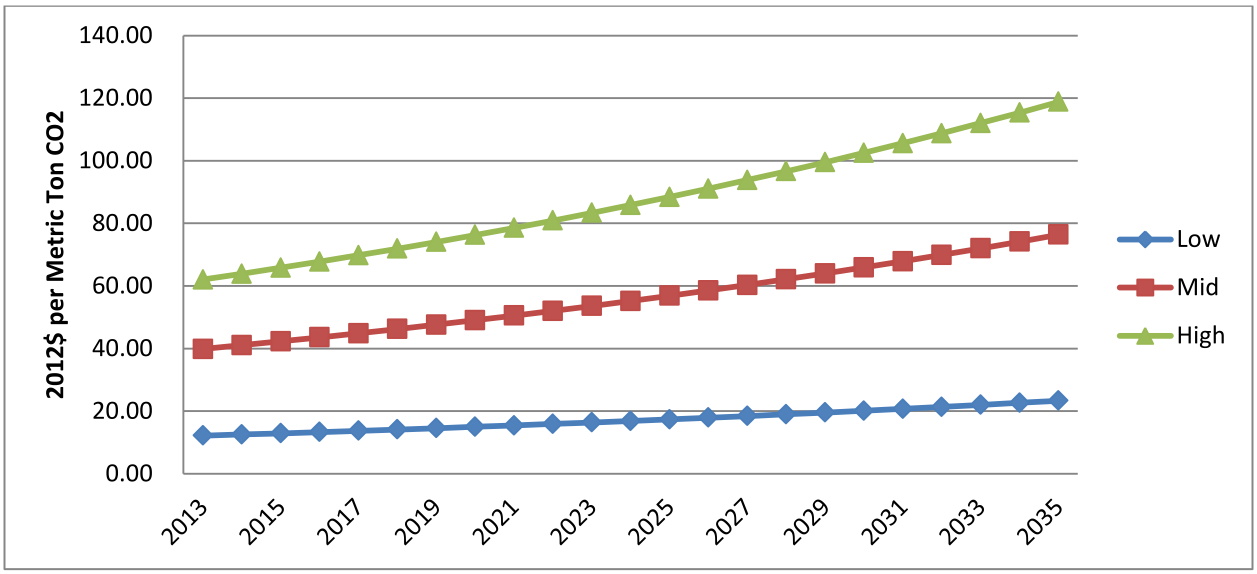
Carbon pricing

We continue to use the federal government's estimates for the social cost of carbon (SCC) that are used in benefit-cost analyses for federally funded projects. In this update, we continue to use the SCC

[2] There are differences in the fuel prices different customers pay. Utilities commonly pay lower prices than retail customers (what a household may pay). Also, there is a difference in the price and cost of fuel used for electricity and fuel used for space heating.

estimates as explained by a working paper from the National Bureau of Economic Research.[3] However, a technical update was published in May 2013 by the Interagency Working Group on Social Cost of Carbon, so we updated accordingly.[4] For the High case, we use the cost of $62 (2012 dollars) per ton of CO2 emissions in 2013. For the Medium case, we use the cost of $40 (2012 dollars) per ton of CO2 emissions in 2013. For the Low case, we use the cost of $12 (2012 dollars) per ton of CO2 emissions in 2013. All three estimates are inflated over time at 3%, which is the average inflation rate of the U.S. Consumer Price Index (CPI) from 1985 to 2012.[5] The carbon pricing methods were modified to reflect current 2012 data. The social cost of carbon is no longer added to the fuel price projections, but rather included separately in the benefit-cost model developed to evaluate proposed projects. However, the flexibility of adding SCC to the price projections remains. Figure 1 summarizes the assumed carbon price trajectories. These assumptions are parameters that can be changed in the model workbook. The data source prior to the June 2011 update was the Massachusetts Institute of Technology.[6]

Figure 1. Carbon price trajectories (year 2012$ per metric ton CO2)



Sources: ISER calculations based on Greenstone (2011 and 2013 update).

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[3] Greenstone, M., Kopits, E., and Wolverton, A. 2011. *Estimating the social cost of carbon for use in U.S. federal rulemakings: a summary and interpretation*. NBER Working Paper 16913, available at: http://www.nber.org/papers/w16913.

[4] Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866. Interagency Working Group on Social Cost of Carbon, United States Government. May 2013. Available at: http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf

[5] Consumer Price Index All Urban Consumers, All items. U.S. Department of Labor, Bureau of Labor Statistics. Available at: ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt. The average CPi from 1985 to 2012 is 2.85%, we use a rounded rate of 3.0%.

[6] In fuel price projections prior to the June 2011 update, the cost of carbon was introduced in the model using the estimates developed by the Massachusetts Institute of Technology (MIT) *Future of Coal* study (Massachusetts Institute of Technology. 2007. *The Future of Coal: Options for a Carbon-Constrained World*. (March). Available at: http://web.mit.edu/coal/).

Natural Gas

Background

The Cook Inlet natural gas market is structurally different from the Lower 48 natural gas markets because it is not connected to a large pipeline network and has relatively few buyers and sellers of gas. As a result, Cook Inlet does not have a natural gas spot market to reveal the true market value of natural gas. In Lower 48 natural gas markets, the market value of gas is revealed by market forces as thousands of buyers and sellers bid on natural gas spot markets. Most natural gas used by Lower 48 utilities is not purchased on the spot market but the physical access to spot markets ensures the price utilities pay for gas reflects the true value of the gas. Public utility regulators in these markets generally do not have to regulate the price utilities pay for natural gas because the price is largely determined by local and regional markets.

In contrast, the Cook Inlet natural gas market has no spot market and thus no clear market signals of value. Instead, all natural gas sales are based on indexed prices agreed upon in contracts negotiated between natural gas producers and a limited number of buyers. As a result, the contract prices negotiated between natural gas producers and utilities may not reflect the true value of the gas because utilities do not actually bear the cost of the gas. Instead the entire natural gas cost is passed on to the utilities' customers who do not directly participate in price contract negotiations; the utilities purchasing the natural gas are also not regulated. The Regulatory Commission of Alaska (RCA) is tasked with protecting the utilities' customers by ensuring that rates are fair and reasonable, which they do through review of natural gas contracts. Unlike its Lower 48 counterparts, the RCA must determine what merits a fair and reasonable natural gas price in the absence of a natural gas market price.

Historically, natural gas prices, as determined by RCA approved contracts, pegged the price of natural gas to a basket of Lower 48 price indexes including natural gas, crude oil, and heating fuel. This pricing method resulted in relatively low natural gas prices until dramatic increases in oil prices drove up the price of Cook Inlet natural gas purchased on these contracts.

Over the last few years when Cook Inlet natural gas prices were especially low, there were concerns regarding future availability of Cook Inlet natural gas because significant capital investment on behalf of the natural gas producers would be necessary to meet growing demand. In the past, producers argued that the return on capital for Cook Inlet natural gas investments needed to be competitive with capital investments in other markets and indicated that they needed the Southcentral price to more closely resemble Lower 48 prices to spur continued investments in field development and production. Under this reasoning the Cook Inlet producers, local utilities, and the RCA began to agree to and approve contracts with the Cook Inlet natural gas price indexed to Lower 48 spot prices.[7]

However, with the sudden rapid increase of shale gas supplies in the Lower 48, natural gas prices dropped significantly. As a result, Cook Inlet became a more appealing natural gas production location given the now relatively higher prices, available infrastructure and ready but less competitive market. This has led to increased exploration and optimism regarding development of Cook Inlet natural gas. In fall 2011, Escopeta Oil company announced that it discovered a large deposit (estimated at 3.5 trillion cubic feet) of Cook Inlet natural gas modifying expectations and assumptions about future Cook Inlet natural gas development and availability. Though there has been no new development in Cook Inlet,

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[7] For more information on Southcentral Alaska natural gas prices and contracts, see the RCA website: http://rca.alaska.gov/RCAWeb/home.aspx

exploration has continued and there are positive expectations about future development. However, prices have continued to decrease. Since 2009, when Cook Inlet gas reached its highest average annual price of $7.80 per Mcf (2012$), prices have fallen an average of 11% annually to $4.84 per Mcf in 2013 (2012$).[8] The largest decrease occurred in 2010 when prices dropped approximately 18%.This natural gas projection attempts to take these factors into consideration. Nevertheless, both the national and Alaska markets are clearly in flux and difficult to predict.

Assumptions

As we mentioned earlier, in Alaska the RCA must approve prices and contracts between natural gas suppliers and utilities. Hence, some contract information is publicly available. The analysis in this report assumes Chugach Electric Association (CEA) is the marginal supplier of electricity in Southcentral Alaska. Also, it assumes that two recent contractual relationships provide the marginal supply of gas for electric power generation. CEA fulfills its unmet needs of natural gas through a contract with Conoco Phillips (2009) and a more recent contract with Hilcorp (previously Marathon Alaska Production, LLC) (Figure 2).

The concept of marginal supply in this context refers to the most recently purchased energy to supply electricity, not to the energy supply that would first be disrupted or offset by a new renewable energy resource. This is appropriate for the projection of prices because the most recently purchased energy is a better indicator of future energy prices than previously purchased energy.

Figure 2. Chugach Electric Association natural gas supply contracts

Summary of Chugach Natural Gas Supply Contracts				
Gas Supplier	Contract Term	Contract	Q2-2013 (Actual)	Q3-2103 (Projected)
ConocoPhillips	1/1/2010 – 12/31/2016	Firm Fixed	$3.44	$4.08
		Firm Variable	$4.53	$4.94
Hilcorp	4/1/2011 – 12/31/2014	Firm	$5.94	$5.94
Hilcorp (Economy)	4/1/2013 – 12/31/2014	Base	$7.75	$7.75

Image reproduced from Chugach Electric Association Tariff Advice Letter to RCA No.373-8 from May, 2013.

The contract between CEA and ConocoPhillips, filed May 12, 2009 (http://rca.alaska.gov/RCAWeb/Certificate/CertificateDetails.aspx?id=7eefd8ff-1630-4ed0-80f6-59e1aed8e391), states that ConocoPhillips will supply natural gas sufficient for CEA to meet 100% of unmet gas requirements through April 2011, roughly 50% of Chugach's unmet gas requirements from June 2011 through 2015, and about 25% of Chugach's unmet needs in 2016 (Figure 3). Hence, currently and over the next two years, ConocoPhillips will supply CEA with enough natural gas to satisfy 50% of its unmet needs, while the other 50% will be supplied by Hilcorp.

[8] Please note that the 2013 average is partial and only includes two quarters of data. The CI NG average price for 2012 was $5.64 per Mcf.

Figure 3. Chugach Electric Association natural gas supply, 2009-2016

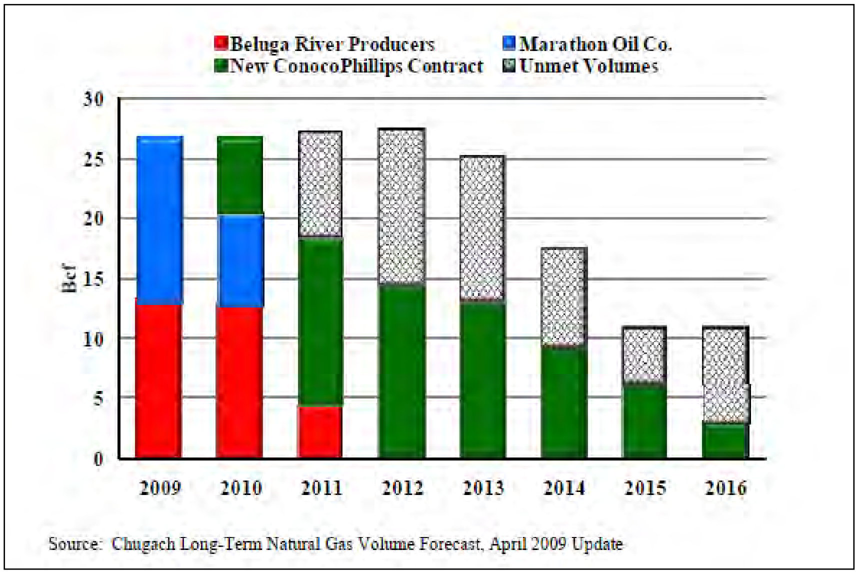

Image reproduced from Chugach Electric Association, Gas Supply Contract with ConocoPhillips, 2009.

The majority of the gas to be supplied to Chugach Electric Association for base load electric generation is termed "Firm Fixed Gas." The price of this gas is based on an index of natural gas spot markets from natural gas producing areas. This index is termed "Production Area Composite Index," or "PACI." The PACI consists of:

- El Paso, Permian Basin; under the heading Permian Basin Area
- Waha; under the heading Permian Basin Area
- ANR, Oklahoma; under the heading Oklahoma
- Columbia Gulf, Louisiana; under the heading Louisiana-Onshore South
- Agua Dulce Hub: under the heading South-Corpus Christi

Until recently, the PACE and Henry Hub prices were highly correlated, the price of PACI was 90% of Henry Hub.[9] However, this correlation changed as a result of the dynamic effects of shale gas development in the Lower 48. The structure of these shale gas markets is still in flux. Although more volatile and less certain, a correlation between PACI and Henry Hub remains since all the producing areas included in PACI and Henry Hub are part of the national natural gas market and they all have been affected by the increase in supply from shale gas.

Furthermore, in 2010 the RCA approved a gas supply agreement between CEA and Marathon Alaska Production, LLC. This agreement allows Marathon to meet 100% of CEA's unmet needs from April 2011 to December 2014. Under this agreement the base price for Firm Gas is calculated using an average of the monthly NYMEX future gas contract prices within a price collar. CEA pays the higher of the two prices which frequently is the floor price. Figure 1 above illustrates the prices CEA expects to pay in the near future under both contracts. Under the Hilcorp agreement Base Gas prices are established at the higher of the annual (or nine months) average of NYMEX future gas contract prices, or the collar floor. Swing Gas is priced at the higher of the collar floor, or 125% of the annual (or nine months) average

[9] Henry Hub is the pricing point for natural gas futures contracts traded on the New York Mercantile Exchange (NYMEX). It is a point on the natural gas pipeline system in Erath, Louisiana.

NYMEX future gas contract prices.[10] Excess Gas is priced the same as Swing Gas. Furthermore, natural gas spot and future prices (NYMEX) are based on delivery at the Henry Hub in Louisiana.[11]

In February 2013, Hilcorp Energy took ownership of most of Marathon's Inlet assets.[12] Hence, it is now Hilcorp Energy who fulfills the gas supply agreement.

Price Projection

The Chugach Electric Association contract assumes one Mcf (one thousand cubic feet) of natural gas equals one MMBtu (million British thermal units) of natural gas. The EIA forecasts the Henry Hub price in dollars per MMBtu but the Chugach Electric Association gas is priced in dollars per Mcf, we assume CEA's Mcf-MMBtu conversion factor.

In Lower 48 markets, the abundant shale gas production continues to result in low natural gas prices. Meanwhile demand continues to put pressure on Cook Inlet supplies, though currently supplies remain limited. Still optimism about Cook Inlet supply is growing. After the purchase of Marathon's assets, Hilcorp external affairs manager, Lori Nelson, commented to the Alaska Journal of Commerce that they (Hilcorp) were "confident they can quickly add production" and that they aim to satisfy demand for the coming years. Moreover, Hilcorp stated that they had a 160% increase in gas production in their fields since January 2012.

The major structural changes in both Cook Inlet and Lower 48 markets are impacting our ability to project natural gas prices with high confidence levels. Both of CEA's contracts are indexed or highly correlated to the Henry Hub spot prices. Hence, we assume that over time the overall relationship between the two will stabilize. Our projection takes the Henry Hub EIA forecast as reference and we adjust it upwards by the average price difference between the EIA forecasted price and Hilcorp Firm gas of $5.94 adjusted to 2012 dollars over the projection time period (Figure 4). To establish low and high scenarios, we adjust the modified reference case informed by the CEA's contractual agreements with its suppliers to 90% for the low scenario and 125% for the high scenario.

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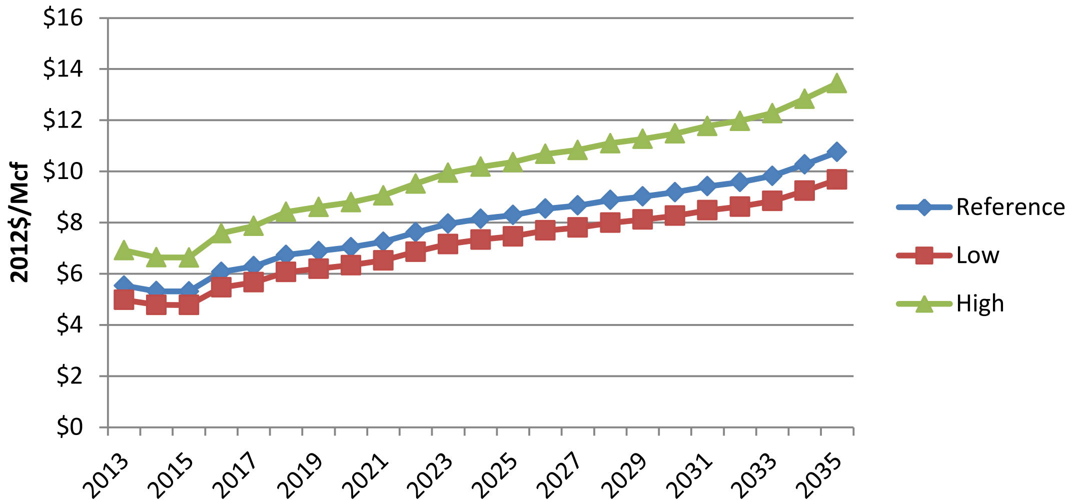
[10] Base gas is gas let in a gas store to provide the pressure needed to produce stored gas, but which itself remains un-produced. Firm gas is gas which a supplier commits to supply to a utility under terms defined in a contract without interruption. Excess gas is either: 1) gas taken at a rate in excess of the daily delivery rate at a premium price; or 2)gas taken in excess to the annual contact quantity. Swing gas, refers to a contractual option where a volume of gas can be supplied between some minimum and maximum limits, and within some defined period at a pre-agreed price.

[11] Official daily closing prices at 2:30 p.m. from the trading floor of the New York Mercantile Exchange (NYMEX) for a specific delivery month.

[12] The fields acquired by Hilcorp include: Ninilchik, Kasilof, Kenai, Cannery Loop, Beaver Creek, Wolf Lake, Trading Bay and McArthur Rivers.

Figure 4. Southcentral natural gas prices, 2013-2035



Sources: U.S. EIA Annual Energy Outlook 2012, ISER calculations.

Fuel Oil

Background

Projecting fuel oil prices requires a different methodology because there are no existing complex contracts that must be approved by RCA. Each utility negotiates individually (or as a group with other utilities or communities) with various fuel suppliers that compete for their business. Our projections are based on U.S. EIA *Annual Energy Outlook 2012* forecasts for crude oil. We use the Composite Refiner Acquisition Cost (CORAC) of crude oil as the basis for the fuel oil projections.

Rural Fuel Prices

This projection update follows the same methodology as the projection update of July 2012 with some improvements. Please refer to Appendix A for added detailed methodology.

The rural regression model assumes that the price of diesel[13] to a particular utility receiving Power Cost Equalization assistance bears a stable linear relationship to the refiner acquisition cost of crude price. In the projections prior to June 2011, parameters were calculated using a pool regression where the coefficient was allowed to be different from 1.0 and **not** allowed to vary by community.[14] A coefficient above 1.0 indicated "percentage markup pricing" as opposed to a straight pass-through of a crude price increase/decrease dollar for dollar.

In contrast, in the current update (and the previous two versions) we ran individual linear regressions for each community, which provides a unique slope and intercept for each community that represents how communities are affected differently by crude oil prices. For example, access to purchased fuel is affected by each community's geographic location; meaning, some communities have more frequent deliveries of fuel than others. To build a more accurate projection, in the June 2011 update we ran two sets of regressions for each community. In one projection, we lagged the crude oil price by one year, while in the other no lag was allowed. The testing of the potential of lagged prices to better explain

[13]PCE prices collected from PCE statistical reports.
[14] Fay, G. and Saylor, B. 2010. *Alaska Fuel Price Projections 2010-2030*, Available at: http://www.iser.uaa.alaska.edu/Publications/oil_price_projection_aea07_2010_v1.xls

some community utility fuel oil prices was based on our research on "components of rural fuel prices" that we completed from 2008 through 2011.[15]

Informed by the regressions, we analyzed which community fuel prices were better explained with a year lag versus those that were not. We used the R-squared and P-values, statistical indicators of the precision of the regression equation's ability to "explain" the historic data, to select the intercept and slopes for each community appropriately. As expected, the scenario without a lag in crude prices better explained the crude and fuel price relationships for communities in the Southeast, Southcentral and Southwest regions where communities have more flexibility in sourcing their fuel and can purchase fuel more frequently. As anticipated, the lagged crude price better reflects the fuel prices for most rural PCE communities where importing fuel is complicated due to their remoteness, and seasonal conditions such as winter sea ice, which permits only one or two fuel deliveries per year. Thus, crude oil price changes have a lagged effect on these communities. Based on that analysis, in the current update, regressions with and without a year lag were run accordingly. The communities that were subject to the No-Lag regression are:

Table 1. Communities that did not show a lagged relationship to crude oil prices

Community ID	Community Name	Census Area
14	Craig	Prince of Wales-Hyder (CA)
28	Hydaburg	Prince of Wales-Hyder (CA)
65	Skagway	Skagway
73	Tok	Southeast Fairbanks (CA)
95	Chalkyitsik	Yukon-Koyukuk (CA)
103	Cordova	Valdez-Cordova (CA)
150	Pelican	Hoonah-Angoon (CA)
151	Perryville	Lake and Peninsula
159	Saint George	Aleutians West (CA)
175	Unalaska	Aleutians West (CA)

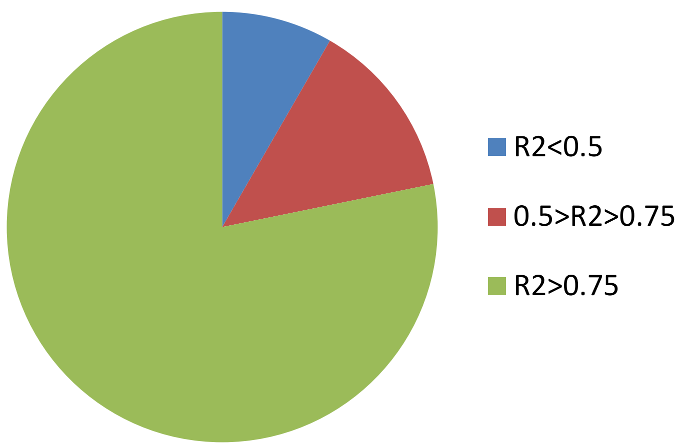
In previous projections, we used the EIA published forecast for Imported Crude Oil Price. However, EIA no longer publishes these prices, and instead publishes prices for Brent Spot (a European terminal) and West Texas Intermediate. Because we are interested in the prices electric utilities are likely to pay and a significant amount of crude oil is still imported into the U.S., we use the simple average of the forecasted prices for both of these terminals in our projection.

[15] Szymoniak, Nick; Fay, Ginny; Villalobos-Melendez, Alejandra; Charon, Justine; Smith, Mark. 2010. *Components of Alaska Fuel Costs: An Analysis of the Market Factors and Characteristics that Influence Rural Fuel Prices*. University of Alaska Anchorage, Institute of Social and Economic Research. Prepared for the Alaska State Legislature, Senate Finance Committee, 78 pages.
Fay, Ginny, Ben Saylor, Nick Szymoniak, Meghan Wilson and Steve Colt. 2009. *Study of the Components of Delivered Fuel Costs in Alaska: January 2009 Update.* Anchorage: University of Alaska Anchorage, Institute of Social and Economic Research. Prepared for the Alaska State Legislature, Senate Finance Committee, 22 pages.
Wilson, Meghan, Ginny Fay, Ben Saylor, Nick Szymoniak, and Steve Colt. 2008. *Components of Delivered Fuel Prices in Alaska*. Anchorage: University of Alaska Anchorage, Institute of Social and Economic Research. Prepared for the Alaska Energy Authority, 70 pages.

In addition, we use diesel prices utilities report under the Power Cost Equalization program. However, some utilities may fail to report every month or year resulting in missing values in the historic data. To provide a more robust projection, we statistically impute missing values, using the statistical software program STATA, based on the output of a linear regression of crude and diesel prices for each community.[16] Given the variation of the original number of observations and of the data quality for each community, some projections may appear to be 'better' than others. In statistical terminology, the coefficient of determination in our model, the Adjusted R-squared, indicates how well observed outcomes are replicated by the model; or in other words how well the independent variable explains the dependent variable. The Adjusted R-squared coefficient ranges from 0 to 1. The higher the coefficient value and the closer to 1, the better the goodness of fit of the model.

We ran regressions for 156 rural communities that experience the lag phenomena. Of these 156 communities, 122 community projections have an Adjusted R-squared value above 0.75, 21 community projections have an Adjusted R-squared value between 0.5 and 0.75 and only 13 communities have an Adjusted R-squared value below 0.5. Most communities with low Adjusted R-squared values are communities for which limited data are available or are located in the North Slope Borough, which has a fuel subsidy program in addition to the Power Cost Equalization program, which lowers variability in fuel prices over time and impacts the estimates' reliability.

Figure 5. Distribution of Adjusted R2 Values for Rural Community Fuel Price Projections



Source: ISER fuel price analysis.

In addition, we ran regressions for ten communities that do not experience the lag phenomena. All projections for these communities resulted in an R-squared value above 0.8.

Urban Fuel Prices

Finally, regressions and projections were also performed for larger communities in Alaska that are not part of the Power Cost Equalization program: Anchorage, Fairbanks, Juneau, Kenai, Ketchikan, Palmer, and Wasilla. Unlike previous reports, the following communities are also included: Kodiak, Petersburg, Sitka and Wrangell. Projections of fuel prices for these communities are also based on the same underlying model described above and do not include a lag. However, public data regarding utility fuel

[16] This process is done using the statistical software STATA using the 'reg' and 'predict' commands.

prices are less available. These projections are based primarily on two sources of retail fuel price data: 1) data collected by the Alaska Housing and Finance Corporation (AHFC) and 2) the University of Alaska Fairbanks Cooperation Extension Service Food Survey (UAF CES). Retail prices can be significantly higher than the wholesale prices utilities pay. The Energy Information Administration also collects price data but these data are not available for all utilities. We conducted an analysis of the price difference for communities for which data are available from all three sources (Fairbanks and Juneau). Our analysis revealed that on average CES prices are about 24% higher than EIA published prices for the same community in the same time period. Also, as expected, AHFC prices are about 21% higher than EIA published prices. Hence, we adjusted fuel prices downward based on our analysis to reflect the likely wholesale prices utilities pay.

Home Heating Fuel Prices

We were not able to rigorously determine a home delivery surcharge by statistical methods. However, there is some evidence of a relationship between residential home heating fuel prices, crude oil prices and PCE utility fuel prices (Table 2).

Table 2. Correlations between residential home heating fuel, PCE utility fuel and crude oil prices

	Residential home heating fuel (rural)	PCE utility fuel	Crude oil
Residential home heating fuel	1.0000		
PCE utility fuel	0.7312	1.0000	
Crude Oil	0.4543	0.3938	1.0000

The average difference between PCE fuel and Alaska Housing Finance Corporation (AHFC) fuel survey prices (retail-heating) between years 2008 to 2011 was $1.58 (2011$). As a result, we suggest that the community utility fuel price plus $1.61 (2012$) per gallon be used as the avoidable cost of home delivery when small amounts of home-delivered fuel are being avoided. However, when substantial amount of delivered fuel is avoided (e.g., a community district heating system or mass retrofit for biomass heating), we suggest that the appropriate credit for avoided delivery charges is zero. The suggested heating fuel premium based on the amount of fuel is shown in Table 3 below. These are the amounts applied in the Renewable Energy Fund project economic review model.

Table 3. Suggested fuel premiums per gallon of displaced fuel

Gallons of Displaced Heating Fuel	Heating Fuel Premium (2012$)
<1,000	$1.61
1,000 < 25,000	$1.07
25,000 > 100,000	$0.54
>100,000	$0.00

Source: ISER fuel price analysis.

Determining the value of an avoided gallon of fuel oil for space heating by renewable energy projects is complex because a substantial portion of the costs that ultimately determine the price per gallon of village home heating fuel are fixed. In addition, specific community circumstances, such as whether a bulk fuel storage facility was recently upgraded or will soon need to be, influence actual potential avoided costs since most of the costs of storage and delivery can only be avoided in "lumps." More analysis of community non-utility fuel use and prices will be necessary as more energy projects displace space heating diesel fuel.

Other important factors besides crude oil prices affect the final community wholesale fuel price. These factors include: the varying time intervals between the placement of orders, the timing of departures of fuel deliveries from refineries, and fuel storage inventories in communities, as well as distances between refineries, fuel distributors and community storage facilities.[17] However, due to data limitations these factors are not represented in our simple statistical regression. Because no additional research was conducted to better inform home heating fuel price differentials, these estimates were adjusted to 2012 dollars only.

[17] Szymoniak, Nick; Fay, Ginny; Villalobos-Melendez, Alejandra; Charon, Justine; Smith, Mark. 2010. *Components of Alaska Fuel Costs: An Analysis of the Market Factors and Characteristics that Influence Rural Fuel Prices*. University of Alaska Anchorage, Institute of Social and Economic Research. Prepared for the Alaska State Legislature, Senate Finance Committee, 78 pages.
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Appendix A. Projection methodology

Fuel Oil Prices – Rural Communities

The fuel oil price projection is based on crude oil price forecasts from EIA's *Annual Energy Outlook 2013* (AEO).

1. Access the EIA's Annual Energy Outlook 2013. Available at: http://www.eia.gov/oiaf/aeo/tablebrowser/

2. Obtain the forecast for Crude Oil Price, Brent and West Texas, from Table 1 for the Reference, Low Oil Price, and High Oil Price cases.

3. Obtain the historical monthly "U.S. Crude Oil Imported Acquisition Cost by Refiners (Dollars per Barrel)" (CORAC) from the following URL: http://tonto.eia.doe.gov/dnav/pet/pet_pri_rac2_dcu_nus_m.htm

4. For each month, adjust crude prices to 2012 dollars ("real crude price") using the appropriate average CPI-U (U.S. Consumer Price Index for All Urban Consumers). Available at: http://www.bls.gov/CPI/.

5. Calculate the average real crude price by fiscal year. Divide by 42 to obtain real crude price per gallon.

6. Obtain PCE fuel prices from fiscal years 1985 – 2012. The PCE Statistical Reports for fiscal years 2002 through 2012 can be obtained from the following URL: http://www.aidea.org/aea/programspce.html.[18]

7. Calculate the average CPI-U by fiscal year, and adjust PCE prices to real dollars based on the average CPI-U.

8. Perform an ordinary least squares regression for each community where the real fuel price per gallon is the dependent variable and real crude price per gallon lagged by one year is the independent variable. Then repeat the regression without lagging the crude oil price. Evaluate the regression output (R-square and P-value) to select the parameters that better explain the crude-fuel relationship for each community. The constant term of the regression represents the intercept of each community and the beta of the crude oil price represents the slope.

9. Some communities with little or no data require using data from other communities as a proxy. The proxy communities suggested by AEA, listed with the original community first, then the proxy, are as follows:

- **For** Dot Lake: **Substitute**: Tok
- Hollis: Craig
- Klawock: Craig

[18] Data from prior years were obtained from printed copies of statistical reports, but are not available through the AEA website. The forecast workbook includes a worksheet with a list of communities and their respective prices from year 1985 to 2011.

- Thorne Bay/Kasaan: Craig
- Kasigluk: Nunapitchuk
- Pitkas Point: St. Mary's
- Chignik Lake: Chignik Lagoon
- Klukwan: Kake
- Kobuk: Shungnak
- Napakiak: Napaskiak

Perform these substitutions not by copying data points from the proxy community into the missing slots, but by copying the regression coefficients from the proxy community.

10. Apply the slope and intercepts from the regression to the EIA *Annual Energy Outlook* forecasts (Low, Reference, and High cases) to predict fuel oil price per gallon for each PCE community as a function of average Crude Oil Price per gallon of the Brent and West Texas forecasts (lagged by one year or not, as appropriate) for each year from 2012 to 2035.

11. Continuing with changes implemented in the June 2011 projection, the 'CO_2 Equivalent Allowance Cost' is no longer added to allow flexibility in the use of these projections. We now appropriately add the 'CO_2 Equivalent Allowance Cost' in the benefit-cost model rather than directly into the fuel price projection.

12. Take the moving average three (MA_3) to smooth out the projections for all three cases.

Fuel Oil Prices – Urban Communities

1. For urban communities: Anchorage, Fairbanks, Juneau, Kenai, Ketchikan, Palmer, Wasilla, Sitka, Wrangell, Kodiak and Petersburg; obtain prices for heating oil from Alaska Housing Finance Corporation's annual fuel price surveys conducted in years 2000 through 2012 (contact ISER or AHFC to obtain this data). Use the average of #1 and #2 heating oil. Where prices are missing, use the price included in the Alaska Food Cost Survey conducted for December (http://www.uaf.edu/ces/fcs/). The Alaska Food Cost Survey includes data from 1996 to 2012. However, even after combining data from both datasets there will be missing data points. Adjust prices to real dollars.

2. Collect fuel price data for urban communities from the U.S. Energy Information Administration Survey Form 923 data file, Schedule 5. Calculate the wholesale-retail price difference (percentage) for each community (when data are available) between EIA and AHFC and CES prices. Adjust downward the prices to be used on the regression by the appropriate percent difference depending on data source.

3. Integrate CORAC real fuel prices for the appropriate period into the dataset.
For each community, perform a linear regression with the diesel price as the dependent variable and CORAC as the independent variable.

4. Use the regression coefficients to project heating diesel prices as a function of the simple average of Brent Spot and West Texas Intermediate forecast prices per gallon (Low, Medium, and High cases) for each year from 2013 to 2035 for each community.

Home Heating Fuel Adder

The calculated prices are for utilities. Calculate the correlation between AHFC and PCE prices. Since no clear relationship was found between AHFC surveyed home heating oil prices and PCE utility fuel prices, estimate the average difference ($1.61, 2012$).

Natural Gas Projection

1. Obtain the U.S. Energy Information Administration forecast of Henry Hub Spot prices. Set forecast as reference case.
2. Adjust forecast to 2012 dollars.
3. Estimate the average percentage difference between the EIA Henry Hub forecasted prices and the floor price per unit of the marginal gas supply. Adjust EIA's reference case by that rate.
4. Adjust the modified Henry Hub projected prices to 90% of the reference case to establish the Low projection.
5. Adjust the modified Henry Hub projected prices to 125% of the reference case to establish the High projection.

Chikuminuk Hydroelectric Project
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Appendix E2 - ISER Bethel & Dillingham Fuel Price Projections: Low, Medium and High

	Bethel Utilities Corporation (Bethel)			Nushagak Electric Cooperative (Dillingham)		
Year	Low	Medium	High	Low	Medium	High
2013	$5.89	$5.89	$5.89	$3.70	$3.70	$3.70
2014	$5.46	$5.46	$5.46	$3.41	$3.41	$3.41
2015	$4.84	$5.48	$6.81	$3.00	$3.42	$4.32
2016	$4.56	$5.45	$7.41	$2.81	$3.40	$4.71
2017	$4.35	$5.56	$7.93	$2.67	$3.48	$5.06
2018	$4.18	$5.74	$8.15	$2.55	$3.60	$5.21
2019	$4.18	$5.86	$8.33	$2.56	$3.68	$5.33
2020	$4.18	$5.98	$8.50	$2.56	$3.76	$5.45
2021	$4.20	$6.10	$8.67	$2.57	$3.84	$5.56
2022	$4.21	$6.21	$8.85	$2.58	$3.92	$5.68
2023	$4.23	$6.33	$9.02	$2.59	$4.00	$5.79
2024	$4.24	$6.46	$9.20	$2.60	$4.08	$5.91
2025	$4.26	$6.58	$9.39	$2.61	$4.16	$6.04
2026	$4.27	$6.71	$9.57	$2.62	$4.25	$6.16
2027	$4.29	$6.84	$9.76	$2.63	$4.33	$6.29
2028	$4.31	$6.97	$9.96	$2.64	$4.42	$6.42
2029	$4.32	$7.11	$10.16	$2.65	$4.51	$6.55
2030	$4.34	$7.25	$10.36	$2.66	$4.61	$6.69
2031	$4.35	$7.39	$10.57	$2.67	$4.70	$6.83
2032	$4.37	$7.53	$10.79	$2.68	$4.80	$6.97
2033	$4.38	$7.68	$11.00	$2.69	$4.90	$7.12
2034	$4.40	$7.83	$11.22	$2.70	$5.00	$7.27
2035	$4.41	$8.00	$11.45	$2.71	$5.11	$7.42

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E3 - Weighted Low, Medium & High Utility Diesel Fuel Price Projections

2012-2013 Fuel Usage by Utility (Gallons)

Bethel	3,197,401	71.6%
Nushakak	1,269,686	28.4%
		100.0%

Year	Low Projection (2012$)			Medium Projection (2012$)			High Projection (2012$)		
	Bethel	Dillingham	Weighted	Bethel	Dillingham	Weighted	Bethel	Dillingham	Weighted
2013	$5.89	$3.70	$5.36	$5.89	$3.70	$5.39	$5.89	$3.70	$5.43
2014	$5.46	$3.41	$4.97	$5.46	$3.41	$5.00	$5.46	$3.41	$5.03
2015	$4.84	$3.00	$4.40	$5.48	$3.42	$5.01	$6.81	$4.32	$6.29
2016	$4.56	$2.81	$4.14	$5.45	$3.40	$4.98	$7.41	$4.71	$6.85
2017	$4.35	$2.67	$3.94	$5.56	$3.48	$5.09	$7.93	$5.06	$7.33
2018	$4.18	$2.55	$3.79	$5.74	$3.60	$5.25	$8.15	$5.21	$7.54
2019	$4.18	$2.56	$3.79	$5.86	$3.68	$5.36	$8.33	$5.33	$7.71
2020	$4.18	$2.56	$3.79	$5.98	$3.76	$5.48	$8.50	$5.45	$7.87
2021	$4.20	$2.57	$3.80	$6.10	$3.84	$5.59	$8.67	$5.56	$8.03
2022	$4.21	$2.58	$3.82	$6.21	$3.92	$5.70	$8.85	$5.68	$8.19
2023	$4.23	$2.59	$3.83	$6.33	$4.00	$5.81	$9.02	$5.79	$8.36
2024	$4.24	$2.60	$3.85	$6.46	$4.08	$5.92	$9.20	$5.91	$8.52
2025	$4.26	$2.61	$3.86	$6.58	$4.16	$6.04	$9.39	$6.04	$8.70
2026	$4.27	$2.62	$3.88	$6.71	$4.25	$6.15	$9.57	$6.16	$8.87
2027	$4.29	$2.63	$3.89	$6.84	$4.33	$6.27	$9.76	$6.29	$9.05
2028	$4.31	$2.64	$3.90	$6.97	$4.42	$6.40	$9.96	$6.42	$9.23
2029	$4.32	$2.65	$3.92	$7.11	$4.51	$6.52	$10.16	$6.55	$9.42
2030	$4.34	$2.66	$3.93	$7.25	$4.61	$6.65	$10.36	$6.69	$9.61
2031	$4.35	$2.67	$3.95	$7.39	$4.70	$6.78	$10.57	$6.83	$9.80
2032	$4.37	$2.68	$3.96	$7.53	$4.80	$6.92	$10.79	$6.97	$10.00
2033	$4.38	$2.69	$3.98	$7.68	$4.90	$7.05	$11.00	$7.12	$10.21
2034	$4.40	$2.70	$3.99	$7.83	$5.00	$7.19	$11.22	$7.27	$10.41
2035	$4.41	$2.71	$4.01	$8.00	$5.11	$7.35	$11.45	$7.42	$10.62
2036			$4.02			$7.50			$10.99
2037			$4.03			$7.65			$11.37
2038			$4.05			$7.81			$11.76
2039			$4.06			$7.97			$12.17

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E3 - Weighted Low, Medium & High Utility Diesel Fuel Price Projections

2012-2013 Fuel Usage by Utility (Gallons)

Bethel	3,197,401	71.6%
Nushakak	1,269,686	28.4%
		100.0%

Year	Low Projection (2012$)			Medium Projection (2012$)			High Projection (2012$)		
	Bethel	Dillingham	Weighted	Bethel	Dillingham	Weighted	Bethel	Dillingham	Weighted
2040			$4.08			$8.14			$12.59
2041			$4.09			$8.30			$13.03
2042			$4.11			$8.48			$13.48
2043			$4.12			$8.65			$13.94
2044			$4.14			$8.83			$14.43
2045			$4.15			$9.01			$14.92
2046			$4.17			$9.20			$15.44
2047			$4.18			$9.39			$15.97
2048			$4.20			$9.58			$16.53
2049			$4.21			$9.78			$17.10
2050			$4.23			$9.98			$17.69
2051			$4.25			$10.18			$18.30
2052			$4.26			$10.39			$18.93
2053			$4.28			$10.61			$19.59
2054			$4.29			$10.83			$20.26
2055			$4.31			$11.05			$20.96
2056			$4.32			$11.28			$21.69
2057			$4.34			$11.51			$22.44
2058			$4.36			$11.75			$23.21
2059			$4.37			$11.99			$24.02
2060			$4.39			$12.24			$24.85
2061			$4.40			$12.49			$25.71
2062			$4.42			$12.75			$26.59
2063			$4.44			$13.01			$27.51

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E4.1 - Base Case Annual Hydro & Diesel Costs

Notes
* Diesel fuel costs escalated on the basis of inflation rate
** Fixed hydro costs (debt service + interest on reserves) are expressed in 2013 dollars based on the discount rate

		Diesel Costs (2013 dollars)			Hydro Costs (2013 dollars)			
Year	Energy Use	Fuel cost* ($/kWh)	O& M ($/kWh)	Diesel Cost/kWh	Fixed** ($M)	Variable ($M)	Diesel Standby	Hydro Cost/kWh
2013	76.5	$0.389	$0.043	$0.431	-39.23	-4.10	$0.025	$0.566
2014	76.5	$0.360	$0.043	$0.403	-38.31	-4.10	$0.025	$0.554
2015	76.5	$0.362	$0.043	$0.404	-37.42	-4.10	$0.025	$0.542
2016	76.5	$0.360	$0.043	$0.402	-36.54	-4.10	$0.025	$0.531
2017	76.5	$0.367	$0.043	$0.409	-35.68	-4.10	$0.025	$0.519
2018	76.5	$0.379	$0.043	$0.421	-34.85	-4.10	$0.025	$0.509
2019	76.5	$0.387	$0.043	$0.430	-34.03	-4.10	$0.025	$0.498
2020	76.5	$0.395	$0.043	$0.438	-33.23	-4.10	$0.025	$0.487
2021	76.5	$0.403	$0.043	$0.446	-32.45	-4.10	$0.025	$0.477
2022	76.5	$0.411	$0.043	$0.453	-31.69	-4.10	$0.025	$0.467
2023	76.5	$0.419	$0.043	$0.461	-30.95	-4.10	$0.025	$0.458
2024	76.5	$0.427	$0.043	$0.470	-30.22	-4.10	$0.025	$0.448
2025	76.5	$0.435	$0.043	$0.478	-29.52	-4.10	$0.025	$0.439
2026	76.5	$0.444	$0.043	$0.486	-28.82	-4.10	$0.025	$0.430
2027	76.5	$0.453	$0.043	$0.495	-28.15	-4.10	$0.025	$0.421
2028	76.5	$0.462	$0.043	$0.504	-27.49	-4.10	$0.025	$0.412
2029	76.5	$0.471	$0.043	$0.513	-26.84	-4.10	$0.025	$0.404
2030	76.5	$0.480	$0.043	$0.522	-26.22	-4.10	$0.025	$0.396
2031	76.5	$0.489	$0.043	$0.532	-25.60	-4.10	$0.025	$0.388
2032	76.5	$0.499	$0.043	$0.542	-25.00	-4.10	$0.025	$0.380
2033	76.5	$0.509	$0.043	$0.552	-24.42	-4.10	$0.025	$0.372
2034	76.5	$0.519	$0.043	$0.562	-23.84	-4.10	$0.025	$0.365
2035	76.5	$0.530	$0.043	$0.573	-23.28	-4.10	$0.025	$0.357
2036	76.5	$0.541	$0.043	$0.583	-22.74	-4.10	$0.025	$0.350
2037	76.5	$0.552	$0.043	$0.595	-22.21	-4.10	$0.025	$0.343
2038	76.5	$0.564	$0.043	$0.606	-21.69	-4.10	$0.025	$0.337
2039	76.5	$0.575	$0.043	$0.618	-21.18	-4.10	$0.025	$0.330
2040	76.5	$0.587	$0.043	$0.630	-20.68	-4.10	$0.025	$0.323
2041	76.5	$0.599	$0.043	$0.642	-20.20	-4.10	$0.025	$0.317
2042	76.5	$0.611	$0.043	$0.654	-19.72	-4.10	$0.025	$0.311
2043	76.5	$0.624	$0.043	$0.667	-19.26	-4.10	$0.025	$0.305

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E4.1 - Base Case Annual Hydro & Diesel Costs

Notes
* Diesel fuel costs escalated on the basis of inflation rate
** Fixed hydro costs (debt service + interest on reserves) are expressed in 2013 dollars based on the discount rate

		Diesel Costs (2013 dollars)			Hydro Costs (2013 dollars)			
Year	Energy Use	Fuel cost* ($/kWh)	O& M ($/kWh)	Diesel Cost/kWh	Fixed** ($M)	Variable ($M)	Diesel Standby	Hydro Cost/kWh
2043	76.5	$0.624	$0.043	$0.667	0.00	-4.10	$0.025	$0.053
2044	76.5	$0.637	$0.043	$0.679	0.00	-4.10	$0.025	$0.053
2045	76.5	$0.650	$0.043	$0.693	0.00	-4.10	$0.025	$0.053
2046	76.5	$0.664	$0.043	$0.706	0.00	-4.10	$0.025	$0.053
2047	76.5	$0.677	$0.043	$0.720	0.00	-4.10	$0.025	$0.053
2048	76.5	$0.691	$0.043	$0.734	0.00	-4.10	$0.025	$0.053
2049	76.5	$0.705	$0.043	$0.748	0.00	-4.10	$0.025	$0.053
2050	76.5	$0.720	$0.043	$0.762	0.00	-4.10	$0.025	$0.053
2051	76.5	$0.735	$0.043	$0.777	0.00	-4.10	$0.025	$0.053
2052	76.5	$0.750	$0.043	$0.792	0.00	-4.10	$0.025	$0.053
2053	76.5	$0.765	$0.043	$0.808	0.00	-4.10	$0.025	$0.053
2054	76.5	$0.781	$0.043	$0.824	0.00	-4.10	$0.025	$0.053
2055	76.5	$0.797	$0.043	$0.840	0.00	-4.10	$0.025	$0.053
2056	76.5	$0.814	$0.043	$0.856	0.00	-4.10	$0.025	$0.053
2057	76.5	$0.831	$0.043	$0.873	0.00	-4.10	$0.025	$0.053
2058	76.5	$0.848	$0.043	$0.890	0.00	-4.10	$0.025	$0.053
2059	76.5	$0.865	$0.043	$0.908	0.00	-4.10	$0.025	$0.053
2060	76.5	$0.883	$0.043	$0.925	0.00	-4.10	$0.025	$0.053
2061	76.5	$0.901	$0.043	$0.944	0.00	-4.10	$0.025	$0.053
2062	76.5	$0.920	$0.043	$0.962	0.00	-4.10	$0.025	$0.053
2063	76.54	$0.939	$0.043	$0.981	0.00	-4.10	$0.025	$0.053

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E4.2 - Lower Limit Annual Hydro & Diesel Costs

Notes
* Diesel fuel costs escalated on the basis of inflation rate
** Fixed hydro costs (debt service + interest on reserves) are expressed in 2013 dollars based on the discount rate

		Diesel Costs (2013 dollars)			Hydro Costs (2013 dollars)			
Year	Energy Use	Fuel cost* ($/kWh)	O& M ($/kWh)	Diesel Cost/kWh	Fixed** ($M)	Variable ($M)	Diesel Standby	Hydro Cost/kWh
2013	78.4	$0.396	$0.020	$0.416	-32.94	-4.00	$0.023	$0.471
2014	79.6	$0.367	$0.020	$0.387	-32.33	-4.00	$0.023	$0.456
2015	80.7	$0.325	$0.020	$0.345	-31.72	-4.00	$0.023	$0.442
2016	81.8	$0.305	$0.020	$0.325	-31.13	-4.00	$0.023	$0.429
2017	82.3	$0.291	$0.020	$0.311	-30.55	-4.00	$0.023	$0.419
2018	82.3	$0.279	$0.020	$0.299	-29.98	-4.00	$0.023	$0.413
2019	82.3	$0.279	$0.020	$0.299	-29.42	-4.00	$0.023	$0.406
2020	82.3	$0.280	$0.020	$0.300	-28.88	-4.00	$0.023	$0.399
2021	82.3	$0.281	$0.020	$0.301	-28.34	-4.00	$0.023	$0.393
2022	82.3	$0.282	$0.020	$0.302	-27.81	-4.00	$0.023	$0.386
2023	82.3	$0.283	$0.020	$0.303	-27.29	-4.00	$0.023	$0.380
2024	82.3	$0.284	$0.020	$0.304	-26.78	-4.00	$0.023	$0.374
2025	82.3	$0.285	$0.020	$0.305	-26.28	-4.00	$0.023	$0.368
2026	82.3	$0.286	$0.020	$0.306	-25.79	-4.00	$0.023	$0.362
2027	82.3	$0.287	$0.020	$0.307	-25.31	-4.00	$0.023	$0.356
2028	82.3	$0.288	$0.020	$0.308	-24.84	-4.00	$0.023	$0.350
2029	82.3	$0.289	$0.020	$0.309	-24.38	-4.00	$0.023	$0.344
2030	82.3	$0.290	$0.020	$0.310	-23.92	-4.00	$0.023	$0.339
2031	82.3	$0.291	$0.020	$0.311	-23.48	-4.00	$0.023	$0.333
2032	82.3	$0.292	$0.020	$0.312	-23.04	-4.00	$0.023	$0.328
2033	82.3	$0.293	$0.020	$0.313	-22.61	-4.00	$0.023	$0.323
2034	82.3	$0.294	$0.020	$0.314	-22.19	-4.00	$0.023	$0.318
2035	82.3	$0.295	$0.020	$0.315	-21.77	-4.00	$0.023	$0.313
2036	82.3	$0.296	$0.020	$0.316	-21.37	-4.00	$0.023	$0.308
2037	82.3	$0.298	$0.020	$0.318	-20.97	-4.00	$0.023	$0.303
2038	82.3	$0.299	$0.020	$0.319	-20.58	-4.00	$0.023	$0.298
2039	82.3	$0.300	$0.020	$0.320	-20.19	-4.00	$0.023	$0.294
2040	82.3	$0.301	$0.020	$0.321	-19.82	-4.00	$0.023	$0.289
2041	82.3	$0.302	$0.020	$0.322	-19.45	-4.00	$0.023	$0.285
2042	82.3	$0.303	$0.020	$0.323	-19.09	-4.00	$0.023	$0.280
2043	82.3	$0.304	$0.020	$0.324	-18.73	-4.00	$0.023	$0.276

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E4.2 - Lower Limit Annual Hydro & Diesel Costs

Notes
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** Fixed hydro costs (debt service + interest on reserves) are expressed in 2013 dollars based on the discount rate

		Diesel Costs (2013 dollars)			Hydro Costs (2013 dollars)			
Year	Energy Use	Fuel cost* ($/kWh)	O& M ($/kWh)	Diesel Cost/kWh	Fixed** ($M)	Variable ($M)	Diesel Standby	Hydro Cost/kWh
2043	82.3	$0.305	$0.020	$0.325	0.00	-4.00	$0.023	$0.048
2044	82.3	$0.306	$0.020	$0.326	0.00	-4.00	$0.023	$0.048
2045	82.3	$0.307	$0.020	$0.327	0.00	-4.00	$0.023	$0.048
2046	82.3	$0.309	$0.020	$0.329	0.00	-4.00	$0.023	$0.048
2047	82.3	$0.310	$0.020	$0.330	0.00	-4.00	$0.023	$0.048
2048	82.3	$0.311	$0.020	$0.331	0.00	-4.00	$0.023	$0.048
2049	82.3	$0.312	$0.020	$0.332	0.00	-4.00	$0.023	$0.048
2050	82.3	$0.313	$0.020	$0.333	0.00	-4.00	$0.023	$0.048
2051	82.3	$0.314	$0.020	$0.334	0.00	-4.00	$0.023	$0.048
2052	82.3	$0.315	$0.020	$0.335	0.00	-4.00	$0.023	$0.048
2053	82.3	$0.317	$0.020	$0.337	0.00	-4.00	$0.023	$0.048
2054	82.3	$0.318	$0.020	$0.338	0.00	-4.00	$0.023	$0.048
2055	82.3	$0.319	$0.020	$0.339	0.00	-4.00	$0.023	$0.048
2056	82.3	$0.320	$0.020	$0.340	0.00	-4.00	$0.023	$0.048
2057	82.3	$0.321	$0.020	$0.341	0.00	-4.00	$0.023	$0.048
2058	82.3	$0.322	$0.020	$0.342	0.00	-4.00	$0.023	$0.048
2059	82.3	$0.324	$0.020	$0.344	0.00	-4.00	$0.023	$0.048
2060	82.3	$0.325	$0.020	$0.345	0.00	-4.00	$0.023	$0.048
2061	82.3	$0.326	$0.020	$0.346	0.00	-4.00	$0.023	$0.048
2062	82.3	$0.327	$0.020	$0.347	0.00	-4.00	$0.023	$0.048
2063	82.32	$0.328	$0.020	$0.348	0.00	-4.00	$0.023	$0.048

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E4.3 - Upper Limit Annual Hydro & Diesel Costs

Notes
* Diesel fuel costs escalated on the basis of inflation rate
** Fixed hydro costs (debt service + interest on reserves) are expressed in 2013 dollars based on the discount rate

		Diesel Costs (2013 dollars)			Hydro Costs (2013 dollars)			
Year	Energy Use	Fuel cost* ($/kWh)	O& M ($/kWh)	Diesel Cost/kWh	Fixed** ($M)	Variable ($M)	Diesel Standby	Hydro Cost/kWh
2013	70.6	$0.360	$0.053	$0.413	-49.64	-4.20	$0.023	$0.763
2014	70.6	$0.333	$0.053	$0.387	-48.15	-4.20	$0.023	$0.742
2015	70.6	$0.417	$0.053	$0.470	-46.70	-4.20	$0.023	$0.721
2016	70.6	$0.454	$0.053	$0.507	-45.30	-4.20	$0.023	$0.701
2017	70.6	$0.486	$0.053	$0.539	-43.94	-4.20	$0.023	$0.682
2018	70.6	$0.500	$0.053	$0.553	-42.61	-4.20	$0.023	$0.663
2019	70.6	$0.511	$0.053	$0.564	-41.33	-4.20	$0.023	$0.645
2020	70.6	$0.522	$0.053	$0.575	-40.09	-4.20	$0.023	$0.627
2021	70.6	$0.532	$0.053	$0.585	-38.88	-4.20	$0.023	$0.610
2022	70.6	$0.543	$0.053	$0.596	-37.72	-4.20	$0.023	$0.594
2023	70.6	$0.554	$0.053	$0.607	-36.58	-4.20	$0.023	$0.578
2024	70.6	$0.565	$0.053	$0.618	-35.48	-4.20	$0.023	$0.562
2025	70.6	$0.576	$0.053	$0.629	-34.41	-4.20	$0.023	$0.547
2026	70.6	$0.588	$0.053	$0.641	-33.38	-4.20	$0.023	$0.532
2027	70.6	$0.600	$0.053	$0.653	-32.38	-4.20	$0.023	$0.518
2028	70.6	$0.612	$0.053	$0.665	-31.40	-4.20	$0.023	$0.504
2029	70.6	$0.624	$0.053	$0.677	-30.46	-4.20	$0.023	$0.491
2030	70.6	$0.637	$0.053	$0.690	-29.54	-4.20	$0.023	$0.478
2031	70.6	$0.650	$0.053	$0.703	-28.65	-4.20	$0.023	$0.465
2032	70.6	$0.663	$0.053	$0.716	-27.79	-4.20	$0.023	$0.453
2033	70.6	$0.676	$0.053	$0.729	-26.96	-4.20	$0.023	$0.441
2034	70.6	$0.690	$0.053	$0.743	-26.15	-4.20	$0.023	$0.430
2035	70.6	$0.704	$0.053	$0.757	-25.36	-4.20	$0.023	$0.419
2036	70.6	$0.728	$0.053	$0.782	-24.60	-4.20	$0.023	$0.408
2037	70.6	$0.754	$0.053	$0.807	-23.86	-4.20	$0.023	$0.397
2038	70.6	$0.780	$0.053	$0.833	-23.14	-4.20	$0.023	$0.387
2039	70.6	$0.807	$0.053	$0.860	-22.45	-4.20	$0.023	$0.377
2040	70.6	$0.834	$0.053	$0.888	-21.77	-4.20	$0.023	$0.368
2041	70.6	$0.863	$0.053	$0.916	-21.12	-4.20	$0.023	$0.358
2042	70.6	$0.893	$0.053	$0.946	-20.48	-4.20	$0.023	$0.349
2043	70.6	$0.924	$0.053	$0.977	-19.87	-4.20	$0.023	$0.341

Chikumiunuk Lake Hydroelectric Project
Interim Feasibility Report
Appendix E4.3 - Upper Limit Annual Hydro & Diesel Costs

Notes
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** Fixed hydro costs (debt service + interest on reserves) are expressed in 2013 dollars based on the discount rate

		Diesel Costs (2013 dollars)			Hydro Costs (2013 dollars)			
Year	Energy Use	Fuel cost* ($/kWh)	O& M ($/kWh)	Diesel Cost/kWh	Fixed** ($M)	Variable ($M)	Diesel Standby	Hydro Cost/kWh
2044	70.6	$0.956	$0.053	$1.009	-19.27	-4.20	$0.023	$0.332
2045	70.6	$0.989	$0.053	$1.042	-18.69	-4.20	$0.023	$0.324
2046	70.6	$1.023	$0.053	$1.076	-18.13	-4.20	$0.023	$0.316
2047	70.6	$1.059	$0.053	$1.112	-17.58	-4.20	$0.023	$0.308
2048	70.6	$1.095	$0.053	$1.148	-17.05	-4.20	$0.023	$0.301
2049	70.6	$1.133	$0.053	$1.186	-16.54	-4.20	$0.023	$0.294
2050	70.6	$1.172	$0.053	$1.225	-16.04	-4.20	$0.023	$0.287
2051	70.6	$1.213	$0.053	$1.266	-15.56	-4.20	$0.023	$0.280
2052	70.6	$1.255	$0.053	$1.308	-15.09	-4.20	$0.023	$0.273
2053	70.6	$1.298	$0.053	$1.351	-14.64	-4.20	$0.023	$0.267
2054	70.6	$1.343	$0.053	$1.396	-14.20	-4.20	$0.023	$0.260
2055	70.6	$1.389	$0.053	$1.442	-13.77	-4.20	$0.023	$0.254
2056	70.6	$1.437	$0.053	$1.490	-13.36	-4.20	$0.023	$0.249
2057	70.6	$1.487	$0.053	$1.540	-12.96	-4.20	$0.023	$0.243
2058	70.6	$1.538	$0.053	$1.591	-12.57	-4.20	$0.023	$0.237
2059	70.6	$1.592	$0.053	$1.645	-12.19	-4.20	$0.023	$0.232
2060	70.6	$1.647	$0.053	$1.700	-11.82	-4.20	$0.023	$0.227
2061	70.6	$1.703	$0.053	$1.757	-11.47	-4.20	$0.023	$0.222
2062	70.6	$1.762	$0.053	$1.815	-11.12	-4.20	$0.023	$0.217
2062	70.6	$1.823	$0.053	$1.876	0.00	-4.20	$0.023	$0.059
2063	70.56	$1.886	$0.053	$1.939	0.00	-4.20	$0.023	$0.059