Appendix 5.17
Moon Lake Pumped Storage Conceptual Study Report (Midgard 2015)

MIDGARD
CONSULTING INC.

Moon Lake – Pumped Storage
Conceptual Study Report

Submitted By: Midgard Consulting Incorporated

Date: December 14, 2015

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Executive Summary

Yukon Energy Corporation ("YEC") is investigating the potential to develop a storage hydro project on Moon Lake, in northwestern British Columbia. As a utility, YEC experiences a winter peak load, combined with a summer peak in generation potential from its hydroelectric generating assets. A storage project at Moon Lake is intended to seasonally shift freshet flows and augment winter generation potential to better align with YEC's annual load profile.

Moon Lake, located 100 km south-southeast from Whitehorse, and 18 km south of the BC Yukon border, drains into Tutshi Lake from the south and is ultimately a tributary to the Yukon River, above Whitehorse. The project drainage area is estimated at 57.4 km^2 yielding an estimated Mean Annual Daily Flow ("MAD") of 0.79 m^3/s.

Midgard Consulting Incorporated ("Midgard") was retained by Yukon Energy Corporation ("YEC") to perform a preliminary study for a storage facility at the Project. Midgard was commissioned to study the Project as:

1) A conventional storage facility, and
2) A pumped storage facility.

Past studies for the Project as a conventional storage scheme or a run-of-river have been performed by Klohn-Crippen Consultant Ltd ("KCCL") in 1992, KGS Group ("KGS") in 2008 and HDR Inc. ("HDR") in 2011. Past studies have all assumed diverting the flows from at least one adjacent basin increasing the project drainage area by 25.7 km^2 to 57.3 km^2. The energy yield estimated from those studies range from 27.4 GWh to 51.3 GWh for a capacity of 6.7 MW to 11.5 MW.

Midgard has studied the Project under the following three scenarios:

1) Conventional Storage: Assuming the Project regulates the flow of the Moon Lake drainage area of 57.4 km^2 and generates from November 1st through May 14th.
2) Pumped Storage (48GWh): Assuming there is 48 GWh of available pumping energy from weeks 20 to 44 (based on YEC 2022 forecast) in addition to the natural inflows at the Project. Generation is assumed from weeks 45 to 19.
3) Pumped Storage (70GWh): Assuming there is 70 GWh of available pumping energy from weeks 20 to 44 in addition to the natural inflows at the Project. Generation is assumed from weeks 45 to 19. This scenario was not based on forecast but was studied to determine the additional energy the Project could yield given additional pumping energy.

The option's Full Supply Level ("FSL") were sized to utilize the available storage while minimizing spills and drawdowns below Minimum Operating Level ("MOL").

As shown in **Table 1**, the Project yields 20 GWh of winter energy as a conventional storage scheme and 54 GWh to 69 GWh as a pumped storage scheme.

Table 1: Moon Lake Storage Energy Summary

Parameters	Conventional Storage	Pumped Storage (48 GWh)	Pumped Storage (70 GWh)
FSL (m)	1121	1125	1129
MOL (m)	1114	1114	1114
TWL (m)	713.2	713.5	713.5
Gross Head (m)	407.8	411.5	415.5
Generation Flow (m^3/s)	2.2	6.0	7.6
Pumping Flow (m^3/s)	N/A	4.1	6.2
Capacity (MW)	7.5	20.2	26.1
Annual Pumping Energy (GWh)	N/A	48	70
Annual Energy Output (GWh)	**20**	**54**	**69**

A pumped storage scheme will incur energy losses through the pumping phase and the generation phase. For the Project, about 30% losses were estimated. Therefore, the roundtrip efficiency of the pumped storage facility is estimated at 70%.

As a pumped storage scheme, the energy yield is limited by the available pumping energy. With an adequately sized dam, the terrain at the Moon Lake reservoir is able to accommodate more water than would be pumped by both the 48 GWh and / or 70 GWh of forecasted available pumping energy.

As the results from the conventional storage study were generally consistent with the results from past studies, it was agreed to primarily analyze the project as a pumped storage scheme and produce conceptual drawings, operation cost estimates, and levelized cost of energy (“LCOE”) for the 48 GWh pumped storage scenario. From this base case alternative, cost estimates were then extended at a high level to the conventional storage and 70 GWh pumped storage alternatives.

The study was based on available previous reports, publically available mapping and hydrological data and from a brief site visit conducted in June 2015.

The proposed 48GWh pumped storage scheme will comprise a 31 m high, 700 m long earth dam at the outflow of Moon Lake, a 5.5 km long, 0.6 m diameter buried steel penstock, and a concrete and structural steel powerhouse some 400 m below on the shore of Tutshi Lake. The installed generation capacity will be 20.2 MW and pumping capacity of 18 MW.

The capital cost estimates for the three alternatives of the studied project options, exclusive of contingency, is shown in **Table 2**.

Table 2: Project Capital Cost Estimates

Project Component	Conventional Storage ($M 2015)	Pumped Storage 48GWh ($M 2015)	Pumped Storage 70GWh ($M 2015)
Project Development	$2.2	$2.2	$2.2
Civil Construction Costs	$105.1	$143.1	$169.1
Generating Equipment Costs	$5.0	$14.0	$22.1
Transmission and Interconnection Costs	$2.8	$2.8	$2.8
Owners Costs During Construction	$2.1	$2.1	$2.1
Total Project Capital Cost	**$117.2**	**$164.2**	**$198.2**
Contingency	$22.6	$32.0	$38.8
IDC	$15.2	$21.4	$25.8
Grand Total Project Capital Cost	**$155.0**	**$217.5**	**$262.9**

Annual operating costs and a financial model for the estimation of the Levelized Cost of Energy ("LCOE") were estimated for the 48 GWh alternative only. For this alternative, the operating costs were estimated to be $1.9 million ($2015).

The resulting project LCOE assuming a full utilization of installed capacity was estimated to be $0.189/kWh. A sensitivity analysis was carried out on LCOE assuming different capacity utilizations. The results of this sensitivity analysis are presented in **Table 3**.

Table 3: LCOE Sensitivity Analysis - 48 GWh PSH Alternative

Capacity Factor	Full Utilization Generation (GWh)	NPE (GWh)	NPV ($M 2015)	LCOE (S/kWh)
100%	54	1,412.8	267.5	0.189
90%	48.6	1,271.5	267.3	0.210
80%	43.2	1,130.2	267.2	0.236
70%	37.8	989.0	267.0	0.270
60%	32.4	847.7	266.8	0.315

Several existing rights have been identified at the project site and its vicinity. Prior to advancing the project further, a detailed investigation of the current and future existing rights is recommended to identify potential development barriers.

If a decision is made to advance the project into the feasibility study stage, the following field studies and data collection programs are recommended:

1) Prepare a submit a **water licence application** to Front Counter BC so as to secure first-in-line water rights to the project ahead of other potential claimants. British Columbia recognizes the rights to water on a first come, first serve basis. Several existing rights have been identified at the project site and its vicinity. Prior to advancing the project further, a detailed investigation of the current and future existing rights is recommended to identify potential development barriers.
2) Project preliminary engineering and design can be further advanced with greater precision topography, obtained with a **LIDAR survey**. This survey is recommended to refine the design and quantity cost estimate. The LIDAR survey area should comprise the dam site, the penstock route, suggested at 200 m each side of the proposed penstock alignment, and the powerhouse site. The estimated area of study is 3.5 km^2.
3) A **geotechnical investigation** program is recommended to assess the foundation conditions of the dam and powerhouse as well potential anchor block locations at select major bends along the penstock alignment.

   During early stage project definition and development, seismic refraction lines present a cost effective alternative to estimate overburden thickness without incurring the cost of mobilization of drilling rigs across Tutshi Lake and into the upper Moon Lake watershed. Two seismic lines are recommended at the dam site: one along the dam axis and one perpendicular to the dam axis at the maximum dam height. Two lines are suggested along the penstock near route and two at the powerhouse. As project certainty is achieved, greater expenditure for project definition is justified and the results from the seismic analysis can be confirmed with boreholes.

   Boreholes are indicated at the powerhouse location because of the importance of better characterizing the construction excavation conditions adjacent to Tutshi Lake as well as characterizing the rock quality at the powerhouse. Further, boreholes are an important along the dam foundation, not only to characterize the depth to bedrock, but to also investigate the rock quality and permeability in order to plan dam foundation treatment. As such, the dam boreholes should extend into bedrock to a depth commensurate with the dam height and include in situ permeability testing of the rock. Location of the boreholes should be determined once greater resolution mapping becomes available.

   Finally, a dedicated site investigation to secure and confirm a source pit for the material for construction or the dam is recommended to be included with any geotechnical programme.

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CPI	Consumer Price Index
EAO	Environmental Assessment Office
FSL	Full Supply Level
IBA	Impact Benefits Agreement
IDC	Interest during Construction
IDF	Inflow Design Flood
ISD	In-Service Date
LCOE	Levelized Cost of Energy
MAD	Mean Average Daily Flow
MAR	Mean Annual Runoff
MOL	Minimum Operating Level
O&M	Operations and Maintenance
POI	Point of Interconnection
PSH	Pumped Storage Hydro
RFP	Request for Proposal
ROR	Run of River
ROW	Right of Way
SRW	Statutory Right of Way
TWL	Tail Water Level
UREP	Use, Recreation and Enjoyment of the Public
VFD	Variable Frequency Drive
WSC	Water Survey of Canada
YEC	Yukon Energy Corporation

1 Introduction

1.1 Background

Yukon Energy Corporation ("YEC") is investigating the potential to develop a storage hydro project on Moon Lake, in northwestern British Columbia. As a utility, YEC experiences a winter peak load, combined with a summer peak in generation potential from its hydroelectric generating assets. A storage project at Moon Lake is intended to seasonally shift freshet flows and augment winter generation potential to better align with YEC's annual load profile.

YEC has a surplus of summer energy, resulting for a lower demand during those months combined with high freshet flows on the Yukon River and others. Currently, installed capacity on the Yukon River at Whitehorse is underutilized during the summer months and the surplus freshet flows are spilled.

Moon Lake, located 100 km south-southeast from Whitehorse, and 18 km south of the BC Yukon border, drains into Tutshi Lake from the south and is ultimately a tributary to the Yukon River, above Whitehorse. The Klondike Highway, between Carcross Yukon and Skagway Alaska traverses the north shore of Tutshi Lake.

A storage project at Moon Lake would have a double benefit to YEC inasmuch as stored summer flows would provide direct winter generation as well as marginally reduced freshet flows that would be spilled at Whitehorse. The winter generation flows at Moon Lake would also, ultimately report to the Whitehorse generating station as well.

A project on Moon Lake has been investigated several times in the past. These include studies by Klohn Crippen Consultants ("KCCL"), in 1992; KGS Group ("KGS"), in 2008; and HDR Inc. in 2011. KCCL and KGS proposed several arrangements of conventional storage schemes, simply storing summer flows at Moon Lake until winter and then slowly generating with those flows during YEC's peak load period (HDR proposed a run-of-river project directly on Moon Creek).

Tutshi Lake and its catchment have even greater flows than available in the Moon Lake catchment. YEC has proposed to develop a seasonal pumped storage scheme at Moon Lake, wherein spilled flows at Whitehorse, as well as other potential intermittent renewable energy sources (such as wind) would be used to pump flows from Tutshi Lake up to a dam on Moon Lake during periods of surplus energy. These flows, would then be stored with the natural flows in currently in the Moon Lake system to be used for generation during periods of generation deficit.

Midgard Consulting Inc. ("Midgard") has been retained to investigate the viability of a seasonal pumped storage hydro ("PSH") scheme on Moon Lake.

1.2 Purpose and Scope of the Report

This report describes available background information and site characteristics as the basis for determining the overall viability of a pumped storage scheme for the Moon Lake Pumped Storage Project ("Project"). It details project site conditions, project hydrology estimates, the proposed project layout and ultimately a Class 5 cost estimate.

The Project, although being proposed by YEC, is in the Province of British Columbia. A high level Project Development Plan has also been prepared that outlines the steps and process, at a high level, to develop a hydroelectric project in that Province. This plan also provides preliminary cost estimates associated with project permitting and development activities, which also feed into the project capital cost estimates.

The report has been prepared to provide YEC with an assessment of the Project's potential to store and re-generate surplus energy from the YEC system to quantify its benefit. This combined with the capital cost estimates, and estimates of project operating costs, feed into an estimate the project's Levelized Cost of Energy ("LCOE").

The LCOE can provide a measure of project value relative to competing sources of winter energy that may be available to meet YEC's load in the future.

1.3 Salient Features of the Project

The proposed project will create a 690 ha reservoir over the existing Moon Lake and draw flows as need for generation from the reservoir. Water is stored directly from flows into the reservoir from the upper Moon Creek catchment as well as from pumped flows up from the lower Tutshi Lake.

Tutshi Lake has a nominal water level of 714 metres. The Moon Lake reservoir level will vary from a Minimum Operating Level ("MOL") of 1,114 meters and Full Supply Level ("FSL") of 1,125 metres.

The proposed project arrangement comprises a 31 m high, 700 m long earthfill dam with south abutment spillway and a low level outlet intake; a 5.24 km long, 1.6 m diameter buried steel penstock; and concrete and steel surface powerhouse containing a 20.2 MW vertical axis Pelton turbine and synchronous generator as well as two 9.4 MW peak power, variable speed drive vertical axis pumps. Flows are discharged to or drawn from a 7 m deep sump connected to Tutshi Lake.

2 Background Information

2.1 Review of Previous Studies

2.1.1 Klohn-Crippen Consultants Ltd. ("KCCL")

KCCL performed a study of the project as a conventional storage facility in 1992. The study proposed three layout alternatives, each involving inter-basin diversion from neighbouring catchments into Moon Lake. For each of the three diversion alternatives, the remaining project layouts remained similar and comprised: an earthfill dam across Moon Creek, downstream of Moon Lake, a combined power canal and buried steel penstock conveyance to a concrete and steel powerhouse, founded on bedrock on the shore to Tutshi Lake.

The three proposed diversion alternatives were the following:

1) **Alternative 1:** Would regulate flows in the 58.9 km^2 Moon Lake catchment and would capture and divert flows from a 25.7 km^2 sub-catchment to the north of Moon Lake. The resulting combined project catchment of 84.6 km^2 would result in a mean annual discharge ("MAD") of 1.35 m^3/s. The 8.5 MW plant would generate an estimated annual energy of 36.3 GWh. Estimated project cost was $28.8 million ($1992) excluding transmission.
2) **Alternative 2:** Would regulate the flow from Moon Lake and divert and capture flow from an additional six neighbouring sub-catchments with a combined drainage area of 57.3km^2. The total resulting project catchment of 116.2 km^2 would result in an estimated average runoff of 1.83m^3/s and annual energy generation of 49.2 GWh from an 11.5 MW plant. Estimated project cost was $35.4 million ($1992) excluding transmission.
3) **Alternative 3:** Would be similar to the Alternative 2 diversion scheme but would generate energy throughout the year as opposed to through the winter period only. This would result in a smaller dam and reservoir as well as a lower installed capacity. Assumed generation throughout the year would be 51.3 GWh on an installed capacity of 8.5 MW. Project cost was estimated to be $30.1 million ($1992) excluding transmission.

It is noted that the proposed project layout by Midgard retains several similarities to the schemes proposed by KCCL. The proposed dam alignment and layout are similar as is the selection of conveyance route and powerhouse location.

However, unlike KCCL, a power canal is not generally suited to a pumped storage scheme, with the need to balance flows both in and out of the reservoir, at varying water levels. Further, in the current permitting regime in British Columbia, it is not considered practical to successfully permit hydroelectric projects that incorporate inter-basin transfer of flows. No such supplementary diversion infrastructure is contemplated in this report.

2.1.2 KGS Group ("KGS")

In 2007 and 2008, KGS prepared an Assessment of Potential Hydroelectric Sites. This study included a concept study of eight potential hydro project sites, one of which was the Moon Lake site.

KGS proposed a conventional storage project with either a 3 m high dam or a 30 m high dam, with a water conveyance along the left (south) bank of Moon Creek and a powerhouse on the shore of Tutshi Lake. KGS also proposed an inter-basin diversion of flows for a total project catchment of 84.6 km^2. The three alternatives were the following:

1) **Alternative A** – 3 m high dam/intake/spillway and intake, with a canal or penstock to one of two powerhouse locations on the east shore of Tutshi Lake. Estimated annual energy was 33 GWh on an installed capacity of 5.7 MW.
2) **Alternative B** – 30 m high dam/intake/spillway, canal or penstock, intake to the powerhouse options on Tutshi Lake. KGS did not report energy and capacity for this alternative.
3) **Alternative C** – 3 m high dam at Moon Lake and a low level intake located further downstream, and then a canal or penstock to the powerhouse on Tutshi Lake. The estimated annual energy was 28 GWh with an installed capacity of 4.9 MW.

2.1.3 HDR Inc. ("HDR")

HDR performed a study of the Project as a run-of-river facility in 2011. The project estimated capacity was 6.7 MW and annual energy was 27.4 GWh.

2.2 Site Investigation

On June 24th 2015, a helicopter over-flight of the site was carried out for the purpose of confirming the overall site terrain as well as providing visual reference to the geological and geotechnical inferences developed from review of previous studies and desktop available data.

Conditions were ideal, with high visibility and calm winds. The itinerary for the visit was as follows:

1. Transit from Whitehorse to Bennett, BC;
2. Flight over upper Tutshi watershed to develop a visual sense of terrain and glacier cover;
3. Flight up Moon Creek from Tutshi Lake to upper Moon Lake catchment to confirm terrain;
4. Touch down on lake to confirm barometric elevation;
5. Slow flight down and then up Moon Creek from dam site to powerhouse to confirm conveyance route and powerhouse location;
6. Touch down on Tutshi Lake to confirm barometric elevation of Tutshi Lake;
7. Fly over Tutshi Lake outflow between Tutshi and Tagish Lakes to develop visual sense of reach aquatic habitat;

8. Return transit to Whitehorse.

Figure 1 shows a partial flight path around Moon and Tutshi Lakes.

Figure 1: Site Visit Flight Path

The following are discussions and conclusions derived from the site visit.

Dam Axis Alignment

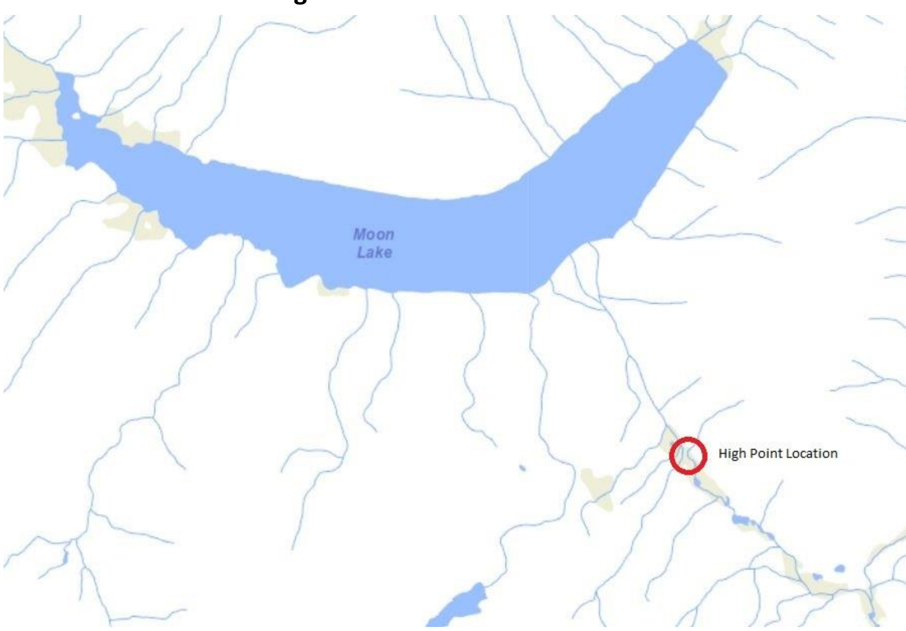
During the site visit, several potential dam alignments were reviewed. It was concluded that a dam axis crossing the creek approximately 1.4 km downstream of the outfall of the lake. The approximate coordinates are Latitude 59°50'16.24"N and Longitude 134°41'56.08"W. This location was selected because of evident surficial bedrock and presumed near surface bedrock along the dam alignment as well as favorable topography along the left abutment that will tend to reduce dam height and material volumes. **Figure 2** provides a view of the proposed dam alignment at the creek, looking upstream toward Moon Lake.

Figure 2: Proposed Dam Location

Maximum Reservoir Containment Elevation

The best available topographic mapping is at a 20 metre contour resolution. A tributary to the lake from the southeast was identified as having a relatively low saddle-break into the adjacent watershed. Using comparative barometric elevations from the lake surface to the saddle-break, it was established that the maximum reservoir elevation that would be contained within the watershed, without the addition of a saddle dam at this location is 1141 metres. The location of the saddle-break is shown on **Figure 3**.

Figure 3: Saddle-Break Location



Penstock Alignment

A conveyance alignment on the river-left (Southwest) bank was selected due to more favorable terrain and lower gradient cross slopes.

Powerhouse Location and Tutshi Lake Elevation

The powerhouse is proposed at a cleared area north of the confluence between Moon River and Tutshi Lake (See **Figure 4**). The Tutshi Lake water level was measured on site at 714 m.

Figure 4: Proposed Powerhouse Location

3 Site Characteristics

3.1 Access

The Klondike Highway, between Carcross, Yukon and Skagway, Alaska, runs along the north shore of Tutshi Lake. There is no current or historical road access to Moon Creek. Construction of road access around the upstream end of Tutshi Lake would require 7 km of new, fairly difficult road construction, combined with a significant bridge span across the Tutshi River.

For the purposes of this study, it is therefore concluded that construction access to the site would be by barge across the lake from the Klondike Highway.

For this purpose, there is ample low bank access to the lake along the highway for barge access on the lake.

3.2 Regional Terrain Characteristics

The Moon Lake watershed lies within the Boundary Ranges of British Columbia Coast Mountains. The topography of the region is typified by broad U-shaped valleys flanked by hanging valleys with steep side slopes.

The Boundary Ranges extend some 800 km northwest from the mount of the Nass River along the BC-Alaskan border into the Yukon. The peaks of this range are typically lower than the peaks of the southern coast mountains but retain significant glaciation due to their northern latitude. Geologically, the predominant bedrock of the region is from granitic intrusions of the Coast Arc Range of the Late Cretaceous geologic period (66 to 100 million years ago). The granitic intrusions formed the basement of the Coast Arc volcanoes, which have substantially eroded away. One notable exception is the Bennett Lake volcanic complex, remnants of which remain some 40 km to the northwest of the project.

SLR characterized the project area more specifically as “mountainous with glaciated valleys having veneer of glacial drift over bedrock. Moon Lake is located within a broad U-shaped valley that is flanked by high elevation mountainous terrain. The area of the outflow channel from Moon Lake and several hundred metres downstream appears to have a thicker organic layer that may have be an infilled section of the lake basin composed of alluvial material. Bedrock outcrops are evident a few hundred metres downstream of Moon Lake becoming more frequent with distance from Moon Lake. It appears that the stream to Tutshi Lake is generally bedrock controlled. Glaciofluvial features also appear to be evident down the valley from Moon Lake to Tutshi Lake where there are high banks of exposed overburden. This material is a possible source of both fine and course dam construction fill (to be verified).” See Appendix A for SLR’s Geotechnical Memorandum.

3.3 Topography

The project general arrangement concepts as well as hydrologic assessment of the watersheds has been carried out using mapping from DataBC with 20 m contours topography based on the Provincial TRIM 20,000 scale dataset.

Bathymetric data for neither Tutshi Lake nor Moon Lake was found. Based on the site visit, it is evident that the outflow of Moon Lake is bedrock controlled, limiting the practicality of accessing negative storage from the existing lake.

3.4 Reservoir Storage Curves

3.4.1 Moon Lake

A reservoir storage curve was developed for the proposed Moon Lake reservoir using the 20 m topography. Reservoir surface areas were measured at 20 m contour intervals and the assumed dam axis alignment. Volumes were computed using an average end area methodology.

In order to establish a base water level, data from the installed Water Survey of Canada ("WSC") gauge near the outflow of the lake was access. Select water levels from that gauge, as measured through 2013, are summarized in **Table 4** below.

Table 4: Moon Lake Measured Water Level

Item	Water Level (m)
Min Water Level (m)	1,113.8
Max Water Level (m)	1,114.2
Average Water Level (m)	1,113.9
Average Winter Lake Level (m)	1,113.8
Average Summer Lake Level (m)	1,113.9

Further, during the June 24th site visit, using a barometric pressure altimeter from the helicopter, the lake water level at Moon Lake was also measured at 1,114 m. For the purposes of this report, it was concluded that, due to the relative low variation in lake level, the base water level at Moon Lake is 1,114 m.

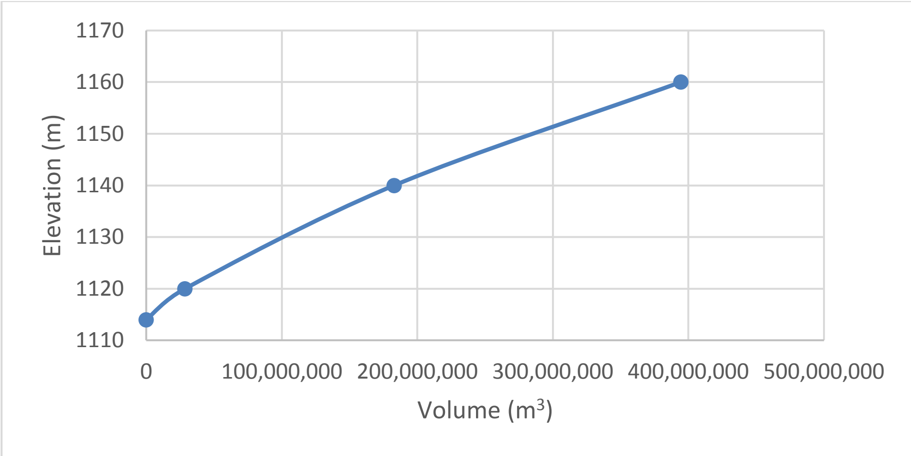
A Moon Lake reservoir storage curve was developed from the base lake level of 1,114 m up to 1,160 m at 20 m intervals. The available live storage volume are shown in **Table 5** and **Figure 5**.

The measured lake area at EL. 1,114 m is 3.44 km^2.

Table 5: Moon Lake Storage Areas

Elevation (m)	Area(km^2)	Volume (m^3)
1,114	3.437838	0
1,120	6.080000	28,553,514
1,140	9.350000	182,853,514
1,160	11.810000	394,453,514

Figure 5: Moon Lake Storage Curve



3.4.2 Tutshi Lake

Similarly, the WSC gauge, 09AA018, at Tutshi Lake recorded lake levels throughout 2012. The lake water level on Tutshi Lake was measured at 714 m during the June 24th site visit. Select measured water levels on Tutshi Lake are shown in **Table 6**.

Table 6: Tutshi Lake Estimated Water Level

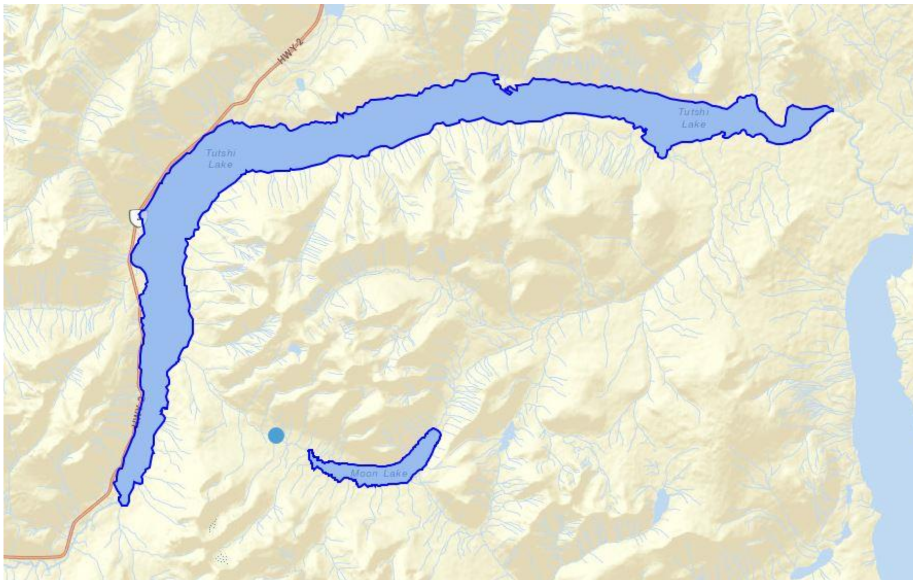
Item	Water Level (m)
Min Water Level (m)	713.1
Max Water Level (m)	714.6
Average Water Level (m)	713.5
Average Winter Lake Level (m)	713.2
Average Summer Lake Level (m)	713.9

A base lake level of 714 m was selected for this report.

The measured surface area of Tushi Lake at EL. 714 m is 52.84 km^2. The Tushi Lake surface area is significantly larger than the proposed Moon Lake reservoir. Further, inflows and outflows from Tutshi Lake will remain uncontrolled during project operations and as such, project operations are not expected to have a material effect on the water levels of Tutshi Lake. Particularly not within the resolution of available mapping. Consequently, no storage curve was developed for Tutshi Lake.

The Project Lake and the Tutshi Lake areas are shown in **Figure 6**.

Figure 6: Moon Lake and Tutshi Lake Areas



3.5 Hydrology

3.5.1 General

Moon Creek is a second order creek draining Moon Lake and the flanks of Jack Peak to the north and Skelly Peak to the south. The drainage basin is situated in the Boundary Ranges of the Coast Mountains of BC and Alaska.

Moon Creek has a drainage area of 57.4 km^2 at the proposed dam, of which 6 percent (3.44 km^2) is lake surface area. There is no appreciable glacial ice within the watershed.

Tutshi River is a third order river draining into Tutshi Lake and from Tutshi Lake to Tagish Lake from its headwaters to the west near the Alaska border. Tutshi Lake, at its outflow, has a drainage area of 979 km^2 of which 6.8 percent is lake surface area (66 km^2) and 1.5 percent (14 km^2) is glacial ice or snow field.

The region's hydrology is nival, driven primarily being the melt of annual snowpack over the summer, which produces a moderate but sustained flow.

3.5.2 Stream Flow Gauges

Environment Canada, through the Water Survey of Canada ("WSC"), maintains two current streamflow gauges in the area of the project. **Table 7** provides a summary of the average annual flows or Mean Annual Runoff ("MAR"), drainage areas and years of record for the two gauges.

Table 7: Regional Stream Flow Gauges

Gauge Name	WSC Number	Period	Complete Years of Record	Drainage Area (km^2)	Mean Annual Runoff ($L/s/km^2$)
Moon Creek near the outlet of Moon Lake	09AA018	2012 - 2015	2	53.0	14.9
Tutshi River at outlet of Tutshi Lake	09AA013	1956-2015	45	989	16.2

The estimation of the project hydrology is very much facilitated in this instance because there has been a gauge installed on the same third order catchment as the project stream and there are at least two concurrent years of data between the project gauge and the long run gauge. The Moon Lake gauge represents 5.3 percent of the Tutshi Lake basin. Both gauges are maintained by the WSC.

Both gauges demonstrate a comparable MAR and both have similar areas of lake coverage. There is marginally more glacial coverage in the Tutshi basin, which, in this period of glacial retreat, can help to explain the marginally higher MAR within that basin.

3.5.3 Hydrology Used in the Energy Production Model

Midgard developed a synthetic daily flow series for the proposed dam site using a regression analysis on the concurrent data from the Moon Lake and Tutshi Lake gauges.

Data was sorted by month and compared using a direct temporal (day for day) comparison in order to generate a relationship for each month. The regression was performed with each daily matched pair of flows from July 27, 2012 through July 6, 2015[1].

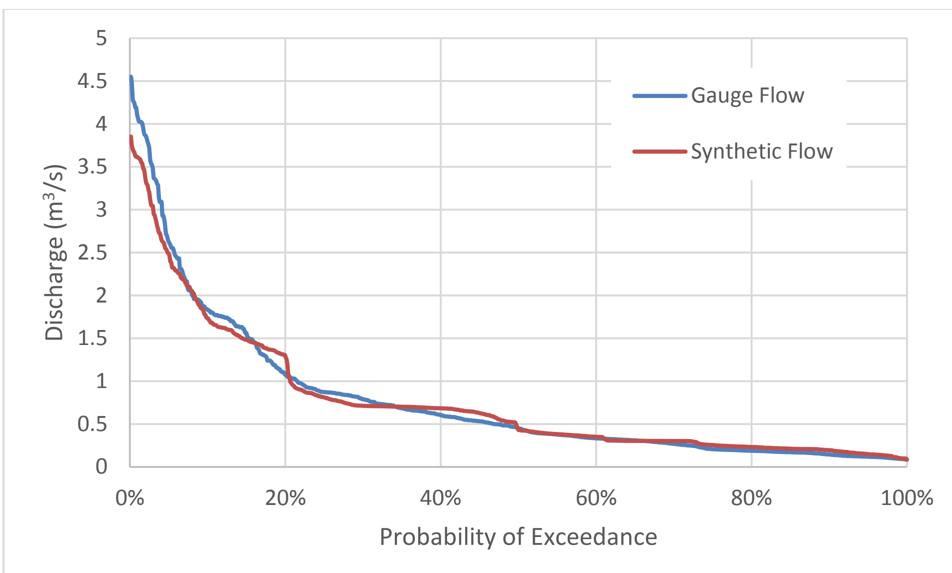
The data at the Moon Lake and Tutshi Lake gauges demonstrated strong correlation as expected. The synthetic average monthly flows are listed in **Table 8** and a comparison of flow duration curves of the measured and the synthetic data set is shown in **Figure 7.**

[1] The 2014 to 2015 data are provisional. Provisional data has not undergone WSC's QA/QC confirmation yet. Midgard chose to make use of the additional data because the benefit of the additional data in refining regression results. The results may be refined when WSC publishes its final data.

Table 8: Synthetic Average Monthly Flows (m³/s)

Month	WSC Gauge Site	Dam Site
January	0.21	0.23
February	0.23	0.25
March	0.21	0.22
April	0.19	0.20
May	0.72	0.78
June	2.25	2.44
July	1.89	2.05
August	0.85	0.92
September	0.71	0.77
October	0.57	0.61
November	0.36	0.39
December	0.30	0.33
Average	**0.71**	**0.77**

Figure 7: Moon Lake Gauge Flow Duration Curves



Based on the regression model results, a synthetic string was obtained from the Tutshi Lake Gauge data and the area proration between the Moon Lake Gauge watershed area and the Project watershed area. The drainage area factor between the gauge and the project is 1.08.

Data was recorded at the Tutshi Lake Gauge from 1956 to today, however, only the data from 1966 to today was recorded continuously. Only partial data was recorded in 1987 and 2000, and no data was recorded in 1998 and 1999, therefore year 1987, 1998, 1999 and 2000 were removed from the dataset to generate a 45-year synthetic string.

3.5.4 *Frequency Distribution and Flood Estimates*

A frequency distribution analysis of the synthetic annual maxima was carried out to estimate expected flood flows and their respective probability at the dam site.

At this level of study, and given the limited amount of regional data, Midgard elected to extend the frequency distribution analysis for extreme floods for the purposes of sizing flood routing capabilities at the dam site up to 1000-year flood. It is acknowledged that an extended frequency distribution for long return period annual maxima is generally considered to be inappropriate for determining the inflow design flood ("IDF") for dam and spillway design. Further flood estimates are warranted if the project advances through higher stages of development and design.

The flood flows, using Log-Pearson III distribution, are presented in **Table 9**. The 500-year and 1000-year floods were estimated by extrapolation.

Table 9: Estimated Flood Flows at the Proposed Dam

Frequency	Flood (m^3/s)
5-year	4.41
10-year	4.98
50-year	6.15
100-year	6.61
200-year	7.06
500-year	7.55
1000-year	7.90

3.6 Existing Water and Land Rights

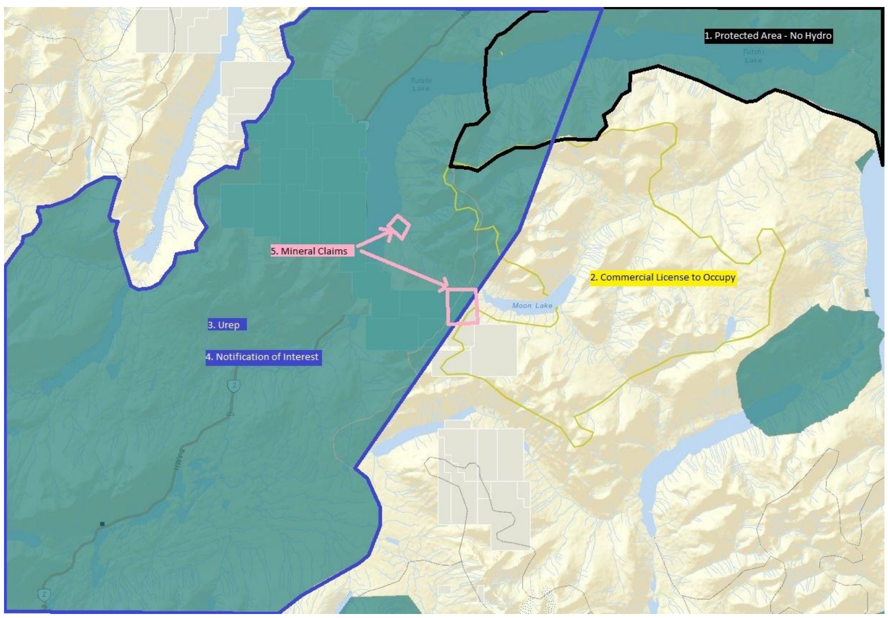
The successful development of a waterpower project in British Columbia on Crown Land presumes that there are no competing prior rights to either the land base or the surface water rights. A preliminary investigation was carried out using the publically available provincial database to ascertain the potential existence of any prior rights.

The search revealed several prior land rights and one water licence being present on or near the project area as summarized in **Figure 8**.

1) A protected area tenure exists on the downstream portion on Tutshi Lake. The tenure has an explicit clause precluding the development of hydroelectric projects or any water control facility. The protected area does not include the project area, but it is worth noting.
2) A Commercial License to Occupy exists on the project area for Guide Outfitters. The tenure does not preclude other licenses on the project area. However, in concert with this licence, there is a cabin near the south shore of Moon Lake which would be impacted by the proposed reservoir of the project.

3) A Use, Recreation and Enjoyment of the Public ("UREP") map reserve exists on Tutshi Lake and the downstream portion of the project. A map reserve is a land use reserve that is established under Sections 11 or 12 of the Land Act over an area of Crown land outside of Provincial Forests to guard against unwarranted disposition or unplanned use (in this case, sale or use that would compromise an area's current or potential recreation values or uses).[2]
4) A notification of interest exists on the project area.[3]
5) Five mineral claims exist on downstream portion of the project area.
6) A historic water licence application was registered in 1991 for a power project on Moon Lake. This application has since been abandoned.

Figure 8: Prior Rights Summary



3.7 Terrestrial Wildlife and Aquatic Habitat

No Specific research was carried out on terrestrial wildlife or aquatic habitat values.

It is noted that the Tutshi River, between Tutshi Lake and Tagish Lake is a broad riffled reach with an average gradient of 0.5% over its 7.3 km length. Visual observation during the over-flight suggests that there are no falls or other potential barriers to fish migration.

[2] https://www.for.gov.bc.ca/hfp/publications/00201/appen05/appen05.htm

[3] A notification of interest is one types of land status regarding the apportionment, setting apart or earmarking of land or water for an indication of interest.

Due to the nature of the channel, a higher than typical instream flow is assumed to be required to maintain an overall wetted perimeter in the channel and preserve fish habitat. An instream flow in the reach is assumed because, pumping flow from Tutshi Lake into Moon Lake can impact outflows from Tutshi Lake.

The Moon Creek reach between Moon Lake and Tutshi Lake is very steep, with an average gradient over 7 percent. Anecdotally, Moon Lake is fish bearing but this has not been confirmed. A lower instream flow release has been assumed between the dam and Tutshi Lake but a cost allowance has been made for maintaining fish passage over the dam.

There were no evident showstoppers to the project from the perspective of terrestrial wildlife values.

4 Facility Description

4.1 Background

The basic concept of the facility is to develop an upper reservoir on Moon Lake that will enable the generation of winter energy, when regional flows and flows on the Yukon River basin are at their lowest. To achieve this, a dam is proposed downstream of the outlet of the lake equipped with a gated intake tower, spillway and low level outlet. A buried penstock will convey flows from the intake to a powerhouse on the shores to Tutshi Lake, some 400 m below in elevation.

As a conventional storage facility, the dam height would be optimized to accommodate the annual freshet and summer flow from the upper basin of Moon Lake, with some allowance for potential spill during extreme flood years. The penstock would be optimized for its cost versus the present value of foregone energy that result from hydraulic losses of head in the system. The powerhouse would house a turbine and generator unit, most likely a Pelton unit given the head and flow profile of the project.

For a pumped storage scheme, the overall project layout would remain the same as a conventional scheme with the following exceptions. First, the dam height would increase to not only impound natural flows from the upper catchment, but also the volume of flow that would be pumped from Tutshi Lake; second, the penstock would be optimized for a higher design flow; and third, the powerhouse would also have to accommodate a pump and intake from Tutshi Lake.

This section describes the conceptual layout of the Project as a pumped storage facility. During high flow period, the energy generated from the spill at Whitehorse hydroelectric station or other to be determined energy sources on the YEC grid, will be used to pump water from Tutshi Lake into the Moon Lake reservoir for winter energy storage. During low flow periods, energy will be generated form the stored water to contribute to the Yukon winter load demand.

4.2 Diversion

In order to construct the dam across the outlet of Moon Lake, it is necessary to divert flows from the dam foundation. Typically, this is accomplished with a temporary diversion channel or tunnel, which allows the dam to be constructed in the dry. In the case of this project, a low-level outlet pipe is proposed under the dam foundation. During construction, the water at Moon Lake will be diverted through the low-level outlet pipe of the dam.

The 200 m long diversion pipe will be encased in concrete. The dam will constructed be on top of the diversion pipe, which will stay in place after construction.

4.3 Dam

The dam will be founded on bedrock. The depth of overburden is assumed to be 3 m and will need to be verified through a geotechnical investigation program. The overburden is assumed to be consisting of glacial moraine deposits and organics. Primary to tertiary grouting curtains will be placed to prepare the foundation.

The project is designed with a 31 m high[4] and 700 m long earthfill dam. The dam structure is primarily composed of a homogeneous core of fine local till material. At this stage the material is assumed sufficiently fine to limit most of the seepage. An upstream bituminous liner may be installed to provide additional seepage control but was no included at this stage. Bituminous liners are often used in the north because of the ease of placement during cold weather and its ability to handle extreme temperature fluctuations. An internal drainage system consisting of a downstream gravel filter and drainage blanket will be incorporated to the structure. Riprap will be placed on the upstream face to provide erosion protection.

Per the Canadian Dam Association's Dam Safety Guidelines:

1) "Significant" hazard classification implies only temporary population at risk within the dam-breach inundation zone (e.g., seasonal cottage use, passing through transportation routes, or participating in recreational activities). In the event of a dam failure, the potential loss of life is unspecified, no significant loss or deterioration of fish or wildlife habitat is expected, and losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes are expected.
2) "High" hazard classification implies only permanent population at risk within the dam-breach inundation zone. In the event of a dam failure, the potential loss of life is 10 or fewer, significant loss or deterioration of *important* fish or wildlife habitat is expected, and high economic losses affecting infrastructure, public transportation, and commercial facilities are expected.

For conservatism at this stage of the study, the dam is classified in the "High" hazard category and is designed for a 2475-year seismic event. The design includes 3 m of freeboard for flood retention and to prevent overtopping, and a spillway over the south rock abutment to pass high flow events such as floods and summer peak flows. The dam crest is assumed to be 6 m wide.

4.4 Spillway

The dam includes a 2 m wide and 300 m long gated concrete spillway structure on the river-left (South) bank rock abutment that controls water flow releases during high flow periods. The spillway is designed to release flows up to the Inflow Design Flood ("IDF")[5]. The spillway structure includes a concrete inlet channel with a 2 m X 2 m gate, stoplogs and concrete chutes which return the water to the river. The foot of the spillway and

[4] Includes 3 m of excavation.

[5] At this stage of study, the IDF is assumed as 1000-year return period flood flow.

area immediately downstream includes a stilling basin designed to withstand the erosive effects of the spillway water flows and to dissipate energy.

4.5 Fish Passage

A fish passage has been assumed to facilitate potential downstream fish migration. Given the overall gradient of the creek below the dam, it is assumed that there will not likely be significant upward fish migration. However, given anecdotal suggestion that the lake is fish bearing, it bears consideration that the lake population may seed downstream fish populations in the creek. Additional research is required to ascertain the practicality of fish passage over the dam.

4.6 Reservoir

The proposed dam creates a reservoir upstream of the dam site. The natural lake level area is 3.44 km^2. The minimum operating level ("MOL") of the water reservoir is 1,114 m. The estimated FSL of the water reservoir is 1,125 m and floods a total area of approximately 6.90 km^2, providing a live storage volume of 67.1 million m^3.[6] The incremental flooding area is from the lake level to FSL is 3.46 km^2.

The flooded area includes an existing outfitter cabin in the southeast shore of Moon Lake.

4.7 Intake

The water intake is a concrete tower structure located on the river-right (North) bank and is based on rock foundation. The intake is connected to the penstock that will convey water for electric generation and pumping during operation up to the full plant design flow of 6 m^3/s. The intake box will provide sufficient submergence to prevent vortex formation from FSL to Minimum Operating Level of 1,114 m.

The main components of the intake include:

1) Trash Racks - To prevent driftwood and other floating debris such leaves from being entrained by the water conveyance structures.
2) Trash Rack Cleaning Equipment - To allow for clearing of entrained debris.
3) Head Gate Structure - To provide the ability to stop water flow into the water conveyance structures as part of regular maintenance or for emergency purposes.
4) Sluice Gate – To flush out the sediment from the intake box.
5) Fish exclusion screen – To prevent fish and other aquatic species from entering the penstock.
6) IFR pipe design for constant IFR of 5% MAD, through the dam
7) Electrical Power Supply and Controls.

[6] Live storage volume is between FSL and MOL.

All steel metal work shall be galvanized for corrosion protection.

4.8 Penstock

A 1.6 m diameter buried steel penstock will convey water for generation and pumping. A minimum of 1.2 m of soil cover is assumed at this stage. The proposed alignment is 5.5 km long on the river-left (Southwest) bank. The alignment includes 7 bends that will likely require structural restraint such as soil restraint or anchor block. The penstock crosses 4 stream channels that will likely require overdrains or bridge crossings. A surge shaft is assumed at this stage, however further transient analysis studies may discard the need for a surge shaft. The penstock includes a bifurcation at the end of the alignment to connect to the pumping and generating unit at the powerhouse.

4.9 Powerhouse

The surface powerhouse is located downstream of the dam on the river-left (Southwest) bank. The approximate footprint of the powerhouse is 550 m^2. The powerhouse is designed one horizontal Pelton unit and one vertical shaft pump.

The powerhouse will be a cast concrete substructure, founded on bedrock, with a pre-fabricated structural steel superstructure.

The powerhouse contains all required operational, maintenance, and protection and control equipment required to operate the facility. Loading bays and an overhead crane will allow for maintenance access during operations. A tailrace channel directs water from the submergence pool back to the river.

4.10 Generating Equipment Selection

The relative smaller scale of the project limits the commercially available alternatives for turbines and pumps. A larger scale pumped storage scheme would typically combine the turbine and pump equipment by using a Francis Turbine, which is physically capable of both modes of operation.

When generating with a Francis turbine, available flows are controlled by the use of wicket gates that can close or open to either control the throughput of the unit, or maximize the efficiency of a unit to available flows. The wicket gates are not used during pumping operations. Pumping can be made more flexible with the addition of a variable frequency drive (“VFD”) which allows the unit to be optimized to available flow and power.

It is unlikely that an optimized and efficient solution is commercially available for an under 20 MW Francis unit. Further, the head and flow profile of the scheme indicates a Pelton generating unit, which is not capable of pumping operations.

Consequently, the selected solution for this report is a vertical axis Pelton turbine with synchronous generator mounted above the 200-year flood level (715.6 m) of Tutshi Lake. The Pelton unit will accommodate generation flows from 3 m^3/s to 6 m^3/s.

Two separate, vertical axis, pumps, with direct coupled VFD and an extended shaft, will be 7 m below normal lake level of 713.5 m for submergence. The pumps have a combined design flow capacity of 4.1 m^3/s. The use of Variable Frequency Drive will allow the pump to accommodate flows from 50% to 100% of the capacity of each pump. Multiple pumps have been selected because of the potential range in pumping energy as well as to minimize overall size of the units.

4.11 Switchyard

The switchyard is a fenced area which contains transformers and electrical protection equipment (such as circuit breakers and disconnect switches). The approximate footprint of the switchyard is 250 m^2. The electricity produced via the turbine-generators inside the powerhouse is conveyed at an intermediate voltage to the switchyard located adjacent to the powerhouse. In the switchyard, the intermediate voltage is transformed up to a 138 kV transmission voltage and transported to the Yukon electrical grid via a 138 kV transmission line.

4.12 Transmission Line and Interconnection

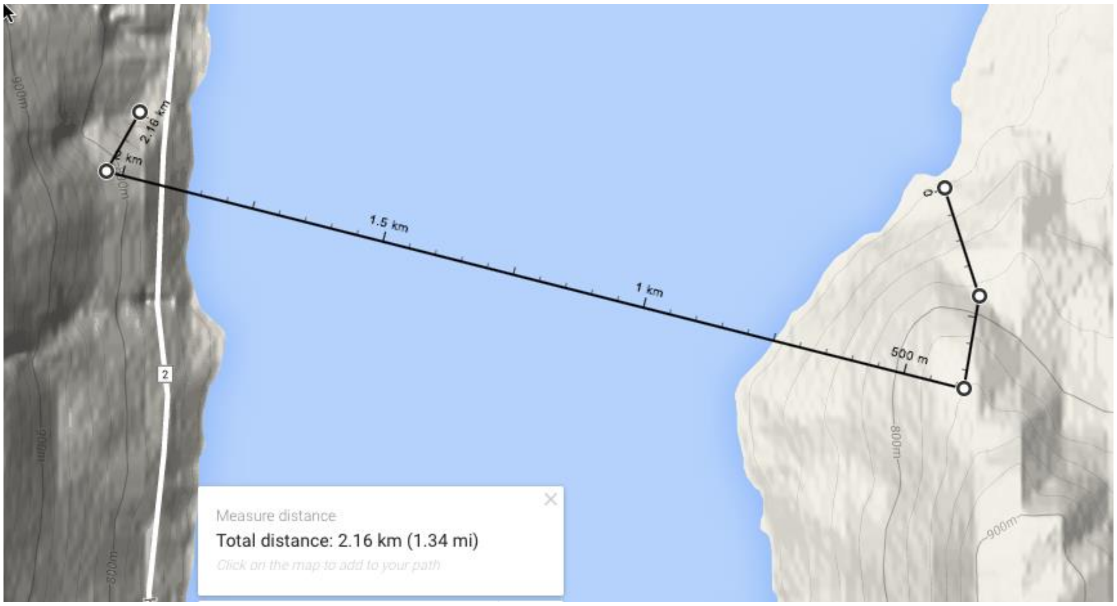
The work assumes the pre-existence of a 138 kV transmission corridor along the South Klondike Highway all the way to Whitehorse.

Two potential interconnection options are available. These are either an overhead span across Tutshi Lake or a sub-marine cable under the lake.

The overhead alternative would comprise an overhead transmission line 400 m south from the powerhouse switchyard up the hill to elevation 840 m, then a 1.6 km span across the lake and a 200 m overhead line down to the assumed 138 kV ROW along the Klondike Highway.

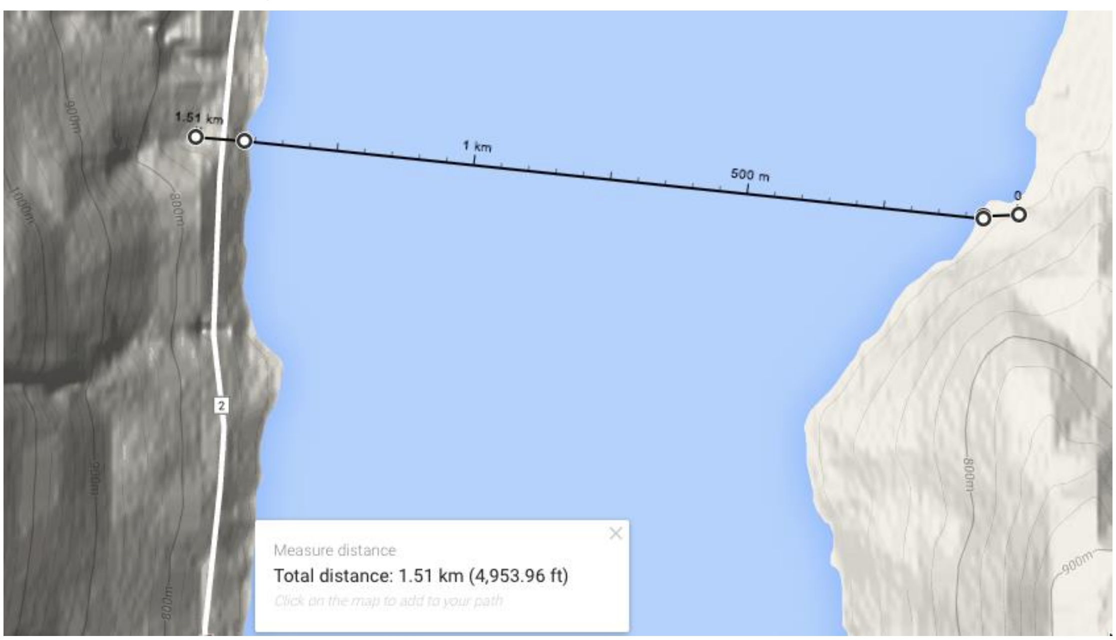
This transmission option is shown in **Figure 9**.

Figure 9: Overhead Transmission Route Alternative



The underwater alternative would comprise a 50 m buried cable, directly from the powerhouse switchyard to the lakeshore and a 1.4 km underwater cable across the lake and a 50 m buried cable to a riser structure at the assumed ROW. This alternative is shown in **Figure 10**.

Figure 10: Underwater Transmission Route Alternative



High level cost estimates indicate that both alternatives have the same order of magnitude cost. The final selection of the alternative will be combination of final cost and permitting constraints.

4.13 Temporary Construction Works

Additionally, a number of temporary construction phase facilities are anticipated during the construction period, including:

1) Site Office and Construction Camp
2) Workshops, labs, and testing facilities
3) Fabrication shops
4) First aid / safety / safety stations
5) Staging / lay down areas
6) Waste water treatment plant
7) Concrete batch plants
8) Truck washing stations
9) Explosives storage
10) Fuel storage and refuelling

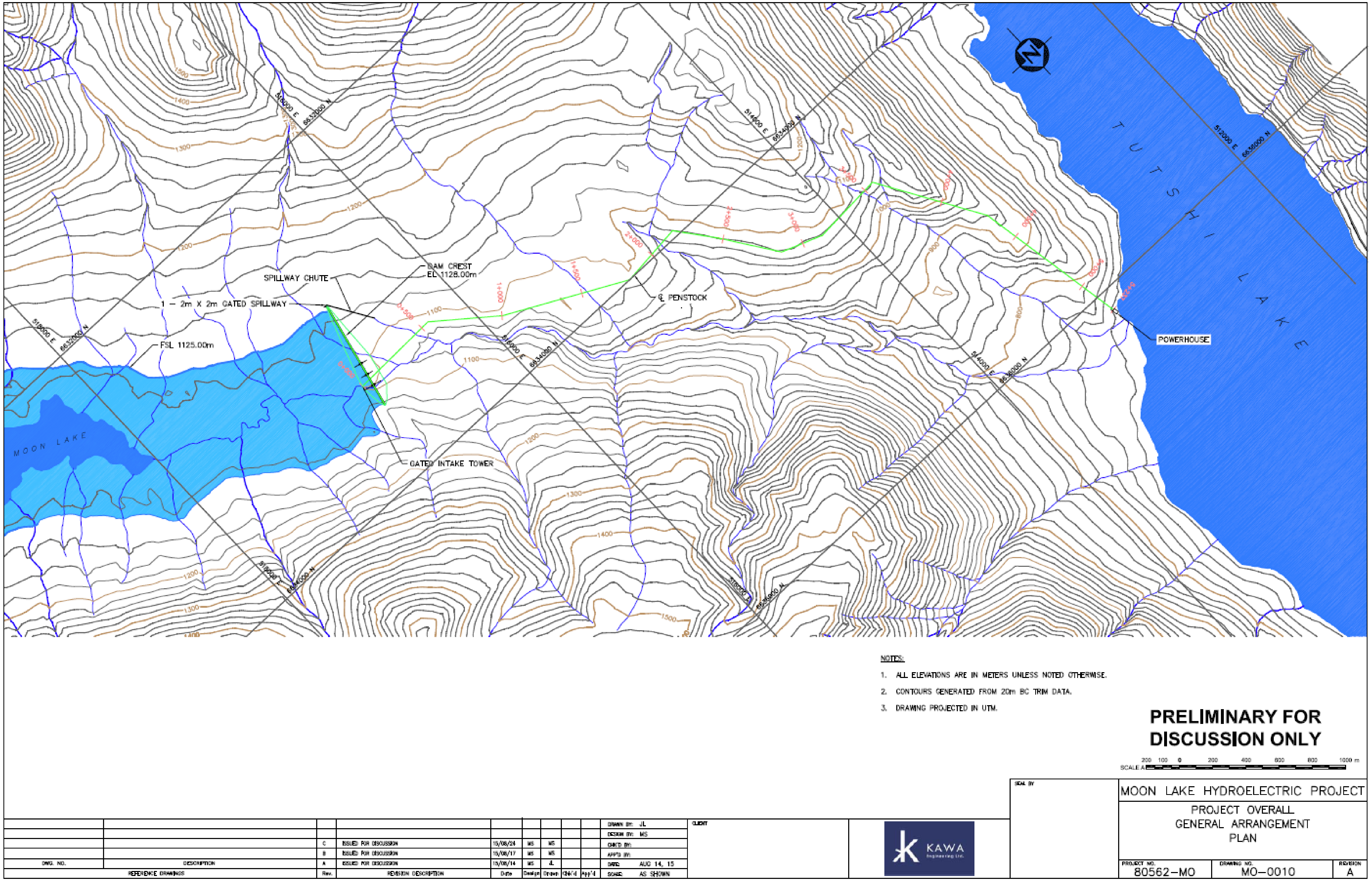
4.14 Access Structure

A barge access from the Klondike Highway to the east shore of Tushi Lake is assumed. Approximately 5.5 km of new road is required to access the project from the barge access to the dam site. The proposed access infrastructure is required for both construction activities (e.g. moving of heavy equipment and materials) and operations activities (e.g. operator access). The road alignment will approximately follow the penstock alignment.

4.15 General Arrangement

Figure 11 shows the proposed general arrangement.

Figure 11: General Arrangement



5 Energy Yield Models

The conversion of a long run flow series to an appropriate forward looking estimate of Project energy generation requires the application of project specific design parameters, environmental in-stream flows and operating assumptions and limitations.

Two energy yield models were developed by Midgard to estimate the energy production of the Project based on the daily synthetic flow series;

- Conventional Storage Model; and
- Pumped Storage Model (48 GWh and 70 GWh scenarios).

The conventional storage model operates on a daily water balance basis. The model estimates the energy generation as a conventional storage project, with flows available only from the upper Moon Lake catchment.

The pumped storage model was created to estimate the energy consumption and net generation of the Project with flows available from both Moon Lake and Tutshi Lake, where flows from Tutshi Lake are pumped into the Project storage reservoir during high flow/low energy demand periods.

Inputs to both models include the daily estimated flow series (based on the WSC gauges); the environmental flows that have been assumed based on the diversion reaches; the conceptual project layout; the available gross head and the estimated hydraulic efficiency of the water conveyance system; the assumed turbine and generator efficiencies; and estimates of transmission and transformer losses.

For the conventional storage scenario, the model examines the daily average flow for each day of the flow series and deducts the In-stream Flow Releases (“IFR”) to obtain the available flows for generation, then calculates the head losses and the resulting net head, selects the appropriate water-to-wire efficiency and calculates the daily energy generation.

For the pumped storage scenario, the model performs an analysis on the season and available flows in Tutshi Lake for pumping to first fill the reservoir and then, estimates winter energy generation as in the conventional scenario.

5.1 Inputs and Assumptions

5.1.1 Hydraulics

The gross and net heads of the plants are governed by natural and existing features as well as the head losses incurred at the plant. For Pelton turbines, the available gross head is defined as the difference between the headwater level in the reservoir and the centreline of the turbine runner.

The powerhouse floor and the resultant turbine runner centreline are typically controlled by the flood elevations for varying flood events with the setting normally being higher than the 200-year flood event level. The gross head inputs for the three scenarios are listed in **Table 10**.

5.1.2 Hydraulic Losses

Hydraulic losses are losses of energy that typically result from the following:

- Hydraulic friction between the water flowing through the passages;
- Changes in flow velocities; and
- Factors that disturb the flow pattern such as trash racks, penstock, trifurcation, needle valves, etc.

The hydraulic losses are measured in meters and vary exponentially with flow velocity. These losses result in a corresponding reduction in the available net head and resultant power output and energy.

Midgard has assumed friction losses within the penstock using as a maximum of 5% of the maximum gross head of the project. The penstock was sized from this assumption. At lesser flows, the hydraulic losses are estimated with the following relationship:

$$Head\ Loss = k \times Q^2$$

Where:

$$k = \frac{5\% \times Max\ Gross\ Head}{Q_D^2}$$

Table 10 presents the Project's hydraulic characteristics utilized as inputs to the energy models.

Table 10: Hydraulic Characteristics

Input	Conventional Storage Model	Pumped Storage Model (48WGh Case)	Pumped Storage Model (70WGh Case)
Maximum Plant Flow (m^3/s)	2.2	6.0	7.6
Full Supply Level (m)	1121	1125	1129
Minimum Tailwater Level (m)	713.2 (Winter Average)	713.5 (Yearly Average)	713.5 (Yearly Average)
Maximum Gross Head (m)	407.8	411.5	415.5
Modeled Maximum Head Losses (5% of Gross Head) (m)	20.4	20.6	20.8
Minimum Net Head (@ Q_D)	387.4	390.9	394.7

5.1.3 Other Model Inputs

The daily flows and the reservoir storage levels that played into the storage models are described in Section 3.5: Hydrology and Section 3.4: Reservoir Storage Curve, respectively.

In-stream Flow Requirements ("IFRs") were assumed to be the following:

a. Moon Lake: Estimated at 5% of MAD throughout the year.
b. Tutshi Lake: Estimated at 10% of MAD from November through May, and 30% of MAD from June through October.

Other major inputs that played into the storage models were assumed as described in **Table 11** below.

Table 11: Energy Model Inputs

Input	Conventional Storage Model	Pumped Storage Model
Turbine efficiencies[1]	90%	90%
Generator efficiencies	98%	98%
Transmission Line Losses[2]	1%	1%
Transformer efficiency	99.5%	99.5%
Pump Efficiency[3]	N/A	90%
Scheduled and Unscheduled Outage	4%	4%
Station Usage	50 kW	50 kW
MOL (m)	1,114	1,114
Daily Generation/Pumping Profile	15 hrs	15 hrs
Yearly Generation Profile	November 1st through May 15th	November 1st through May 15th
Energy output estimate	At POI	At POI

Note 1: A preliminary turbine efficiency is assumed to be a flat 90%. This will be refined when the models are refined and the turbine and generator solution for the project is selected.
Note 2: Assumed from the point of interconnection ("POI") to the switchyard.
Note 3: Preliminary assumption of 90% until a final pump solution is determined.

5.2 Conventional Storage Scheme

The conventional storage scheme assumes the project would regulate the flow of the Moon Lake drainage area of 57.4 km^2 (MAD = 0.79 m^3/s). The dam height was optimized to:

- Contain most of the summer flows in the reservoir while spilling excess water for 4 years out of 45-year hydrology string,
- Use all the storage water for generation while drawing down to MOL only 1 year out of the 45-year hydrology string.

The estimated FSL of the project is 1,121 m and its gross head is 407.8 m. The design flow is assumed at 2.2 m^3/s.

5.3 Pumped Storage Scheme

The Yukon energy load and surplus energy profile forecast was provided by YEC for years 2022, 2028, 2029 and 2030 as shown in **Table 12** below. The available energy for pumping includes surplus hydro (Whitehorse spill) and wind generation. The diesel generation to be displaced represents the load "shortfall" that is forecast to be generated with thermal generation sources (diesel or the LNG system in Whitehorse). This is effectively the target energy that winter generation at Moon Lake could serve over time.

Table 12: Yukon Energy Forecast

Year	Surplus Energy Available for Pumping (MWh)	Diesel Generation to be Displaced (MWh)
2022	47,939	23,754
2028	39,183	36,360
2029	34,789	45,878
2030	30,946	56,308

As can be noted, over time, the system load increases, which both reduces the available surplus for available for pumping and increases the load that would be served by Moon Lake.

After discussions with YEC, it was concluded to size a project that reflected the surplus available in 2022 based on the assumption that incremental renewable generation resources could be added to the system which the PSH project at Moon Lake could support.

In order to model the project's performance from week to week, the forecast weekly distribution of surplus energy, including that estimated from potential wind generation resources was applied to the model. This distribution, as provided by YEC, is shown in **Table 13**.

Table 13: Surplus Energy Available for Pumping

Yearly Generation /Pumping Profile			
Week	**Surplus Energy with Wind (MWh)**	**Week**	**Surplus Energy with Wind (MWh)**
20	389	33	2912
21	701	34	2501
22	1190	35	2476
23	1544	36	1814
24	1860	37	1944
25	2194	38	1913
26	2346	39	1915
27	2525	40	2007
28	2840	41	1632
29	3094	42	726
30	3095	43	215
31	3015	44	74
32	3017	**TOTAL**	**47,939**

The pumped storage scheme assumes the project regulates the flow of the Moon Lake drainage area of 57.4 km^2 (MAD=0.79 m^3/s) in addition to pumped flow. The assumption was made that the desired scheme would be to store during the weeks where surplus energy for pumping is available (i.e., week 20 to 44) and generate during the other weeks (i.e., week 45 to 19).

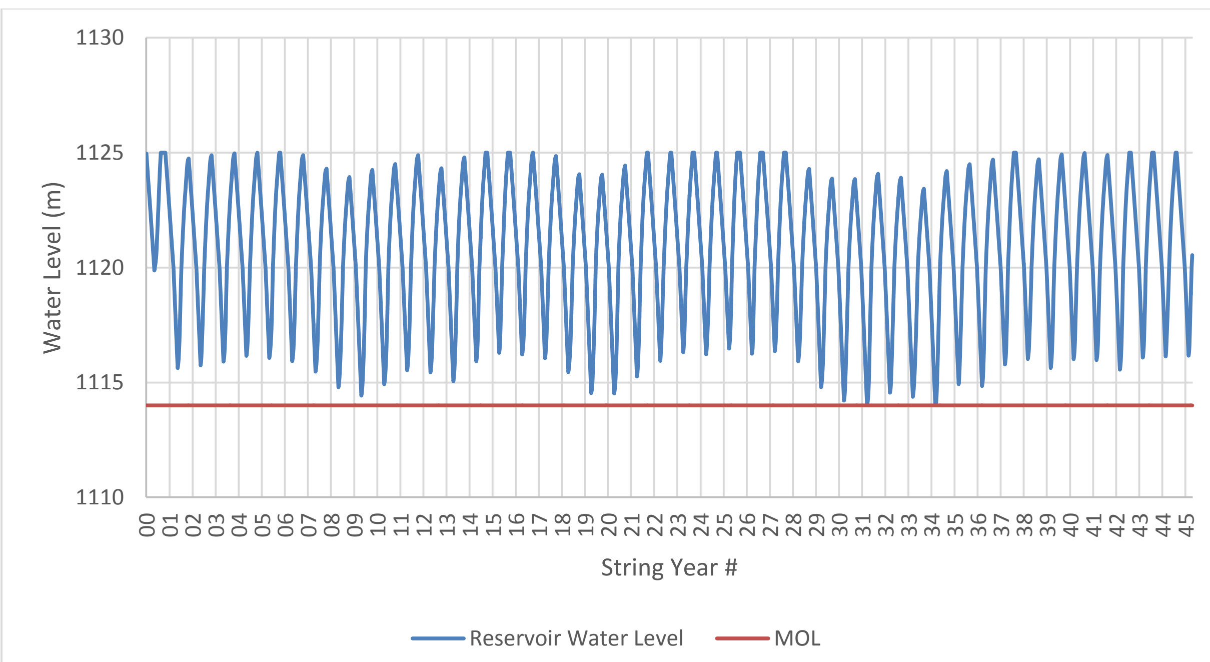
The dam height was optimized to contain most of the summer flows and pumped flows in the reservoir, and use all the storage water for generation while remaining above MOL.

5.3.1 48 GWh Scenario

In the 48 GWh scenario, the available pumping energy is based on the available surplus energy forecast listed in **Table 13**. The estimated FSL of the project is 1,125 m and its gross head is 411.5 m. The generation design flow is assumed at 6 m^3/s and the pumping design flow is estimated at 4.1 m^3/s.

Assuming the available pumping energy remains constant at 48 GWh, the water level at the Project over the 45-year hydrology string is shown in **Figure 12**. Out of the 45-year string, the water at the reservoir is estimated to spill 16 years and draw down to MOL 2 years out of the string.

Figure 12: Pumped Storage – 48GWh Scenario – Water Level



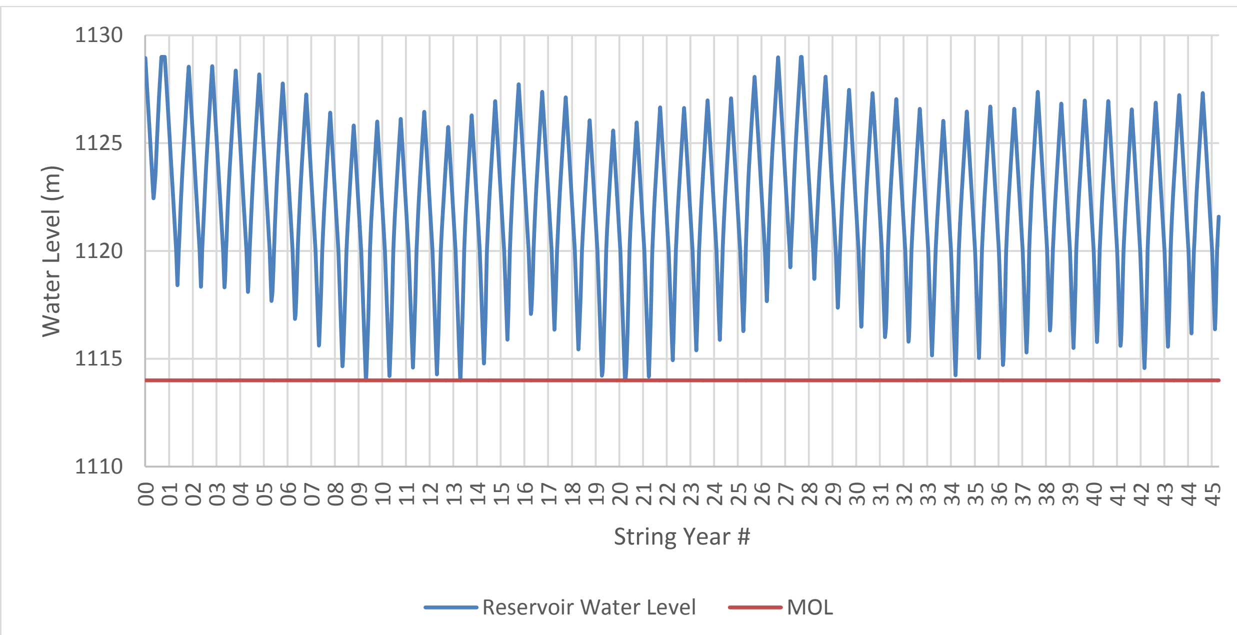
5.3.2 70 GWh Scenario

A second scenario was assessed, which would assume an annual surplus of 70 GWh available for pumping. The intent of this second scenario was to evaluate the potential system performance assuming greater increment generation resources on the YEC system over time. The project described herein does not contemplate the infrastructure required for this larger system. The scenario is described here only as the energy potential of a larger scheme.

In the 70 GWh scenario, the available pumping energy is not based on forecast but was rather suggested by YEC. The weekly available energy for pumping was assumed constant from week 20 to 44 (25 weeks) for a total of 70 GWh over the pumping period (2.8 GWh/week). This scenario illustrates the ability to store and generate additional energy at Moon Lake should additional surplus energy for pumping become available in the future.

The estimated FSL of the project is 1,129 m and its gross head is 415.5 m. The generation design flow is assumed at 7.6 m^3/s and the pumping design flow is estimated at 6.2 m^3/s. Assuming the available pumping energy remains constant at 70 GWh, the water level at the Project over the 45-year hydrology string is shown in **Figure 13**. Out of the 45-year string, the water at the reservoir is estimated to spill 2 years and draw down to MOL 3 years out of the string.

Figure 13: Pumped Storage – 70GWh Scenario – Water Level



5.4 Results

As a conventional storage scheme, the project yields an annual winter energy output of 20 GWh from the natural inflows at Moon Lake with a capacity of 7.5 MW.

As a pumped storage scheme with an annual summer pumping energy of 48 GWh, the project yields an annual winter energy output of 54 GWh for a plant capacity of 20.2 MW. The energy yields at Moon Lake for the different surplus energy at a given year are shown in **Table 14**.

Table 14: Pumped Storage – 48GWh Scenario - Results

Year	Surplus Energy Available for Pumping (GWh)	Diesel Generation to be Displaced (GWh)	Moon Lake Generation (GWh)	Net Diesel Generation (GWh)
2022	48	24	54	-30
2028	39	36	47	-11
2029	35	46	43	3
2030	31	56	40	16

As a pumped storage scheme with an annual summer pumping energy of 70 GWh, the project yields an annual winter energy output of 69 GWh for a plant capacity of 26.1 MW.

In addition, the pumped energy will incur losses through the pumping and the generation process. Overall, the pumped storage scheme roundtrip efficiency is estimated at 70% which includes all losses described in Section 5.1: Inputs and Assumptions.

Average monthly energy yields for the three alternatives are shown in **Table 15**.

Table 15: Monthly Energy Yields (GWh)

Month	Conventional Storage	Pumped Storage (48GWh)	Pumped Storage (70GWh)
Jan	3.3	8.8	11.3
Feb	3.0	8.0	10.2
Mar	3.2	8.7	11.2
Apr	3.0	8.4	10.7
May	1.3	2.7	3.5
Jun	0.0	0.0	0.0
Jul	0.0	0.0	0.0
Aug	0.0	0.0	0.0
Sep	0.0	0.0	0.0
Oct	0.0	0.1	0.2
Nov	3.2	8.1	10.5
Dec	3.3	8.8	11.3
Total Annual	**20**	**54**	**69**

Table 16 summarizes the modeling results for the three alternatives.

Table 16: Moon Lake Energy Yield Summary

Parameters	Conventional Storage	Pumped Storage (48GWh)	Pumped Storage (70GWh)
FSL (m)	1121	1125	1129
MOL (m)	1114	1114	1114
TWL (m)	713.2	713.5	713.5
Gross Head (m)	407.8	411.5	415.5
Generation Flow (m^3/s)	2.2	6.0	7.6
Pumping Flow (m^3/s)	N/A	4.1	6.2
Capacity (MW)	7.5	20.2	26.1
Annual Pumping Energy (GWh)	N/A	48	70
Annual Energy Output (GWh)	**20**	**54**	**69**

6 Project Development in British Columbia

6.1 Project Permitting

Water rights in BC are owned by the Crown and are devolved through water licences on a first in line rights basis. A water licence is appurtenant to a neighbouring land parcel.

The development of a waterpower project in BC requires the proponent to secure a water licence and rights to the land base. A well defined process has evolved over the past 15-years which outlines the expectations of provincial regulators prior to the issuance of a waterpower water licence.

In the instance of Moon Lake, this would require a water licence with a Point of Diversion ("POD") on Moon Creek, at the dam site. A second POD would be required under this licence for Tutshi Lake. Finally, a Storage Licence would be required to permit the creation of the reservoir. This process will be complicated by the Commercial Licence to Occupy land tenure in the Moon Lake catchment.

The dam, penstock and powerhouse would be covered under a long term licence of occupation. The bed of the reservoir would likely be covered under a Permit Over Crown Land.

The process to obtain these primary permits requires the preparation of a Project Development Plan. The Development Plan is a key deliverable and contains a detailed description of the project as well as a summary of environmental and hydrological studies. It is submitted as part of the Water Licence application to FrontCounter BC.

The Development Plan must include:

- Introduction, project purpose and description
- Preliminary or conceptual design drawings
- Description of electrical works, to point of grid interconnection
- Description of: staging areas, access roads, fish passage requirements, intake, penstock, powerhouse and tailrace, switchyard and transmission lines, debris management, area flooded
- Elevation/capacity curves, slope stability
- Geotechnical considerations: site geology and any subsurface exploration
- Seismic considerations
- Flooding and erosion concerns
- Complete legal description of affected lands including new roads and transmission lines
- Water *quantity* information including:
    - Period of time and amount of water required
    - Any reserves or restrictions
    - Climatic information
    - Watershed area, aspect and slope
    - All sources of inflow

- Flow estimation methodologies, hydrographs, mean annual discharge
- Flow duration for streams that are not year-round
- Inflow design flood, design flood water level
- Return period of design flood
- Area-Elevation curves
- Flow estimates of water availability (mass curve and water balance)

- Water *quality* information (e.g. temperature)
- Instream requirements: assessment of fish species, distribution, timing.
- Recreational, aesthetic and cultural uses
- Affected water users downstream
- Construction schedule, methodology and timeframe, including description of how instream work can be done to minimize impacts, engineering review if required
- Downstream consequences of failure, and hazard classification according to Schedule 1 – Dam Safety Regulation
- Operation order or rule, monitoring and record keeping
- Archeological information known, use of environmental monitors
- Labour pool requirements

Site environmental baseline studies are multi-year studies, which are expected to collect baseline data over multiple seasons and several years. Each project is unique and subject to its own data requirements.

After the collection of baseline data and the preparation of the Project Development Plan, a review period of 6-months to a year often passes before the issuance of licence and land tenures.

The Moon Lake project proposes a larger dam with a significant reservoir and would project its zone of impact to Tutshi Lake and below because of the withdrawals of water from that waterbody. For these reasons, we would estimate project permitting costs, for studies, application preparation, process shepherding, and project management to be in the range of $1.0 to $1.5 million.

Because the rated capacity of the Moon Lake Project is less than 50 MW, the project falls below the threshold of review by the Environmental Assessment Office (“EAO”) of the BC Government.

6.2 Development phases

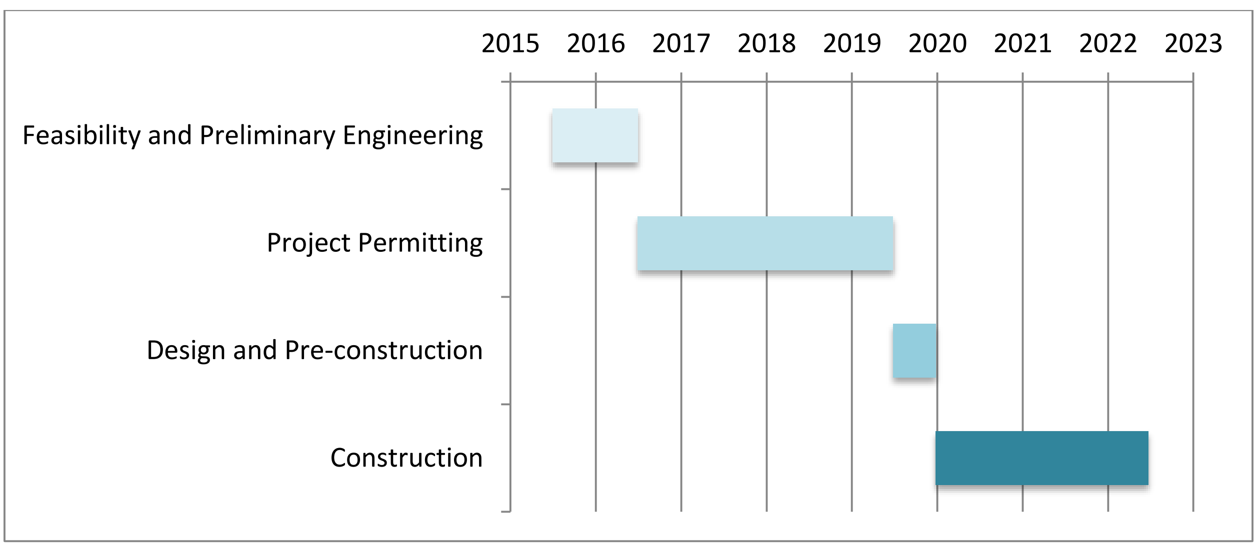
Four phases of development have been assumed for the Project. Below is a brief summary of those phases as well as estimates of project costs that have been assumed for each phase. Those costs have been assumed to be capitalized into the total project cost for the purposes of estimating the LCOE.

The timelines proposed are high level estimates. It is expected that the can be some overlap in the phases – particularly in early stage collection of baseline environmental data. In total, it is expected that, this project, pursued continuously and diligently, would take in the order of 6 years to achieve operations.

A. **Feasibility and Preliminary Engineering** *(Estimated 1 year)* - The purpose of the Feasibility phase is to study the project to a sufficient level of detail to allow for a go/no-go gate review decision to continue investing and begin the permitting phase of development. Work completed in this phase includes refined assessments of available resources (using site specific gauge data), site investigations, updated design and preliminary engineering, capital cost estimates, and financial modeling. A review of existing data, including environmental assessments done to date, is completed in preparation for the commencement of multi-year field studies. *Budget assumed is $200,000.*
B. **Project Permitting** *(Estimated 2.5-3 years)* - Obtain all licenses, tenures, and other material permits required for construction and commissioning of the project. *Budget assumed is $1.5 million.*
C. **Design & Pre-Construction** *(Estimated 6 months)* - The purpose of Design & Pre-Construction is to prepare the execution of project construction. Work completed in this phase includes contractor selection, negotiation and execution of engineering and construction contracts, submitting for and obtaining all required late-stage permits, ensuring all other required agreements are in place, and completing the design of the project. The construction contractor is readied to initiate work and any long-lead time equipment is selected and ordered as required. *Budget assumed is $500,000. This budget is for preliminary engineering only and does not include the cost of final engineering and design of the project, which has been included within the project capital cost estimates.*
D. **Construction** *(Estimated 2.5 years)* – The Construction phase (the most critical phase) covers the project's construction. Additional tasks also fall into this phase, including continued environmental monitoring, and the execution of the environmental management plan.

The project development schedule is shown in **Figure 14**.

Figure 14: Project Development Phases Schedule



7 Cost Estimates

Project costs, which are a fundamental input into estimates of the project's LCOE are comprised of upfront capital costs, and ongoing operation costs.

7.1 Project Capital Costs

A capital cost estimate has been developed for the project which is comprised of capitalized development costs, civil construction costs, water to wire equipment costs, transmission and interconnection costs, and capitalized interest costs from the construction period.

It is important to note that at this stage, no estimate was considered for the following project aspects:

1) First Nation consultation, assessments, studies, agreements, royalty payments etc.
2) Archeological assessments
3) Impact benefit assessments
4) Property tax

7.1.1 Project Development Costs

A high level estimate of project development costs was presented in Section 6. These costs are summarized in **Table 17**.

Table 17: Project Development Costs

Development Phase	Cost Estimate ($ 2015)
Feasibility and Preliminary Engineering	$200,000
Project Permitting	$1,500,000
Design and Pre-construction	$500,000
TOTAL	**$2,200,000**

7.1.2 Civil Construction Costs

Kawa Engineering ("Kawa") was retained to develop a civil capital cost estimate and corresponding bill of quantity.

The estimate was specified as a Class 5 estimate, per the standardized AACE International Cost Estimate Classification System. A Class 5 estimate is intended for concept screening and represents a level of project definition of 0% to 2%. The expected low accuracy ranges from -20% to -50% and the high accuracy ranges from +30% to +100%.[7]

Kawa prepared the cost estimate using a combination of quantity estimates for the large, significant project components such as the dam and penstock etc., and used a parametric relationships for the balance of the plant. A summary of the Kawa cost estimate is presented in **Table 18**.

Table 18: Summary of Civil Capital Costs

Project Component	Cost Estimate ($M 2015)
General Cost[8]	$32.7
Dam (Earthworks, Grouting, Spillway)	$55.9
Diversion	$1.0
Intake	$1.1
Powerhouse Civil	$5.5
Penstock	$43.6
Switchyard – Civil Works	$2.0
Roads	$1.3
Total Civil Works Cost	**$143.1**

The detailed bill of quantity from Kawa is presented in Appendix B: Generating Facility Capital Cost Estimate.

7.1.3 Generating Equipment Costs

The cost estimate for the turbine, generator and associated balance of plant was estimated based on previous delivered equipment for projects in BC. These are summarized in **Table 19**.

Table 19: Summary of Generating Equipment Costs

Project Component	Cost Estimate ($M 2015)
Turbine and Generator	$5.5
Pumps with variable frequency drives	$5.0
Balance of plant	$3.5
Total Generating Equipment Cost	**$14.0**

[7] AACE International Recommended Practice No. 17R-97

[8] General costs include mobilization and demobilization, reservoir clearing, engineering, miscellaneous metals, contractor's insurance, permits, land use and survey.

An inquiry was initiated with equipment supplier, Andritz, who have significant experience in the smaller hydro space as well as with pumped storage equipment. At the time of this report, response was still outstanding.

7.1.4 Transmission Line and Interconnection Costs

The estimated cost for the transmission is $2.3 million and is based on the sub-marine cable cost estimate. The transmission line costs were estimated based on parametric assumptions based on previous similar operating voltage projects in BC, taking into account the voltage and capacity of the line.

The main step-up transformer, disconnects and circuit breakers for the switchyard plant was been assumed to be $500,000 installed.

Transmission and interconnection costs are summarized in **Table 20**.

Table 20: Transmission and Interconnection Cost Estimate

Project Component	Cost ($M)
Transmission Line	$2.3
Switchyard Electrical	$0.5
Total Tx and Interconnection Costs	**$2.8**

7.1.5 Owner's Costs During Construction

Certain costs will be incurred be the owner during the construction period. These include onsite administration and overhead, engaging the Independent Engineer and Independent Environmental Monitor, as required under water licencing regulations, and funding ongoing compliance monitoring during construction.

The estimate of these costs are provided in **Table 21**.

Table 21: Owners Costs During Construction

Project Component	Cost ($M)
Administration and Overhead	$0.5
Land Tenure Surveys	$0.2
Compliance Monitoring	$0.2
Independent Engineer	$0.4
Independent Env. Monitor	$0.8
Total Owners Costs During Construction	**$2.1**

7.2 Capital Cost Summary

The total estimated project capital cost estimate, exclusive of contingency, for the 48 GWh pumped storage scenario is show in **Table 22** below. A project contingency of 20% of capital costs exclusive of owner's costs has been added at this time and interest during construction estimated assuming a 2-year construction term, with 100% debt finance at the blended cost of capital of 5.45%.

Table 22: Project Capital Cost Estimate

Project Component	Cost ($M)
Project Development	$2.2
Civil Construction Costs	$143.1
Generating Equipment Costs	$14.0
Transmission and Interconnection Costs	$2.8
Owners Costs During Construction	$2.1
Total Project Capital Cost	**$164.2**
Contingency	$32.0
IDC	$21.4
Grand Total Project Capital Cost	**$217.6**

For comparison purposes, a high level capital cost estimate for the conventional storage and the 70 GWh pumped storage options was extended from the 48 GWh alternative cost estimate. This was achieved by scaling the quantity estimates and unit costs from the 48 GWh alternative based on dam height, penstock diameter, reservoir size and installed capacity. A summary of the cost estimates for the conventional storage and the two pumped storage options (48 GWh and 70 GWh) is shown in **Table 23**.

Table 23: Project Options Capital Cost Estimate

Project Component	Conventional Storage ($M 2015)	Pumped Storage 48GWh ($M 2015)	Pumped Storage 70GWh ($M 2015)
Project Development	$2.2	$2.2	$2.2
Civil Construction Costs	$105.1	$143.1	$169.1
Generating Equipment Costs	$5.0	$14.0	$22.1
Transmission and Interconnection Costs	$2.8	$2.8	$2.8
Owners Costs During Construction	$2.1	$2.1	$2.1
Total Project Capital Cost	**$117.2**	**$164.2**	**$198.2**
Contingency	$22.6	$32.0	$38.8
IDC	$15.2	$21.4	$25.8
Grand Total Project Capital Cost	**$155.0**	**$217.5**	**$262.9**

7.3 Operating Costs

Project operating costs are categorized into the general operating and maintenance expenses in running and maintaining the plant and indirect and overhead costs associated with plant operations. The O&M expenses arise from labour costs for plant operators, minor spare parts, consumable supplies, and contract labour for irregular maintenance activities. Other direct operating costs comprise water rental and land lease fees to the BC government. Indirect operating costs include overhead and administration costs, insurance etc.

Finally, a fixed annual contribution to a Major Maintenance Reserve Account ("MMRA") is assumed for sustaining capital investments and is intended to account for semi-regular major maintenance items that are expected over the life of the plant.

All costs are stated in $2015.

The general O&M cost is estimated based on an assumed labour pool of 2 full time equivalent operators and an allowance for expenses, consumable supplies and contract labour. It is assumed that operating labour will be staffed by YDC and appropriate shift coverage will be allocated across plants. **The all in cost is estimated to be $400,000**.

An MMRA deposit of $75,000 is assumed to be adequate for covering major maintenance items.

The annual water rental rates associated with power production are estimated based on published rates established by the BC government. As of 2015, rates are assessed for both the installed capacity of the plant and the actual energy generated. Further, there is a rental rate for water storage. Land costs have been estimated based on published rates. The rates and project costs are summarized in **Table 24**.

Table 24: Provincial Resource Fees

Resource	Rate ($2015)	Project Cost $2015
Water Rental – Capacity Charge	$4.334 / kW	$90,000
Water Rental – Energy Charge	$1.301 / kWh	$70,000[9]
Water Rental – Storage Charge	$0.01 / 1000 m^3	$1,000
Permit over Crown Land - Dam	$120 / ha.	$1,000
Permit over Crown Land – Flooded Reservoir	$7.50 / ha.	$5,000
Land Lease – Powerhouse	Based on land value	$500
ROW - Penstock	Based on land value	$500
ROW – Transmission Line	Based on land value	$500
Total Resource Fees – Operating Cost		**$168,500**

[9] This assumes a plant output of 24 GWh, which is the forecasted energy deficit for 2022. The cost is variable from year to year depending on the amount of energy actually generated at the plant.

Management, administration and overhead cost is assumed to be $250,000/year. Insurance, using a premium based on $3 per $1,000 of constructed cost, is assumed at $500,000/year. Finally, it is assumed that the project will attract property tax at the assumed rural mill rate of $2.87 per $1000 of assessed value, which equals $500,000. The resulting estimated annual operating cost associated with the project is summarized in **Table 25**.

Table 25: Project Annual Operating Costs

Component	Cost ($2015)
General O&M	$400,000
Major Maintenance Allowance	$75,000
Provincial Resource Fees	$168,500
Management, Administration and Overhead	$250,000
Insurance	$500,000
Property Tax	$500,000
Total Annual Operating Cost	**$1,893,500**

8 Financial Modeling

8.1 LCOE

In the 2011-2030 Resource Plan YEC defined the LCOE as:

> *"LCOE indicates on a consistent and comparable basis each option's overall costs per kWh. It includes capital and operating costs and, where specified, any related transmission, storage or capacity costs. This cost is subject to ongoing annual inflation for each subsequent year of operation in order to assess costs over the option's economic life."*[10]

The LCOE is calculated as follow:

$$LCOE = \frac{Present\ Value\ of\ Costs}{Present\ Value\ of\ Energy\ Output}$$

The Project LCOE was calculated for the 48 GWh pumped storage scenario and is described in the following sections.

8.2 Assumptions

The following economic assumptions were used to calculate the Project LCOE:

1) Blended cost of capital: 5.45%;
2) Inflation: 2%;
3) Real Discount Rate: 3.38% based on blended cost of capital and inflation rate from the RFP. LCOE discounts both costs (numerator) and energy (denominator) using the Real Discount Rate; and
4) Life Span: 65 years.

8.3 Full Utilization LCOE

The full utilization LCOE assumes constant pumping energy and constant load profile. It implies that the Yukon will install new generation (wind or hydro) to maintain the amount of available low cost summer energy for pumping as the energy load increases. It also implies that the full energy output at Moon Lake is generated every year for the life of the project and that all energy is consumed.

The project Full Utilization LCOE is $0.189/kWh.

[10] Source Details: Yukon Energy Corporation, "20-Year Resource Plan: 2011-2030", December 2011, p. 67

8.4 LCOE Sensitivity Analysis

The LCOE is directly related to the actual usable energy from the project. Because the YEC grid is islanded from other load jurisdictions, the utilization of the Moon Lake project is dependent on both the surplus energy from the YEC system that is available energy for pumping, as well as the system load that can ultimately be served from the reciprocal generation. Further, the surplus energy and load balance will change over time, depending of the planning forecast of the system.

The LCOE estimate was based on a 65-year project life, which, while appropriate for a long-lived asset such as a hydroelectric plant, is beyond the planning horizon of YEC. In order to estimate the sensitivity of the Moon Lake project to differing scenarios of surplus energy and load, a sensitivity analysis was performed for the Project LCOE by simply adjusting plant capacity factors ranging from 60% to 100% as shown in **Table 26**.

The capacity factor represents the plant utilization over the generation period. The 100% capacity factor scenario is the base case scenario for which the energy yield were estimated in this report.

Table 26: LCOE Sensitivity Analysis

Capacity Factor	Full Utilization Generation (GWh)	NPE (GWh)	NPV ($M 2015)	LCOE (S/kWh)
100%	54.0	1,412.8	267.5	0.189
90%	48.6	1,271.5	267.3	0.210
80%	43.2	1,130.2	267.2	0.236
70%	37.8	989.0	267.0	0.270
60%	32.4	847.7	266.8	0.315

9 Results and Recommendations

9.1 Results

As shown in **Table 27**, as a conventional storage scheme, the Project yields 20 GWh of winter energy. As a pumped storage scheme, the Project yields 54 GWh of winter energy with 48 GWh of available pumping energy, or 69 GWh with 70 GWh of available pumping energy.

Table 27: Moon Lake Energy Yield Summary

Parameters	Conventional Storage	Pumped Storage (48 GWh)	Pumped Storage (70 GWh)
FSL (m)	1,121	1,125	1,129
MOL (m)	1,114	1,114	1,114
TWL (m)	713.2	713.5	713.5
Gross Head (m)	407.8	411.5	415.5
Generation Flow (m^3/s)	2.2	6.0	7.6
Pumping Flow (m^3/s)	N/A	4.1	6.2
Capacity (MW)	7.5	20.2	26.1
Annual Pumping Energy (GWh)	N/A	48	70
Annual Energy Output (GWh)	**20**	**54**	**69**

A breakdown for estimated cost estimate exclusive of contingency for the 48 GWh pumped storage scenario is show in **Table 28**.

Table 28: Project Capital Cost Estimate

Project Component	Cost ($M)
Project Development	$2.2
Civil Construction Costs	$143.1
Generating Equipment Costs	$14.0
Transmission and Interconnection Costs	$2.8
Owners Costs During Construction	$2.1
Total Project Capital Cost	**$164.2**
Contingency	$32.0
IDC	$21.4
Grand Total Project Capital Cost	**217.6**

The estimated yearly cost associated with the projects are shown in **Table 29**.

Table 29: Project Annual Operating Costs

Component	Cost ($2015)
General O&M	$400,000
Major Maintenance Allowance	$75,000
Provincial Resource Fees	$168,500
Management, Administration and Overhead	$250,000
Insurance	$500,000
Property Tax	$500,000
Total Annual Operating Cost	**$1,893,500**

The project full utilization LCOE is $0.189/kWh.

9.2 Recommendations

Several existing rights have been identified at the project site and its vicinity. A detailed investigation of the current and future existing rights is recommended to identify potential development barriers.

If a decision is made to study the project further, first and foremost, it is strongly recommended that YEC prepare and submit a Water Licence Application from Front Counter BC to secure first-in-line rights to the water. Subsequent to this, the following steps, field studies and data collection programs are recommended:

1) Prepare a submit a **water licence application** to Front Counter BC so as to secure first-in-line water rights to the project ahead of other potential claimants. British Columbia recognizes the rights to water on a first come, first serve basis. Several existing rights have been identified at the project site and its vicinity. Prior to advancing the project further, a detailed investigation of the current and future existing rights is recommended to identify potential development barriers.
2) Project preliminary engineering and design can be further advanced with greater precision topography, obtained with a **LIDAR survey**. This survey is recommended to refine the design and quantity cost estimate. The LIDAR survey area should comprise the dam site, the penstock route, suggested at 200 m each side of the proposed penstock alignment, and the powerhouse site. The estimated area of study is 3.5 km^2 (See **Figure 15**).
3) A **geotechnical investigation** program is recommended to assess the foundation conditions of the dam and powerhouse as well potential anchor block locations at select major bends along the penstock alignment (See **Figure 16**).

   During early stage project definition and development, seismic refraction lines present a cost effective alternative to estimate overburden thickness without incurring the cost of mobilization of drilling rigs across Tutshi Lake and into the upper Moon Lake watershed. Two seismic lines are recommended at the dam site: one along the dam axis and one perpendicular to the dam axis at the maximum dam height. Two lines are suggested along the penstock near route and two at the powerhouse. As project certainty is achieved, greater expenditure for project definition is justified and the results from the seismic analysis can be confirmed with boreholes.

Boreholes are indicated at the powerhouse location because of the importance of better characterizing the construction excavation conditions adjacent to Tutshi Lake as well as characterizing the rock quality at the powerhouse. Further, boreholes are an important along the dam foundation, not only to characterize the depth to bedrock, but to also investigate the rock quality and permeability in order to plan dam foundation treatment. As such, the dam boreholes should extend into bedrock to a depth commensurate with the dam height and include in situ permeability testing of the rock. Location of the boreholes should be determined once greater resolution mapping becomes available.

Finally, a dedicated site investigation to secure and confirm a source pit for the material for construction or the dam is recommended to be included with any geotechnical programme.

Figure 15: Recommended LiDAR Survey Area

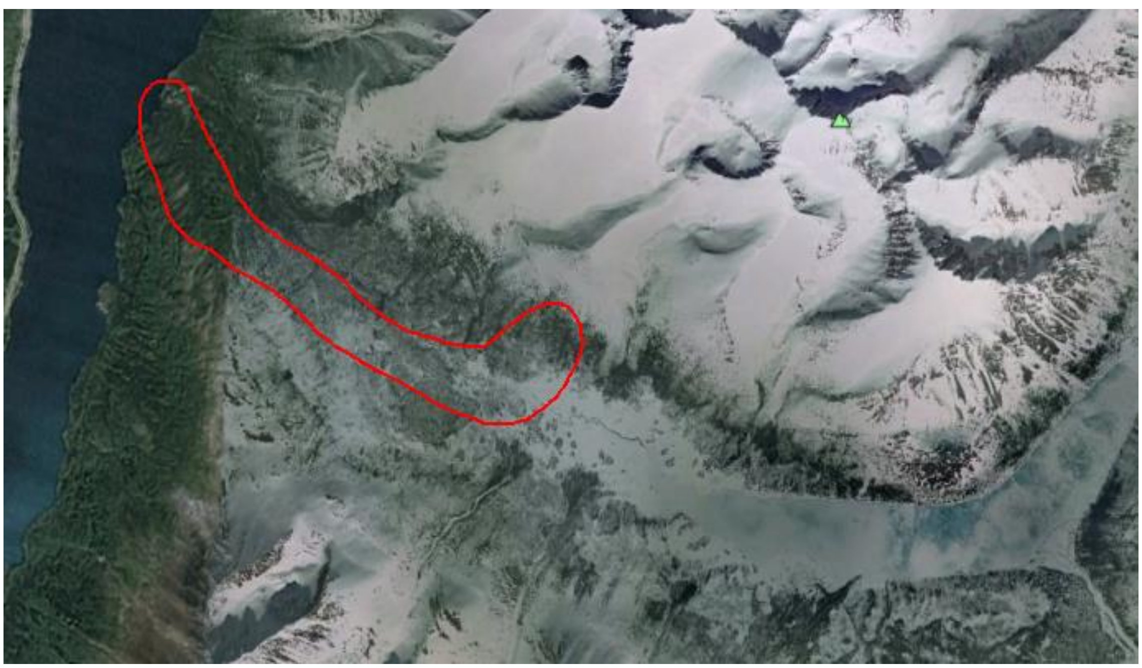
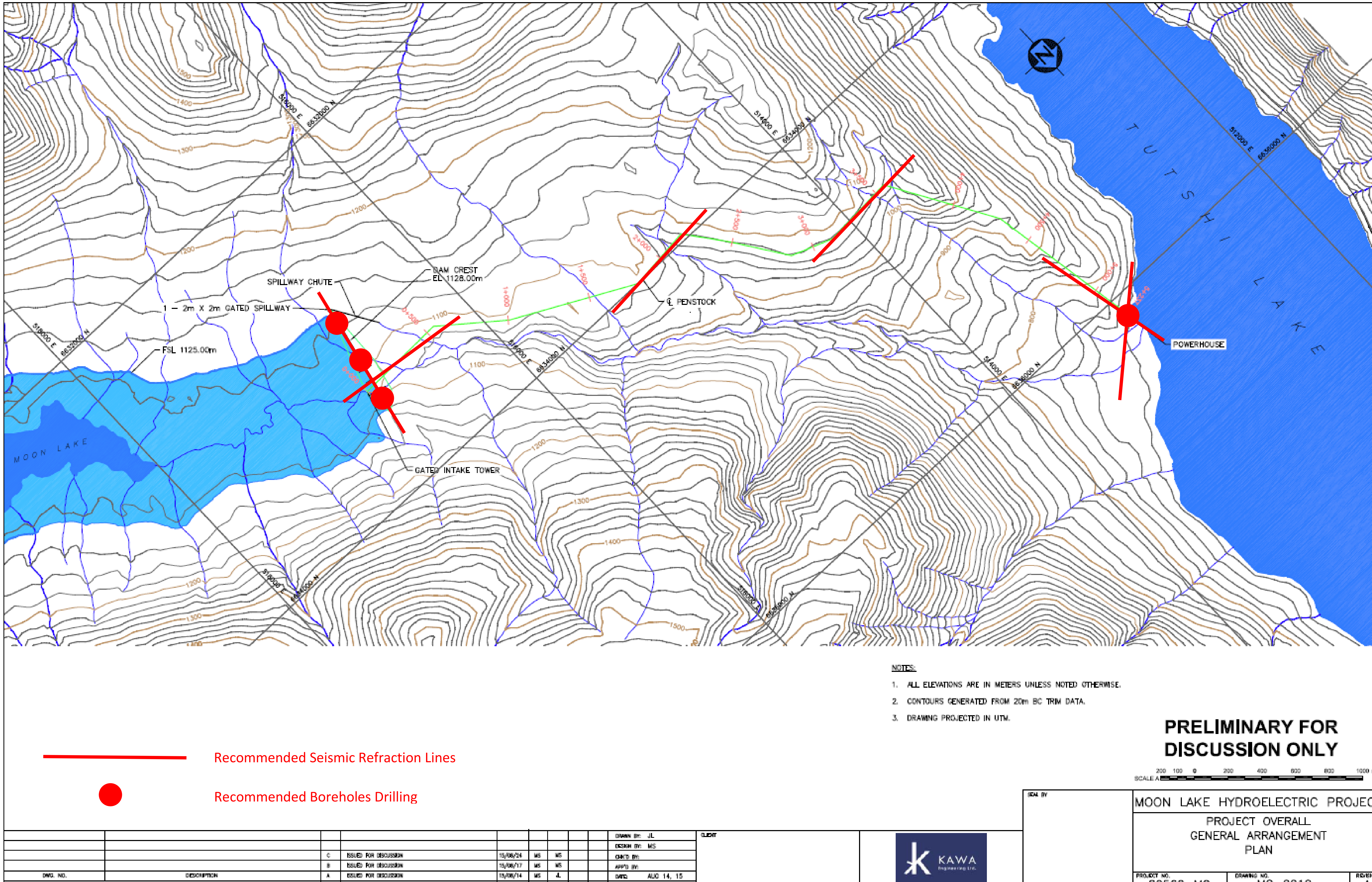


Figure 16: Recommended Seismic Refraction Line and Boreholes Drilling



Appendix A: Geotechnical Memo

A geotechnical memo about the observation and conclusion from previous studies review and the June 24th site visit is included in the section.

SLR Consulting (Canada) Ltd.
200-1620 West 8th Avenue
Vancouver, BC V6J 1V4

Tel: 604-738-2500
Fax: 604-738-2508

Memorandum

To:	Michael Potyok	**From:**	Stephen Morison, M.Sc., P.Geol. Irwin Wislesky, P.Eng.
Company:	MIDGARD Consulting Inc.		
cc:		**Date:**	December 18, 2015
Subject:	***FIELD SITE REPORT FOR THE PROPOSED MOON LAKE HYDRO PROJECT***		

1.0 INTRODUCTION

Midgard Consulting Inc. (Midgard) retained SLR Consulting (Canada) Ltd. (SLR) to assist them in providing a geotechnical/geological assessment with regards to design and construction of an earth fill dam near the outlet of Moon Lake. Moon Lake is located about 100 km south of Whitehorse in British Columbia, just south of the Yukon border.

The purpose of constructing a dam across the outlet of Moon Lake is to provide additional water storage capacity within the Moon Lake Basin for winter hydro-power production. The intention is to pump water from Tutshi Lake into Moon Lake during the summer months when there is excess water and store it there until the winter when water availability for hydro-power is limited and demand is high.

SLR's scope of work for this project included a review of existing documentation and participation in a reconnaissance site visit by helicopter. The site visit took place on June 24, 2015 along with Michael Potyok and Anna Le of Midgard and Glen Ichikawa of Kawa Engineering. The information provided for review included the following documents:

- KGS Group draft report to Yukon Energy on the Assessment of Potential Hydroelectric Sites, Conceptual Study, dated February 2008.
- KGS Group Draft Memorandum to Gord McPhail Re: Summary of site inspection and Terrain Assessment for the Moon Lake Site, Northern British Columbia, dated February 14, 2008.
- Klohn-Crippen report to Yukon Electrical Company Ltd. titled, "Moon Lake Hydroelectric Project, Layout Report (Report No. KCCL-106, dated January 1992.
- Moon and Tutshi Hydroelectric Projects, General Arrangement Plan, by HDR for Peter Kiewit Infrastructure Co., October 31, 2011, DWG 172193-G-0001 Revision A.
- Moon and Tutshi Hydroelectric Projects, Earthworks quantities, by HDR for Yukon Energy, October 31, 2011

2.0 SITE VISIT

Prior to the site visit, the information provided by Midgard was reviewed to gain a general appreciation of the site conditions and to plan the field visit. There are no roads to the site, thus the site was accessed by helicopter from Whitehorse. The field visit included:

- Aerial tour of Moon Lake and the surrounding catchment;
- Aerial view along the outlet channel from Moon Lake down to Tutshi Lake;
- Aerial view in the likely area for the proposed powerhouse near the shore of Tutshi Lake, by the outflow from Moon Lake;
- Aerial view along Tutshi Lake and the outlet stream into Tagish Lake and one stop on land downstream of Moon Lake where extensive bedrock outcropping was observed; and
- Two landings downstream of Moon Lake to traverse and view ground conditions at potential dam locations and one upstream of Moon Lake along one of the tributaries that flow into Moon Lake.

During the site visit several photographs were taken and approximate GPS coordinates/ elevations were recorded to mark key features and elevations.

2.1 Visual Site Description

The area can generally be characterized as mountainous with glaciated valleys having a variety of glacially related landforms over bedrock. Moon Lake is located within a broad U-shaped valley that is flanked by high elevation mountainous terrain. The area of the outflow channel from Moon Lake and several hundred metres downstream appears to be dominated by a wetlands with a thicker surface organic layer that may have been an infilled section of the lake basin composed of alluvial material. Bedrock outcrops are evident a few hundred metres downstream of Moon Lake becoming more frequent down gradient from Moon Lake. It appears that the stream to Tutshi Lake is generally bedrock controlled. Glaciofluvial features also appear to be evident down the valley from Moon Lake to Tutshi Lake where there are high banks of exposed gravelly sediments. This material is a possible source of both fine and course dam construction fill (to be verified).

2.2 Possible Dam Locations

Three possible locations have been previously identified by others for a dam near the outlet of Moon Lake. One is at the lake outlet; a second is located about 800m downstream and; a third is located about 1300m downstream in an area where bedrock outcropping is predominant. During this site reconnaissance, the downstream area was flown over to view the outcrops and general ground conditions. Scattered bedrock outcroppings were observed a few hundred metres downstream of the Moon Lake outlet along with the occasional overburden knoll rising a few metres above the generally flat terrain. From these observations it appears that bedrock is generally located at shallow depth but could be quite variable and is likely at greater depth near the lake. The stream flow near Moon Lake (within 1 km) is shallow and meandering, with the stream bottom covered in gravel, indicating possible shallow bedrock. The quality of the bedrock was difficult to assess, however bedrock was highly fractured where exposed in the stream.

Several considerations must be evaluated prior to selecting the optimum location for the dam and these include the following:

- The height of the required dam will be greater the farther it is from Moon Lake because of an increase in the catchment area and the drop off in the ground level.
- The elevation requirement for the dam and ultimate lake level may be lower, the farther the dam is from Moon Lake because of the greater area available for storage.
- Additional streams can enter Moon Lake and add to the catchment the further downstream the dam is located (this may not be important if pumping water into Moon Lake during the summer is considered free).
- If bedrock is relatively shallow, the depth of cut-off required may not be significantly different between locations suggesting the location providing the shortest and least height (least fill volume) might be the best (from a strictly geotechnical perspective).
- The location for the dam should take into consideration a spillway within bedrock at one of the abutments.

From the site visit and review of the data, the preliminary recommendation for the dam location is in the area near the first bedrock exposure downstream of the lake (see photo below). This site was selected because of bedrock outcrops and an apparent rise in the ground level on both sides of the stream which could minimize excavation as well as fill materials required to construct the dam. In addition, the ground level has not dropped off significantly at this point from Moon Lake.

Proposed Dam Location (red line). Easterly view towards Moon Lake.

2.3 Geological Hazards and Construction Considerations

A detailed assessment of geologic hazards has not been carried out for this study, however during the field investigation no major hazards were observed. However, given the location of the Moon Lake site and the high elevation setting, possible effects from earthquake must be considered in the design of the dam including foundation stability and the possible consequences of a failure. This would require a surface and subsurface assessment of the bedrock including lithology, faulting, depths and subsurface profiles, distribution, thickness and genesis of surficial geological landforms, permafrost characteristics and other features such as organic landforms. There are other factors that will need to be integrated into the planning of this facility including local climate characteristics such as snow depth, hydrology, storm events and other natural events.

Construction in this area will likely involve issues such as excavation in discontinuous permafrost, a short construction season, frozen overburden that must be thawed prior to use as fill, bedrock grouting where frozen rock and possible ice lenses occur, dewatering, water diversion and restricted access for equipment and supplies. Clear logistics planning and scheduling will be required to facilitate construction of the dam and ancillary features.

3.0 CONCLUSIONS AND RECOMMENDATIONS

This assessment has been based primarily on a short aerial field tour and review of reconnaissance level information. Of primary importance is the need for better ground survey data since the contour accuracy from existing topographic maps that are available are not sufficient to accurately establish a location, length and volume of the dam. Once this has been made available, several seismic lines could be investigated to establish depth of bedrock along preferred locations. This could be followed by a drilling investigation to confirm overburden depths and the bedrock profile and condition along the dam alignment, as well as investigate possible borrow materials for dam construction.

4.0 CLOSURE

SLR trusts that this report suitably provides the preliminary site assessment requested by Midgard. Please contact the undersigned to discuss any of the issues raised in this document or your needs with respect to the next phase of this project. It has been a pleasure working with you on this most interesting project and hope to be of continued service in the near future.

Yours very truly,

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Appendix B: Generating Facility Capital Cost Estimate

The detailed cost estimate for the dam, intake, spillway, penstock, switchyard, powerhouse and appurtenances is included in this section.

MIDGARD CONSULTING INC.

MOON LAKE PROJECT

SCHEDULE OF QUANTITIES
DATE: 09/21/2015

REVISION: B

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	NOTES
1000	**GENERAL AND MISCELLANEOUS**					
1001	MOBILIZATION & DEMOBILIZATION	% of total	1	$ 11,000,000.00	$ 11,000,000	ASSUMED 10% OF SUBTOTAL, INCLUDES BARGE LANDING AND CAMP
1002	RESERVOIR CLEARING AND GRUBBING	m^2	3,500,000	$ 1.00	$ 3,500,000	LAKE AREA PROVIDED AS 3.46 km^2
1003	ENGINEERING SERVICES FOR DETAILED DESIGN AND CONSTRUCTION SUPERVISION	% of total	1	$ 8,800,000.00	$ 8,800,000	ASSUMED 8% OF SUBTOTAL
1004	FISH LADDER AND MISCELLANEOUS METALS (RAILINGS, LADDERS ETC.)	% of total	1	$ 5,600,000.00	$ 5,600,000	ASSUMED DENIL TYPE FISH LADDER
1005	CONTRACTORS INSURANCE	% of total	1	$ 440,000.00	$ 440,000	ASSUMED 0.4% OF SUBTOTAL
1006	PERMITS	% of total	1	$ 2,800,000.00	$ 2,800,000	ASSUMED 2.5% OF SUBTOTAL
1007	SURVEYING	% of total	1	$ 550,000.00	$ 550,000	ASSUMED 0.5% OF SUBTOTAL
1008	PERMINANT ACCESS ROAD	km	8.6	$ 150,000.00	$ 1,290,000	ASSUMED TO GENERALLY FOLLOW PENSTOCK ROUTE
2000	**DAM STRUCTURE COMPONENTS**					
2100	**DAM EARTHWORKS**					
2101	DAM SITE CLEARING AND GRUBBING	m^2	130,000	$ 1.50	$ 195,000	INCLUDES AREA REQUIRED FOR DAM, COFFER DAMS, AND DIVERSION SYSTEM.
2102	EXCAVATION - ROCK	m^3	58,000	$ 48.00	$ 2,784,000	
2103	EXCAVATION - SOIL MATERIALS	m^3	180,000	$ 9.00	$ 1,620,000	
2104	EMBANKMENT FILL SUPPLY, HAULING AND COMPACTED	m^3	650,000	$ 45.00	$ 29,250,000	
2105	FILTER SAND SUPPLY, HAULING AND COMPACTION	m^3	16,000	$ 54.00	$ 864,000	
2106	GRAVEL FILTER SUPPLY, HAULING AND COMPACTION	m^3	170,000	$ 30.00	$ 5,100,000	
2107	RIPRAP SUPPLY, HAULING AND PLACED	m^3	58,000	$ 25.00	$ 1,450,000	INCLUDES UPSTREAM FACE OF DAM AND PERIMETER AT BASE OF DAM
2200	**DAM GROUTING**					
2201	FOUNDATION TREATMENT	LUMP SUM	1	$ 13,000,000.00	$ 13,000,000	APPROXIMATED AS 30% OF DAM EARTHWORKS AND CONCRETE, INCLUDES GROUTING AND DRAIN HOLES
2300	**SPILLWAY**					
2301	CLEARING AND GRUBBING	m^2	900	$ 0.60	$ 540	
2302	EXCAVATION - ROCK	m^3	1,200	$ 48.00	$ 57,600	
2303	EXCAVATION - SOIL MATERIALS	m^3	1,200	$ 9.00	$ 10,800	
2304	CONCRETE	m^3	580	$ 2,500.00	$ 1,450,000	INCLUDING FORMWORK AND REBAR
2305	GATES	LUMP SUM	1	$ 160,000.00	$ 160,000	INCLUDES GUIDES AND HOIST, TRANSPORTATION, INSTALL
3000	**DIVERSION SYSTEM / SLUICEWAY / LOW LEVEL OUTLET**					
3001	GATE	LUMP SUM	1	$ 600,000.00	$ 600,000	COST INCLUDES TWO GATES TO BE USED FOR DIVERSION AND AS SLUICEWAY
3002	CONCRETE	m^3	110	$ 2,500.00	$ 275,000	INCLUDING FORMWORK AND REBAR
3003	PIPE WYE	LUMP SUM	1	$ 100,000.00	$ 100,000	
3004	PIPE TEE	LUMP SUM	0	$ -	$ -	INCLUDED IN INTAKE TOWER QUANTITIES
4000	**INTAKE & RELATED WORKS**					
4001	EXCAVATION - ROCK	m^3	0	$ 48.00	$ -	INCLUDED IN DAM QUANTITIES
4002	EXCAVATION - SOIL MATERIALS	m^3	0	$ 9.00	$ -	INCLUDED IN DAM QUANTITIES
4003	HEAD GATES	LUMP SUM	1	$ 300,000.00	$ 300,000	INCLUDES GUIDES AND HOIST, TRANSPORTATION, INSTALL
4004	TRASHRACKS	LUMP SUM	1	$ 96,000.00	$ 96,000	INCLUDES SUPPLY AND INSTALL
4005	TOWER AND BRIDGE	LUMP SUM	1	$ 640,000.00	$ 640,000	INCLUDES SUPPLY AND INSTALL
4006	MISC. SYSTEMS (RACK CLEANER, CONTROL SYSTEMS, CORROSION PROTECTION)	LUMP SUM	1	$ 40,000.00	$ 40,000	APPROXIMATED AS 10% OF TOTAL INTAKE WORKS
5000	**POWER HOUSE WITH AUXILIARY EQUIPMENT AND TAILRACE**					
5001	EXCAVATION - ROCK	m^3	5,500	$ 48.00	$ 264,000	ASSUME 25% SOIL CUT, 75% ROCK CUT, INCLUDES TAILRACE
5002	EXCAVATION - SOIL MATERIALS	m^3	1,900	$ 9.00	$ 17,100	ASSUME 25% SOIL CUT, 75% ROCK CUT, INCLUDES TAILRACE
5003	CONCRETE	m^3	1,100	$ 2,500.00	$ 2,750,000	ASSUMED SOFT ROCK FOUNDATION
5004	SUPERSTRUCTURE (STEEL STRUCTURE, WALLS, AND ROOFING)	LUMP SUM	1	$ 2,500,000.00	$ 2,500,000	ASSUMED PREENGINEERED BUILDING
5005	TURBINE, TIV AND GENERATOR	LUMP SUM	1	$ -	$ -	PRICE PROVIDED BY OTHERS
5006	PUMP	LUMP SUM	1	$ -	$ -	PRICE PROVIDED BY OTHERS
5007	BALANCE OF PLANT	LUMP SUM	1	$ -	$ -	40% OF TURBINE, TIV AND GENERATOR
5008	OTHER (CRANE, HVAC, WATER SYSTEMS, ROCK ANCHORS, MISC METALS) AS % OF PH COSTS	LUMP SUM	1	$ -	$ -	5% OF TURBINE, TIV AND GENERATOR
6000	**PENSTOCK**					
6001	PENSTOCK	TONNES	2,000	$ 12,000.00	$ 24,000,000	INCLUDES TRANSPORTATION, WELDING, COATING

MIDGARD CONSULTING INC.

MOON LAKE PROJECT

SCHEDULE OF QUANTITIES
DATE: 09/21/2015
REVISION: B

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	NOTES
6002	EXCAVATION - ROCK	m³	200,000	$ 48.00	$ 9,600,000	ASSUME 75% SOIL CUT, 25% ROCK CUT
6003	EXCAVATION - SOIL MATERIALS	m³	64,000	$ 9.00	$ 576,000	ASSUME 75% SOIL CUT, 25% ROCK CUT
6004	BACKFILL	m³	120,000	$ 24.00	$ 2,880,000	PRICE IS BASED ON WEIGHTED AVERAGE OF DIFFERENT MATERIALS
6005	ANCHOR BLOCK CONCRETE	m³	2,500	$ 2,500.00	$ 6,250,000	
6006	SURGE SHAFT	TONNES	24	$ 12,000.00	$ 288,000	
7000	**SWITCHYARD**					
7001	SWITCHYARD	LUMP SUM	1	$ 2,000,000.00	$ 2,000,000	ASSUMED $100,000/MW
	SUBTOTAL				$ 110,000,000	INCLUDES ALL ITEMS EXCEPT THOSE IN SECTION 1000
	TOTAL CONSTRUCTION COST				**$ 150,000,000**	