Appendix 5.6
Mayo Hydro Future Facility Options Report
(KGS 2016)

Mayo Hydro (MH0) Future Facility Options
Concept Design Report

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Concept Design Report

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EXECUTIVE SUMMARY

This concept design report assesses four options for the future of the Mayo Hydro (MH0) facility. It presents a conceptual design, cost estimates and an economic assessment of each option. The four options considered are:

1. Option #1 – Replace the Mayo Hydro station.
2. Option #2 – Refurbish the Mayo Hydro station.
3. Option #3 – Remove the facility and return the site to a near greenfield condition.
4. Option #4 – Make safe and abandon in situ.

It is expected that, given appropriate maintenance and overhauls, Options 1 and 2 would provide 65 years or move of plant life.

The total present value was compared for all four options and found that Option 2 was the most economical with a total present value of $10,000,000 and a levelized cost of energy of $0.15/kWhr. Option 1 had the next highest total present value of $6,600,000 and a levelized cost of energy of $0.17/kWhr. These were followed by Option 4 and then Option 3 which had net present values of $2,950,000 and $1,250,000, respectively.

A 7.6 m/s design capacity for Option 1 and Option 2 was selected based on a combination of the minimum flow requirements of the Mayo Hydro tailrace (as per the water license), and maximum flows allowed while both Mayo B Hydro units are operating. Design capacities using higher flows were not financially attractive because they would result in very little additional energy and the additional capacity would only be usable when at least one of the Mayo B units is forced off-line, which occurs for a limited number of hours throughout a typical year.

Option 1 entails the replacement of the hydro facility, retaining the foundations and select embedded parts. It would provide one new turbine and generator unit, powerhouse, balance of plant systems, support systems, control room, powerhouse crane and surge tank. This option would include geotechnical work to stabilize slopes, and make repairs to the access road and tailrace.

Option 2 involves the refurbishment of the existing facility, retaining the foundations, embedded parts, powerhouse superstructure and the embedded spiral case, stay ring and discharge cone of the Unit 2 turbine. It would provide one new generator, new turbine components, other than those mentioned above, a new turbine inlet valve (TIV), balance of plant systems, support systems, control room and surge tank. Repairs/upgrades to the existing powerhouse superstructure and modernization of the crane were included. This option would include geotechnical work to stabilize slopes, and repair the roads and the tailrace.

Option 3 entails the complete demolition of the powerhouse (excluding the foundation) and the surge tank. It includes permanently plugging the tunnel upstream of the surge tank take-off and backfilling the powerhouse foundation and tailrace to return the site to a near greenfield condition.

Option 4 will abandon the powerhouse in place. The facility would be made safe for abandonment, the tunnel would be permanently plugged upstream of the surge tank, and the tailrace would be backfilled.

Complete cost estimates were prepared for each option and included all costs and a 30% contingency to account for unknowns given the level of design. An economic assessment was performed using a 65 year facility life span, 5.45% (nominal) weighted average cost of capital and 2% inflation for computing present value. Assumptions were made for the operating and maintenance cost, the capital expenditures cost, benefit of an increase in capacity and the benefit of an increase in annual energy production. Option 3 and 4 were assumed to be operational for an additional 10 years prior to removing the facility from service.

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1.0 INTRODUCTION

Yukon Energy Corporation (YEC), established in 1987, is a publicly owned electrical utility which provides reliable electricity to almost 15,000 consumers. The hydro facilities at Whitehorse, Mayo, and Aishihik Lake provide 92 megawatts of power to the surrounding communities. With 31 megawatts produced by diesel generators (primarily used for back up), 8.8 megawatts by liquefied natural gas (used for back up), and .65 megawatts by a small wind turbine on Haeckel Hill near Whitehorse, Yukon Energy has the capacity to generate close to 132 megawatts.

The Mayo Hydro and Mayo B Hydro stations are located approximately 400 kilometers north of Whitehorse. Mayo Hydro started to produce power in 1952 and Mayo B Hydro in 2012. Mayo Hydro and Mayo B Hydro are fed from Wareham Lake and operate with a maximum total combined flow of 25 cubic meters per second (m^3/s) (19 m^3/s through Mayo B Hydro and 6 m^3/s through Mayo Hydro). Mayo Hydro has the capacity to pass up to 17 m^3/s; however, the design of the intake and penstocks restrict the combined flow to 25 m^3/s.

As per the water license for the Mayo River and Mayo Lake, in the channels downstream of the Mayo Hydro Powerhouse, a minimum instantaneous flow of 6 m^3/s is required from May 1 to September 30, and a minimum flow of 5 m^3/s is required for the remainder of the year. If Mayo Hydro is not operating, this minimum flow and potential energy must be passed through the spillway. Due to the higher water head available at Mayo B Hydro, the preference is to operate both Mayo B units and to operate Mayo Hydro at the minimum required flow.

The Yukon Energy Corporation is considering 4 options for the future of the Mayo Hydro facility.

- Option #1 – Replace the Mayo Hydro station.
- Option #2 – Refurbish the Mayo Hydro station.
- Option #3 – Remove the Mayo Hydro facility and return the site to a near greenfield condition.
- Option #4 – Make the facility safe and abandon in situ.

KGS Group was retained to assess each option at a conceptual level and recommend the most economical choice. The design life of Option 1 and Option 2 will be 65 years.

This Conceptual Design Report covers the economic assessment and cost estimates for the future options. The following sections summarize and explain the results of the analysis and a final recommendation is provided.

A condition assessment of the Mayo Hydro powerhouse was done in 2013/2014. This assessment and the associated report were updated by KGS Group in 2016. The study assesses the current condition of the facility and its components, prioritizes the required upgrades and presents costs estimates for the work required. It found that many of the systems have reached the end of their useful life and that extensive repairs/upgrades are required to maintain the facility in operation. The age and condition of the facility and the need for significant repairs or upgrades provide context for, and support, the recommendations of this report. Refer to the “Mayo Hydro (MH0) Asset Assessment Update” report for a detailed review of the facility’s condition.

2.0 THE FACILITY

Mayo Hydro is a two vertical Francis unit hydroelectric generating station located just north and outside of the town of Mayo, in the Yukon Territory. It has a maximum continuous rating of 5.1 MW. The facility was placed into service in 1952 with the commissioning of Unit MH1. Unit MH2 was placed into service in 1957.

The Mayo Hydro facility includes the following structures:

- One powerhouse building.
- One switchgear building (blue building).
- One surge tank.
- One tunnel.
- One substation/transformer yard.
- One intake structure.
- One spillway control structure.

The substation/transformer yard, intake structure and spillway control structure are not included in the scope of work for this project because these components are shared with Mayo B Hydro and will be required regardless of which option is chosen for the future of the Mayo Hydro facility. The switchgear building is not included in the scope of work because it will be relocated to the Mayo S249 substation as part of a separate project, regardless of which option is chosen.

3.0 OPTION 1 – REPLACE THE FACILITY

In accordance with the terms of reference, Option 1 entails replacement of the hydro facility, retaining only the foundations and other embedded parts. As discussed in Section 3.3, the surge tank will also be replaced. The hydro facility replacement will include a new powerhouse building, balance of plant systems and one new turbine/generator unit and its supporting equipment, complete with a new control room and powerhouse crane. Given appropriate maintenance and overhauls, it is expected that the life of the plant, post-replacement, would be 65 years or more.

3.1 PLANT CAPACITY

Prior to construction of Mayo B, Mayo Hydro had a plant design flow of 17 m^3/s. As detailed in the "Mayo A and Mayo B Generating Stations Optimizing Plant Operations Testing Results, May 2013" KGS Group (Appendix A), for most Wareham Lake levels, Mayo Hydro is restricted to operate at 6 m^3/s while two Mayo B units are running.

In order to determine a design capacity of a new turbine/generator unit for this study, Yukon Energy Corporation provided historical flow data for the Mayo Hydro plant. Flow data for the period of February 8, 2013 to February 18, 2016 was used, refer to Figure 1.

Because of the operational constraints of the Mayo Hydro/Mayo B Hydro complex (i.e. flow limitations at Mayo Hydro) and supported by the flow data in Figure 1, possible plant flows in the range of 6 m^3/s to 10 m^3/s were investigated. The four options that were considered are:

- Case 1: 1 unit sized for 9.7 m^3/s.
- Case 2: 2 units sized for 5 m^3/s each.
- Case 3: 1 unit sized for 6 m^3/s.
- Case 4: 1 unit sized so winter flow results in approximately 90% turbine efficiency.

To review the four cases, Andritz's Francis turbine efficiency curve data from the Mayo B bid was used. To estimate efficiencies using this efficiency curve, the axis with absolute flow values was converted to a percentage of rated flow and the efficiency for a given percentage of rated flow was assumed to be the same, regardless of the rated flow. For example, the efficiency for a unit operating at 75% rated flow was the same regardless of the unit size.

The efficiency curve data is proprietary information that is closely guarded by the turbine suppliers. As such, the source curve has not been included in this report. However, Yukon Energy Corporation is in possession of this information from the Mayo B Hydro project.

Case 1: Single unit sized to maximize MH0 capacity (peak flow of 9.7 m^3/s).

This case coincides with the maximum possible flow that can be passed simultaneously through Mayo B Hydro and Mayo Hydro. This corresponds to 19 m^3/s through Mayo B and 9.7 m^3/s through Mayo Hydro. Note that this case is only reasonable if Wareham Lake is operated at or near the maximum license level of 574.5 masl.

In the winter, the single unit would run at 5 m^3/s (51.5% of rated flow). This results in a relatively low turbine efficiency (generator and transformer efficiency not considered here) of 82.5%. In the summer, the single unit would run at 6 m^3/s (61.8% of rated flow, with a turbine efficiency of approximately 89%). When needed, and the Wareham Lake levels and Mayo B operation allow, the flow could be ramped up to 9.7 m^3/s.

The current MH0 units are rated for 8.5 m^3/s each. Given newer technology, it is likely that the 9.7 m^3/s can be passed safely through the existing, or similar, water passage dimensions. This is an increase of 15% in the flow. Recent turbine upgrades have shown that flow increases on the order of 20% are usually possible without risking excessive cavitation, etc. The new manufacturing techniques in use today allow for more precise manufacturing and the increased flows.

Case 2: Two units sized for 5 m^3/s each.

- In winter, run one unit at rated flow for an approximate turbine efficiency of 94%.
- In summer, run two units at 60% flow with an approximate turbine efficiency of 88%.
- When conditions at Wareham Lake and Mayo B allow, run both units up to 97% flow.

This case is similar to Case 1, as it provides the installed capacity to fully utilize the capacity at the site, except that two units are provided instead of one. This would allow for the plant to produce electricity with a higher efficiency. Again, this capacity is only available when Wareham Lake is operated at the maximum license limit or when at least one Mayo B unit is off line.

A disadvantage of this option is that both units would be required to pass the minimum riparian flows in the summer.

Case 3: One unit rated for 6 m^3/s.

- In winter, run one unit at 83.3% of rated flow for an approximate turbine efficiency of 93%.
- In summer, run the unit at 100% of rated flow with an approximate turbine efficiency of 94%.
- With this case, the unit would always operate at very high efficiency. It would essentially be base loaded. It would contribute only limited spinning reserve in the winter and none in the summer.

Case 4: One unit sized so winter flow results in 90% turbine efficiency.

On the representative turbine efficiency curve used, 90% efficiency occurs at approximately 66% of rated flow, resulting in a unit sized for a maximum flow of 7.6 m^3/s.

- In winter, run the unit at 66% of rated flow for an approximate turbine efficiency of 90%.
- In summer, run the unit at 80% of rated flow with an approximate turbine efficiency of 92%.
- With this case, the unit would always operate at relatively high efficiency. It would essentially be base loaded. It would contribute limited spinning reserve in both winter and summer.

3.2 SELECTION OF CAPACITY

After reviewing the options, Case 4 was selected. That is, one unit rated for a maximum flow of 7.6 m^3/s.

Cases 1 and 2 were discounted because with these options, the plant would seldom run at rated load because of the flow limitations of the combined Mayo Complex. The full capacity can only be used when at least one Mayo B unit is off-line or when Wareham Lake is operated at or very near its maximum licence level. Wareham Lake is not usually operated at or very near the maximum license limit level because doing so causes some flooding upstream, reduces the time available for staff to react in the event of a load rejection (need to operate the spillway faster) and there is limited freeboard at the spillway gates which prevents raising the lake level too much. Also, Mayo B units are offline for a limited number of hours throughout the year.

Although a two unit arrangement (Case 2) provides redundancy and some increased capacity that could be used when Mayo B Hydro is shut down or running with a single unit, it significantly increases cost and given the very limited operating time a second unit would run, it is not financially justifiable. To illustrate this, a rough costing exercise was undertaken and it was determined that providing two units instead of one would increase the total project cost by approximately $9,000,000 to $14,800,000, depending on size of the units and if they are new or refurbished. Since the total annual production for Mayo Hydro will remain nearly the same, due to the 6 m^3/s flow limitation most of the time, a second unit will account for an approximate increase of $0.044/kW.h to $0.073/kW.h in the levelized cost of energy. Furthermore, since Mayo B Hydro operates at much higher head (approx. 60 m net head versus 34.6 m for Mayo Hydro), more energy is produced by a given amount of water at Mayo B.
Case 4 was chosen over Case 3 because it provides minimal additional capacity and spinning reserve and it more closely matches the recent historical plant flows shown in Figure 1.

Andritz Hydro, a turbine and generator supplier provided a preliminary unit selection (Appendix B). Selection was limited to vertical units that could re-use the existing foundation and water passages. The setting elevation of the turbine runner was considered given the constraints of the existing foundation.

The following sections detail the concept design to replace the Mayo Hydro facility.

3.3 DEMOLITION

The demolition will include the removal of:

- The existing powerhouse superstructure.
- Turbine/generators, TIVs and their related components.
- There are no electrical systems with sufficient value to justify retaining for reuse. To be re-used, a component would have to be carefully removed, packaged, stored and re-installed in a new installation. It is expected that the added complexity in design, construction and commissioning would negate any cost savings associated with the reuse of the components. Therefore, all electrical systems (generator, balance of plant, building systems) should be demolished and replaced with new.
- Asbestos abatement (generators, roof panels).
- Disposal of any PCBs, lead, oil, and potentially small amounts of mercury.
- Spiral cases and both TIV pedestals.
- The powerhouse mechanical systems, including: domestic, sanitary, compressed air, fire protection, HVAC systems.
- Surge tank superstructure.
- Surge tank mechanical and electrical.

The existing septic field will be abandoned in place.

The existing draft tube sectional gates and guides will be re-used for Unit 1.

The replacement of the surge tank is included in this study as its interior condition is unknown. If inspections during later phases of the project show that the surge tank is in good condition, it may be reused to reduce costs.

3.4 MECHANICAL AND ELECTRICAL

3.4.1 Turbine and Generator

The new turbine/generator will be placed in Unit 1’s current location since this allows for a larger service bay on the access road side of the powerhouse (Figure 2 and Figure 3). A service bay incorporating the space formerly occupied by Unit 2 will allow trucks to back directly into the powerhouse to unload/load. The penstock feeding the unused turbine pit will be permanently plugged and its TIV pit modified to suit the needs of the new facility. The new unit will be:

- Vertical Francis turbine.
- 7.6 m^3/s at 34.6 m of net head.
- 2300 kW, 6.9 kV synchronous generator with static excitation, 600 rpm.
- 986 mm runner diameter.

The turbine and generator will be supplied with a new electronic governor system.

At this concept stage, the design details of the equipment were not specified, but it is assumed that the new turbine and generator equipment would consist of:

- Generator:
  a. Standard catalogued air-cooled generator. That is, the generator would not be a custom design.
  b. Global VPI type insulation with resins that do not support combustion when energy sources are removed.
  c. Inertia would consist of the natural inertia of the unit only.
  d. Capable of withstanding runaway speeds for extended periods.
- Turbine:
  a. Stainless steel runner and wicket gates.
  b. Greaseless bushings throughout.
- Turbine Inlet Valve (TIV):
  a. New butterfly valve, complete with new hydraulic actuator and counterweight closure capability, rated for single point of isolation.
- Governor:
  a. Digital PLC-based governor.
  b. High pressure HPU with a backup pump and motor.
  c. Nitrogen charged bladder-type accumulators sized to provide stored energy for two close strokes and one open stroke of the wicket gates and one open stroke of the TIV.
- Excitation:

a. No redundant bridge.
b. Ceiling voltage capability: 2 pu.

- The unit will be provided with vibration monitoring equipment.
- Unit control and monitoring systems and SCADA systems.
- Neutral grounding resistor cubicle and a new phase (power lead connection) cubicle, complete with surge arrestors and capacitors.
- A cooling water filtering skid will be provided to filter cooling and shaft seal water.

The above parameters have been assumed at this time. The detailed design phase should include appropriate grid and hydraulic transient studies to determine generator and excitation system requirements. For example, these studies should include an assessment of whether brushless excitation would be acceptable instead of the more expensive static excitation included herein and ceiling voltage requirements, as well as the required generator inertia and electrical parameters.

The concept design includes the capability to restart the unit using on site stored energy (in accumulators and DC battery banks), in a fashion that is similar to the current plant and no diesel generator has been allowed for at this time. This would allow staff to restart the unit to power the station service, etc. Given the smaller size of the unit, it is unclear at this time what line charging and grid restoring capabilities this unit would have. This would have to be determined at the beginning of the detailed design phase following the results of the above-mentioned grid and hydraulic transient studies.

3.4.2 Balance of Plant

The powerhouse will require the following new mechanical balance of plant systems:

- Domestic water.
- Sanitary waste (including holding tank).
- Station drainage (including an oil/water separator).
- Compressed air.
- HVAC (including surge tank).
- Fire protection.

- Powerhouse crane.
- Draft tube crane.

Due to the powerhouse's proximity to the river, a new septic field is not feasible. Instead, a sewage holding tank will be provided. The holding tank will be buried and be equipped with heat tracing for the drain lines.

The TIV pit of Unit 2 will be converted into an oil/water separator, complete with coalescing filters/plate pack and drainage pumps (Figure 3). The oil-water-separator will be housed in a concrete pit and sized to accommodate normal station drainage and fire protection water flows.

The fire protection system will be fed from the penstock and will be comprised of listed strainers, piping, hose stations and a fire detection and alarm system. The new generators will be fabricated with self-extinguishing insulating materials; therefore a generator deluge system will not be required.

The powerhouse crane will be an overhead top running bridge crane. The draft tube crane will be an electric monorail crane.

The powerhouse will require the following electrical balance of plant systems:

- Grounding systems.
- Lighting and emergency lighting.
- Fire alarm system.
- Telephone system.
- Control and corporate data networks.
- Security and card access systems.
- Station service distribution panels and convenience transformer.
- Communication relocation.
- New cables and cable trays.
- DC power system.
- Station service transformer (SST) with an automatic transfer scheme.

- 15 kV arc-proof metal-clad switchgear (with unit protections).

All communications from Mayo B, Mayo Hydro, the Wareham spillway and the intake have fibre communication which route through Mayo Hydro. Prior to performing demolition, the communications/fibre will need to be relocated to the switchyard or otherwise bypassed. It is proposed that this equipment and cabling be permanently relocated to a new communications building in the switchyard.

3.5 STRUCTURAL

A new insulated metal clad powerhouse superstructure will be installed on the existing foundation. The powerhouse will be designed to current design standards to withstand seismic loads and loads from the cranes, wind, snow, etc.

The new spiral case and discharge cone will be anchored/grouted in place of the removed Unit 1. Unused openings within the generator and turbine floors will be filled with concrete. If additional laydown space is required on the turbine floor, the concrete that supported the Unit 2 generator may be removed and the floor reinforced as required; it is expected that the cost of this rework would be significant. Minor concrete rehabilitation is likely required over the concrete foundation.

Unit 2's draft tube will be sealed with a structural wall immediately behind the gate guides and then infilled with lean concrete to the generator floor level for improved structural stability. Unit 2's penstock will be plugged and a blanking plate will be installed in the powerhouse.

In addition to the added mass from infilling the decommissioned draft tube, allowances have been included for the installation of post-tensioned rock anchorage to improve powerhouse stability (powerhouse anchors) for updated seismic loading.

A new control room, complete with fire rated wall separations will be provided. The switchgear will be located on the generator floor.

As discussed in Section 3.3, a new surge tank superstructure will be provided. The concrete foundation has been assumed to be suitable for reuse; however, a detailed inspection will be required to confirm this assumption.

3.6 GEOTECHNICAL

3.6.1 Slope Above Powerhouse

The stability of the slope immediately behind the powerhouse structure has been, and continues to be, of concern due to the possibility of a slope failure damaging the critical infrastructure (surge tank, powerhouse, electrical, etc.) that is supported on the slope. The rock mass behind the powerhouse structure will need to be stabilized in order to reduce the risk for damage to the building and/or injury to employees. This is achieved by:

- Scaling and removal of loose rock and debris through hand removal (using rope access) or mechanical means (using long arm backhoe or jackhammer).
- Installation of rockfill catch ditches and catch fences to impede rockfall from traveling onto the back of the powerhouse
- Flatten the top of the slope area and grade it such that positive drainage is achieved in order to reduce the potential for erosion and surface water infiltration into the rock mass.
- Reinforce the excavated rock faces to prevent any loose rock from potentially damaging the structures by installing new wire mesh and rock anchors.

3.6.2 Tailrace

The bottom row of gabion baskets and the underlying gabion mattress below the tailrace water level has failed due to the constant wear of high velocity streams and ice on the galvanized wire baskets. The gabion wall will be repaired.

3.6.3 Access Road

There is a steep section of the road immediately east of the 69 kV substation where runoff water has been allowed to flow directly down the shoulder of the road resulting in gully erosion which also affects the access road to Mayo Hydro. The shoulder area where the gully has formed will need to be repaired and an appropriately sized rip-rap lined ditch will be designed and constructed at the location of the gully to convey surface run-off. The access road to the surge tank location will also require upgrading to facilitate demolition and re-construction of the new structure.

3.7 COST ESTIMATE

Table 1 provides a summary of the total project costs. For a detailed contractor direct cost estimate, refer to Appendix C.

TABLE 1
TOTAL PROJECT COST - OPTION 1 – REPLACEMENT

ITEM			COST
Contractor Direct Costs			**$13,284,000**
Site Work			$120,000
Slope, Tailrace & Access Road Stabilization			$1,897,000
Decommissioning and Demolition			$799,000
Structure Rehabilitation (Concrete, Anchoring, Repairs)			$1,014,000
New Structures (Powerhouse and Surge Tank)			$1,062,000
New Turbine, Generator & TIV			$4,416,000
Electrical and Mechanical Balance of Plant			$3,976,000
General Contractor Indirect Costs	**35%**	**of Directs**	**$4,650,000**
Travel and Camp Costs (or accommodations)	**6%**	**of Directs**	**$800,000**
Subtotal			**$18,734,000**
Contingency	**30%**	**of Subtotal**	**$5,620,000**
Total Construction Cost			**$24,354,000**
Contractor Markups			**$4,920,000**
Profit	*12%*	*of Const.*	$2,922,000
Head Office Overhead	*7.0%*	*of Const.*	$1,705,000
Bonding & Insurance	*1.2%*	*of Const.*	$292,000
Total Contractor Price			**$29,274,000**
Owner Costs			**$2,710,000**
Environmental Licencing/Consulting	*3.0%*	*of Directs*	$399,000
Final Design	*7.0%*	*of Directs*	$930,000
Site Assistance & Quality Assurance	*6.0%*	*of Directs*	$797,000
Owner's Administration	*2.0%*	*of Contract*	$585,000
Total Project Cost			**$32,000,000**

The total project cost of $32,000,000 is expected to be inclusive of all project costs. Given the limited amount of design work performed to date, a contingency of 30% has been included. Also, the allowances for contractor indirect costs, travel and accommodation, profit, overhead, etc. are based on KGS Group's recent experience on hydroelectric development projects in various remote locations in Canada (including the Mayo B Hydroelectric project).

3.8 SCHEDULE

A preliminary design and construction schedule is shown on Figure 7 (end of report). A pre-design phase includes the environmental licensing and would begin immediately. The detailed design phase would include inspections of the surge tank and spiral cases, multiple studies to refine the turbine/generator selection, hydraulic transient study, grid/electrical study, and drawings and specifications.

Turbine and Generator procurement will commence during detailed design and span into the construction schedule.

During construction, a total of three Mayo B plant outages are expected (1 month, 2 months, 2 weeks). The total process from pre-design to commercial operation is expected to span 2.25 to 2.5 years in duration.

4.0 OPTION 2 – REFURBISH THE EXISTING FACILITY

Option 2 involves the refurbishment of the existing facility. The work entails the refurbishment of Unit 2 only, replacement of the powerhouse mechanical and electrical balance of plant systems, replacement of the surge tank, and the removal of Unit 1. Unit 2 will be refurbished since its embedded spiral case and stay ring will be reused and they are newer (1969 compared to 1952) than Unit 1. Additionally, Unit 2 has a slightly higher capacity than Unit 1 (2.9 MW vs 2.7 MW). At the beginning of the detailed design phase, both units should be inspected and a final decision should be made as to which unit is to be refurbished.

The intent is to essentially replace all of Unit 2, with the exception of the embedded spiral case, stay ring and discharge cone. These embedded components would be refurbished in situ, thereby eliminating the need to cut them out of the concrete substructure. Although the existing turbine runner is only approximately 15 years old, a new runner is contemplated at this time. This allows for the selection of a higher synchronous speed, thereby requiring a less expensive generator; resulting in a lower overall cost along with a new runner. A new TIV, certified for use as a single point of isolation, will also be provided, as it is not expected that the existing one will provide reliable service for the life of the station (assumed to be 65 years from the date of refurbishment).

Given appropriate maintenance and overhauls, it is expected that the life of the plant, post-refurbishment would be 65 years or more.

The Unit 1 penstock will be plugged and its TIV pit modified to suit the needs of the facility. The proposed refurbished unit will have the same capacity as the unit described in Option 1. The service bay will be placed in the current location of Unit 1 (Figure 4). The powerhouse crane will be used to hoist loads off of trucks that are backed into the powerhouse. Clearances between the truck and new generator will be limited, but there is sufficient space. Loads will be lifted and moved over the new unit into the service bay.

This option is similar to Option 1, with the exception that the powerhouse building superstructure, the powerhouse crane, and embedded components will be retained and refurbished. All other systems will be replaced with new systems. Most of the mechanical and electrical balance of plant systems have reached the end of their life and require either replacement or refurbishment. Given the extent of work proposed, the replacement of the balance of plant systems is warranted. It is expected that this option will provide similar reliability and service as Option 1.

The arrangement of the refurbished powerhouse is shown in Figure 4 and Figure 5. The following sections further detail the concept design to refurbish the Mayo Hydro facility.

4.1 DEMOLITION

The demolition will include the removal of:

- Unit 1 generator and associated equipment.
- Unit 2 generator and governor, turbine bearing, head cover.
- There are no electrical systems with sufficient value to justify retaining for reuse. To be re-used, a component would have to be carefully removed, packaged, stored and re-installed in a new installation. It is expected that the added complexity in design, construction and commissioning would negate any cost savings associated with the reuse of the components. Therefore, all electrical systems (generator, balance of plant, building systems) should be demolished and replaced with new.
- Disposal of any PCBs, lead, oil, and potentially small amounts of mercury.
- Unit 1 spiral case and TIV pedestal.
- The powerhouse balance of plant mechanical systems, including: domestic water, sanitary sewer, fire protection, and HVAC systems.
- Compressed air system excluding the compressors and receiver tank. Re-use of the relatively new compressors has been assumed.
- Surge tank superstructure.
- Surge tank mechanical and electrical.

The existing septic field will be abandoned in place.

The existing draft tube sectional gates and the Unit 2 guides will be re-used.

The replacement of the surge tank is included in this study as its interior condition is unknown. If inspections during later phases of the project show that the surge tank is in good condition, it may be reused to reduce costs.

The existing governor has been problematic ever since an upgrade to an electronic Woodward 505 governor was performed. The supplier's prior attempts to correct the problems have failed. For this reason, a new electronic governor and HPU will be provided.

4.2 MECHANICAL AND ELECTRICAL

4.2.1 Turbine and Generator

As discussed above, the Unit 2 will be refurbished. The refurbished unit would entail:

- New vertical Francis turbine runner (to match existing spiral case).
- Rated 7.6 m^3/s at 34.6 m of net head.
- New 2300 kW, 6.9 kV synchronous generator with static excitation, 600 rpm.
- New head cover, wicket gates, servo and bearings.

The spiral case, discharge cone and stay ring will be sandblasted, inspected and, if required, repaired in situ, then repainted.

The turbine and generator will be supplied with a new electronic governor system.

A service bay incorporating the space formerly occupied by Unit 1 will allow for sufficient lay down and maintenance space. The penstock feeding the unused turbine pit will be permanently plugged and its TIV pit modified to suit the needs of the new facility.

At this concept stage, the design details of the equipment were not specified, but it is assumed that the new/refurbished turbine and generator equipment would consist of:

- Generator:

a. Standard catalogued air-cooled generator. That is, the generator would not be a custom design.
b. Global VPI type insulation with resins that do not support combustion when energy sources are removed.
c. Inertia would consist of the natural inertia of the unit only.
d. Capable of withstanding runaway speeds for extended periods.

- Turbine:

  a. Stainless steel wicket gates.
  b. Greaseless bushings throughout.

- Turbine Inlet Valve (TIV):

  a. New butterfly valve, complete with new hydraulic actuator and counterweight closure capability, rated for single point of isolation.

- Governor:

  a. Digital PLC-based governor.
  b. High pressure HPU with a backup pump and motor.
  c. Nitrogen charged bladder-type accumulators sized to provide stored energy for 2 close strokes and one open stroke of the wicket gates and one open stroke of the TIV.

- Excitation:

  a. Static excitation.
  b. No redundant bridge.
  c. Ceiling voltage capability: 2 pu.

- The unit will be provided with vibration monitoring equipment.
- Unit control and monitoring systems and SCADA systems.
- Neutral grounding resistor.
- A cooling water filtering skid will be provided to filter cooling and shaft seal water.

The above parameters have been assumed at this time. The detailed design phase should include appropriate grid and hydraulic transient studies to determine generator and excitation system requirements. For example, these studies should include an assessment of whether brushless excitation would be acceptable instead of the more expensive static excitation included herein and ceiling voltage requirements, as well as the required generator inertia and electrical parameters.

The concept design includes the capability to restart the unit using on site stored energy (in accumulators and DC battery banks), in a fashion that is similar to the current plant and no diesel generator has been allowed for at this time. This would allow staff to restart the unit to power the station service, etc. Given the smaller size of the unit, it is unclear at this time what line charging and grid restoring capabilities this unit would have. This would have to be determined at the beginning of the detailed design phase following the results of the above-mentioned grid and hydraulic transient studies.

4.2.2 Balance of Plant

The following new mechanical balance of plant systems will be provided:

- Domestic water system.
- Sanitary waste (including holding tank and heat traced piping).
- Station drainage (including an oil/water separator).
- Compressed air system.
- HVAC (including surge tank).
- Fire protection.

Due to the powerhouse's proximity to the river, a new septic field is not feasible. Instead, a sewage holding tank will be provided. The holding tank will be buried and be equipped with heat tracing for the drain lines.

The TIV pit of Unit 1 will be converted into an oil/water separator, complete with coalescing filters/plate pack and drainage pumps (Figure 5). The oil/water separator will be housed in a concrete pit and will be sized to accommodate normal station drainage and fire protection water flows.

The fire protection system will be fed from the penstock and will be comprised of listed strainers, piping, hose stations and a fire detection and alarm system. The new generators will be fabricated with self-extinguishing insulating materials; therefore a generator deluge system will not be required.

The powerhouse and draft tube cranes will be modernized.

The powerhouse will require the following electrical balance of plant systems:

- Unit control and monitoring systems and SCADA systems.
- Neutral grounding resistor and phase cubicle (c/w surge arrestors and capacitors).
- Lighting and emergency lighting.
- Fire alarm system.
- Telephone system.
- Control and corporate data networks.
- Security and card access systems.
- Station service distribution panels and convenience transformer.
- Communication relocation.
- New cables and cable trays.
- DC power system.
- Station service transformer (SST) with an automatic transfer scheme.
- 15 kV arc-proof metal-clad switchgear (with unit protections).

All communications from Mayo B, Mayo Hydro, the Wareham spillway and the intake have fibre communication which route through Mayo Hydro. Prior to performing demolition, the communications/fibre will need to be relocated to the switchyard or otherwise bypassed. It is proposed that this equipment and cabling be permanently relocated to a new communications building in the switchyard.

Grounding for the Mayo Hydro plant appears to be provided embedded into the structure itself and where exposed, appears to be in reasonable condition. The grounding will require a ground resistivity measurement and potential upgrade.

The neutral grounding resistor will need to be replaced due to its age and to better suit the new generator. The new generator would be provided with a phase cubicle for connection of the power leads.

It has been assumed that all of the electrical balance of plant systems will be replaced. Most of the systems are at the end of their useful lives and the amount of effort and cost to reuse select components or subsystems greatly outweighs the cost of its replacement. This will apply to security and card access systems, communications, lighting, etc.

4.3 STRUCTURAL

The existing structure will need reinforcements and anchoring to meet current design codes, particularly for seismic load conditions. The existing powerhouse roof reportedly contains asbestos and would need to be encapsulated in place or removed. A new roof membrane will be installed on top of the existing structure. All windows and doors will be replaced with maintenance-free and energy efficient products.

The powerhouse block walls will need to be repointed and a new fire-rated control room will be constructed. Insulation for the roof and walls will be added. Any openings within the generator and turbine floors will be filled with concrete. If additional laydown space is required on the turbine floor, the support concrete that supported the Unit 1 generator may be removed and the floor reinforced as required; it is expected that the cost of this rework would be significant. Minor concrete rehabilitation is likely required over the concrete foundation.

Unit 1's draft tube will be sealed with a structural wall immediately behind the gate guides and then infilled with lean concrete to the generator floor level for improved structural stability. Unit 1's penstock will be plugged and a blanking plate will be installed in the powerhouse. In addition to the added mass from infilling the decommissioned draft tube, allowances have been included for the installation of post-tensioned rock anchorage to improve powerhouse stability (powerhouse anchors) for updated seismic loading.

As discussed in Section 4.1, a new surge tank superstructure will be provided. The concrete foundation has been assumed to be suitable for reuse; however, a detailed inspection will be required to confirm this.

4.4 GEOTECHNICAL

The geotechnical considerations for this option are the same as they are for Option 1. Refer to Section 3.5 for details.

4.5 COST ESTIMATE

Table 2 below outlines the total project costs. For a detailed contractor direct cost estimate, refer to Appendix C.

TABLE 2
TOTAL PROJECT COST - OPTION 2 – REFURBISHMENT

ITEM			COST
Contractor Direct Costs			**$11,870,000**
Site Work			*$120,000*
Slope, Tailrace & Access Road Stabilization			*$1,897,000*
Decommissioning and Demolition			*$497,000*
Structure Rehabilitation (Concrete, Anchoring, Repairs)			*$1,559,000*
New Structures (Powerhouse and Surge Tank)			*$266,000*
New Turbine, Generator & TIV			*$3,142,000*
Electrical and Mechanical Balance of Plant			*$4,389,000*
General Contractor Indirect Costs	**35%**	**of Directs**	**$4,150,000**
Travel and Camp Costs (or accommodations)	**6%**	**of Directs**	**$710,000**
Subtotal			**$16,730,000**
Contingency	**30%**	**of Subtotal**	**$5,020,000**
Total Construction Cost			**$21,750,000**
Contractor Markups			**$4,390,000**
Profit	*12%*	*of Const.*	*$2,610,000*
Head Office Overhead	*7.0%*	*of Const.*	*$1,523,000*
Bonding & Insurance	*1.2%*	*of Const.*	*$261,000*
Total Contractor Price			**$26,140,000**
Owner Costs			**$2,420,000**
Environmental Licencing/Consulting	*3.0%*	*of Directs*	*$356,000*
Final Design	*7.0%*	*of Directs*	*$831,000*
Site Assistance & Quality Assurance	*6.0%*	*of Directs*	*$712,000*
Owner's Administration	*2.0%*	*of Contract*	*$523,000*
Total Project Cost			**$28,600,000**

4.6 SCHEDULE

A preliminary design and construction schedule is shown on Figure 8 (end of report). A pre-design phase includes the environmental licensing and would begin immediately. The detailed design phase would include inspections of the surge tank and spiral cases, multiple studies to refine the turbine refurbishment, the generator selection, transient study, grid/electrical study, and drawings and specifications.

Turbine and generator procurement will commence during detailed design and span into the construction phase.

During construction, a total of three Mayo B plant outages are expected (1 month, 2 months, 2 weeks). The total process from pre-design to commercial operation is expected to span 2.25 to 2.5 years in duration.

5.0 OPTION 3 – REMOVE THE FACILITY AND RETURN SITE TO NEAR GREENFIELD CONDITION

Option 3 consists of returning the site to a near greenfield condition. This includes the removal of the surge tank and powerhouse, but the foundations would remain in place and be backfilled.

The following sections detail the concept design to return the site to a near greenfield condition.

5.1 DEMOLITION

The demolition will include the removal of:

- The existing powerhouse superstructure.
- Turbine/generators and their components.
- Disposal of any PCBs, lead, oil, and potentially small amounts of mercury.
- Both TIVs.
- All powerhouse mechanical and electrical systems.
- Surge tank.
- Surge tank mechanical and electrical systems.
- Draft tube gates.

The existing septic field will be abandoned in place.

5.2 COMMUNICATIONS

All communications from Mayo B, Mayo Hydro, the Wareham spillway and the intake have fibre communication which route through Mayo Hydro. Prior to performing demolition, the communications/fibre will need to be relocated to the switchyard or otherwise bypassed. It is proposed that this equipment and cabling be permanently relocated to a new communications building in the switchyard.

5.3 STRUCTURAL

The penstock upstream of the surge tank take-off would be plugged and sealed with a concrete wall.

5.4 GEOTECHNICAL

The powerhouse foundation will be backfilled, topped with topsoil, graded and potentially seeded with grass. The topsoil will extend into the existing parking lot area. The tailrace will be infilled with rockfill.

The slope stabilization, the tailrace gabion basket repair and the road repairs that are described in Section 3.5 will not be required for this option.

Following the completion of the work, the road down to Mayo Hydro will be barricaded with a barrier and a fence to prevent access.

5.5 COST ESTIMATE

Table 3 below outlines the total project costs. For a detailed contractor direct cost estimate, refer to Appendix C.

TABLE 3
TOTAL PROJECT COST - OPTION 3 – DEMOLISH AND RETURN TO GREENFIELD

ITEM			COST
Contractor Direct Costs			**$1,675,000**
Site Work			*$60,000*
Slope, Tailrace & Access Road Stabilization			*$0*
Decommissioning and Demolition			*$1,040,000*
Structure Rehabilitation (Concrete, Anchoring, Repairs)			*$0*
New Structures (Powerhouse and Surge Tank)			*$0*
New Turbine, Generator & TIV			*$0*
Electrical and Mechanical Balance of Plant			*$575,000*
General Contractor Indirect Costs	**35%**	**of Directs**	**$590,000**
Travel and Camp Costs (or accommodations)	**6%**	**of Directs**	**$100,000**
Subtotal			**$2,365,000**
Contingency	**30%**	**of Subtotal**	**$710,000**
Total Construction Cost			**$3,075,000**
Contractor Markups			**$620,000**
Profit	*12%*	*of Const.*	*$369,000*
Head Office Overhead	*7.0%*	*of Const.*	*$215,000*
Bonding & Insurance	*1.2%*	*of Const.*	*$37,000*
Total Contractor Price			**$3,695,000**
Owner Costs			**$330,000**
Environmental Licencing/Consulting	*3.0%*	*of Directs*	*$50,000*
Final Design		*	*$100,000*
Site Assistance & Quality Assurance	*6.0%*	*of Directs*	*$101,000*
Owner's Administration	*2.0%*	*of Contract*	*$74,000*
Total Project Cost			**$4,000,000**

* For options 3 & 4, design cost would be more than 7%. An allowance of $100,000 was used.

5.6 SCHEDULE

A preliminary design and construction schedule is shown on Figure 9 (end of report). A pre-design phase includes the environmental licensing and would begin immediately. The detailed design phase would include demolition, drawings and specifications detailing the work.

During construction, one Mayo B plant outage is expected (2 months) to plug the tunnel upstream of the surge tank. The total process from pre-design to project completion is expected to span 1 to 1.25 years in duration.

6.0 OPTION 4 – ABANDON THE FACILITY IN PLACE AND MAKE SAFE

Option 4 will abandon the powerhouse in place and make the site safe as required. The following sections detail the concept design to render the station safe for abandonment.

6.1 DEMOLITION

The demolition will include the removal of:

- Access ladders on the surge tank and powerhouse.
- Disposal of any PCBs, lead, oil, and potentially small amounts of mercury.
- Electrical feeds to the powerhouse.

6.2 COMMUNICATIONS

All communications from Mayo B, Mayo Hydro, the Wareham spillway and the intake have fibre communication which route through Mayo Hydro. Prior to performing demolition, the communications/fibre will need to be relocated to the switchyard or otherwise bypassed. It is proposed that this equipment and cabling be permanently relocated to a new communications building in the switchyard.

6.3 STRUCTURAL

The penstock upstream of the surge tank take-off will be plugged and sealed with a concrete wall.

The windows and doors in the powerhouse will be boarded and sealed to prevent access into the powerhouse. Access hatches to confined spaces (spiral case, surge tank, etc) will be welded shut.

6.4 GEOTECHNICAL

The slope stabilization, the tailrace gabion basket repair and the road repairs that are described in Section 3.5 will not be required for this option. The tailrace will be infilled with rockfill. Following the completion of the work, the road down to Mayo Hydro will be barricaded with a barrier and a fence to prevent access.

6.5 COST ESTIMATE

Table 4 below outlines the total project costs. For a detailed contractor direct cost estimate view Appendix C.

TABLE 4
TOTAL PROJECT COST - OPTION 4 – ABANDON IN SITU

ITEM			COST
Contractor Direct Costs			**$945,000**
Site Work			*$60,000*
Slope, Tailrace & Access Road Stabilization			*$0*
Decommissioning and Demolition			*$290,000*
Structure Rehabilitation (Concrete, Anchoring, Repairs)			*$20,000*
New Structures (Powerhouse and Surge Tank)			*$0*
New Turbine, Generator & TIV			*$0*
Electrical and Mechanical Balance of Plant			*$575,000*
General Contractor Indirect Costs	**35%**	**of Directs**	**$330,000**
Travel and Camp Costs (or accommodations)	**6%**	**of Directs**	**$60,000**
Subtotal			**1,335,000**
Contingency	**30%**	**of Subtotal**	**$400,000**
Total Construction Cost			**$1,735,000**
Contractor Markups			**$350,000**
Profit	*12%*	*of Const.*	*$208,000*
Head Office Overhead	*7.0%*	*of Const.*	*$121,000*
Bonding & Insurance	*1.2%*	*of Const.*	*$21,000*
Total Contractor Price			**$2,085,000**
Owner Costs			**$230,000**
Environmental Licencing/Consulting	*3.0%*	*of Directs*	*$28,000*
Final Design		*	*$100,000*
Site Assistance & Quality Assurance	*6.0%*	*of Directs*	*$57,000*
Owner's Administration	*2.0%*	*of Contract*	*$42,000*
Total Project Cost			**$2,300,000**

* For options 3 & 4, design cost would be more than 7%. An allowance of $100,000 was used.

6.6 SCHEDULE

A preliminary design and construction schedule is shown on Figure 10 (end of report). A pre-design phase includes the environmental licensing and would begin immediately. The detailed design phase would include demolition, drawings and specifications detailing the greenfield site.

During construction, one Mayo B plant outage is expected (2 months) to plug the tunnel upstream of the surge tank. The total process from pre-design to project completion is expected to take less than one year.

7.0 ECONOMIC ASSESSMENT

The economic assessment of the options is summarized in Table 5 and the detailed economic assessment for each Option is detailed in Appendix D. The economic assessment of Option 1 and Option 2 was performed using the following:

- 65 year life span.
- 5.45% (nominal) weighted average cost of capital.
- 2% inflation for computing the present value.
- An assumed $7.10/MWhr operating and maintenance cost.
- $1.15/MWhr capital expenditure costs were taken from similar KGS Group projects.
- No water rental cost.

For Option 3 and 4, it was assumed that the hydro plant would continue in operation until the plant could no longer be operated. During that period regular maintenance activities would continue, however no dollars will be spent on capital expenditures. By operating only 1 unit at a time, it is assumed that:

- A 10 year remaining life span could be achieved with the hydro plant.
- 2% inflation for computing the present value.
- An assumed $7.10/MWhr operating and maintenance cost.
- No water rental cost.

YEC provided the energy benefit per MWhr for all four Options for years 2006 to 2035. The economic analysis performed in this study started at year 2016 in the provided data, and the 2035 projection was taken and extended for years 2036 to 2081 (Options 1 and 2 only).

The existing station switchgear is operating well beyond its expected life. The switchgear may operate for another 10 years of service, but proper consideration of safe working distances and operating boundaries should be incorporated into the work procedures for the site to limit potential for worker hazard in case of unexpected failure.

For all options it was assumed that the units will operate at a maximum of 2.3 MW. This reduces the power rating of Options 3 and Option 4, however with the max flow rate of 6 m^3/s (while both Mayo B units are running) this is assumed to be an accurate assumption that allows a more direct comparison between options.

To aid in comparing all options on a total present value basis, KGS Group incorporated costs of construction, operation, capital expenditures, produced energy benefit and the benefit of an increase in capacity. The energy and capacity benefit were taken from an email sent by YEC (Appendix E). The email pertains to the “Aishihik Rerate and Assessment” project performed by KGS Group, which assessed a comparable project and was assumed to be acceptable for this analysis. The email states the following:

- Benefit of an increase in capacity - $2.5M per MW based on avoided capital cost of new natural gas generation.
- Benefit of an increase in annual energy - $200,000 per GWh based on avoided operating (i.e. variable cost) cost of natural gas.
- Sensitivity analysis for energy benefit going from $100,000 (best possible natural gas operating cost) to $300,000 (diesel operating cost).

These options do not increase the total capacity of YEC system, however Option 3 and 4 will reduce the capacity and the “benefit of an increase in capacity” will act negatively to those options.

TABLE 5
ECONOMIC ANALYSIS SUMMARY

	OPTION 1 REDEVELOPMENT	OPTION 2 REFURBISHMENT	OPTION 3 DEMOLITION	OPTION 4 ABANDON IN SITU
Assessment Factors				
Total Project Cost	$32,000,000	$28,600,000	$4,000,000	$2,300,000
Plant Size (MW)	2.3	2.3	2.3	2.3
Annual Energy (GWhrs/yr)	10.4	10.4	7.2	7.2
Life Cycle Costs - Present Value				
Total Operating Costs	$2,100,000	$2,100,000	$500,000	$500,000
Total Capital Expenditures	$400,000	$400,000	$0	$0
Energy Benefits - Present Value				
MWhr Produced - Year 1 to 10 (Present Value)	98,771	98,771	57,278	57,278
MWhr Produced - Year 11 to 65 (Present Value)	106,528	106,528	0	0
Total MWhr Produced (Present Value)	205,300	205,300	57,278	57,278
Total Energy Benefit (@ $200/MWhr)	$41,100,000	$41,100,000	$11,500,000	$11,500,000
Increased Capacity Benefit - Present Value				
Capacity Increase (MW)	0	0	-2.3	-2.3
Total Benefit (@ $2.5M/MW)	$0	$0	-$5,750,000	-$5,750,000
Cost Indicators				
Total Present Value	$6,600,000	$10,000,000	$1,250,000	$2,950,000
Installed Project Cost ($/kW)	$13,910	$12,430		
Levelized Cost ($/kWhr)	$0.17	$0.15		
Levelized Cost ($/MWhr)	$166	$150		

The assessment in Table 5 shows that Option 2 has the greatest total present value and lowest levelized cost. Both Option 1 and 2 have a large present value compared to Option 3 and 4. Option 1 and 2 do have a large initial cost, however this cost does contain a 30% contingency and would need to be developed further to achieve a cost estimate with an improved accuracy. Option 2 is more viable than Option 1 mainly due to costs associated with demolition and construction of a new powerhouse, new cranes, new embedded components (spiral case and stay ring) and additional concrete work. Otherwise, Option 1 and 2 will have the same produced energy benefit, maintenance costs and capital expenditures. The success of Option 1 and 2 may be highly dependent on the assumed energy benefits, so a sensitivity analysis was performed and the results are summarized in Table 6 below and they are graphically represented in Figure 6.

TABLE 6
ENERGY BENEFITS SENSITIVITY ANALYSIS

	OPTION 1 REDEVELOPMENT	OPTION 2 REFURBISHMENT	OPTION 3 DEMOLITION	OPTION 4 ABANDON IN SITU
Total Present Value (@ $100/MWhr)	-$14,000,000	-$10,600,000	-$4,600,000	**-$2,900,000**
Total Present Value (@ $125/MWhr)	-$8,900,000	-$5,500,000	-$3,100,000	**-$1,400,000**
Total Present Value (@ $150/MWhr)	-$3,800,000	-$400,000	-$1,700,000	**$100,000**
Total Present Value (@ $175/MWhr)	$1,500,000	**$4,900,000**	-$300,000	$1,500,000
Total Present Value (@ $200/MWhr – Reference Price)	$6,600,000	**$10,000,000**	$1,300,000	$3,000,000
Total Present Value (@ $225/MWhr)	$11,700,000	**$15,100,000**	$2,700,000	$4,400,000
Total Present Value (@ $250/MWhr)	$16,900,000	**$20,300,000**	$4,100,000	$5,800,000
Total Present Value (@ $275/MWhr)	$22,000,000	**$25,400,000**	$5,600,000	$7,300,000
Total Present Value (@ $300/MWhr)	$27,100,000	**$30,500,000**	$7,000,000	$8,700,000

Note 1: Bolded cells indicate the highest present value for each energy benefit rate.
Note 2: Shaded cells indicate a positive present value.

Table 6 shows that Option 2 has the best total present value at energy benefits slightly above $150/MWhr and higher, and that Option 1 becomes more viable than Option 3 and 4 for an energy benefit of approximately $175/MWhr and higher.

The economics of Option 3 and 4 are highly dependent on the assumed increased capacity benefits, so a sensitivity analysis was performed using a constant energy benefit of $200,000 per GWHr and the results are summarized in Table 7.

TABLE 7
INCREASED CAPACITY BENEFITS SENSITIVITY ANALYSIS

	OPTION 1 REDEVELOPMENT	OPTION 2 REFURBISHMENT	OPTION 3 DEMOLITION	OPTION 4 ABANDON IN SITU
Total Present Value (@ $2.5M/MW – Reference Benefit)	$6,600,000	$10,000,000	$1,250,000	$2,950,000
Total Present Value (@ $4.5M/MW)	$6,600,000	$10,000,000	-$3,350,000	-$1,650,000
Total Present Value (@ $6M/MW)	$6,600,000	$10,000,000	-$6,800,000	-$5,100,000

Table 7 shows that the economics of Option 3 and 4 become progressively worse as the increased capacity benefit increases.

8.0 RECOMMENDATION

Based on the results of the economic assessment, the refurbishment of the existing plant (Option 2) is recommended as it has the highest present value and lowest levelized cost of energy for energy benefit rates slightly in excess of $150,000 per GWHr and higher, for all capacity benefit rates studied.

Should this project proceed, the following is a list of activities that will be required:

- Environmental Approval and Licensing.
- Inspection of surge tank and spiral cases.
- Study on whether to replace or reuse the runner.
- Refinement of runner/turbine rating (if runner is replaced).
- Hydraulic transient study.
- Grid/electrical parameters study.
- Detailed design, drawings and specifications.
- Equipment procurement.
- Construction.
- Commissioning.

9.0 STATEMENT OF LIMITATIONS AND CONDITIONS

9.1 THIRD PARTY USE OF REPORT

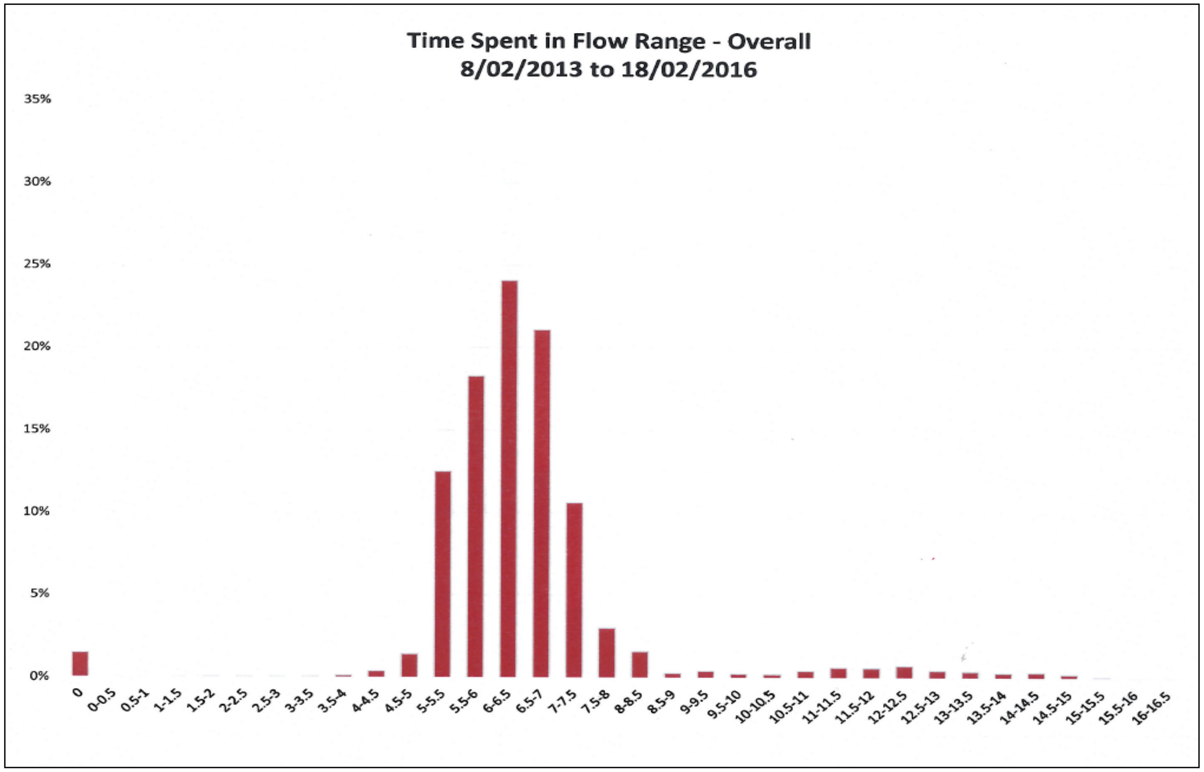
This report has been prepared for the Yukon Energy Corporation to whom this report has been addressed and any use a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

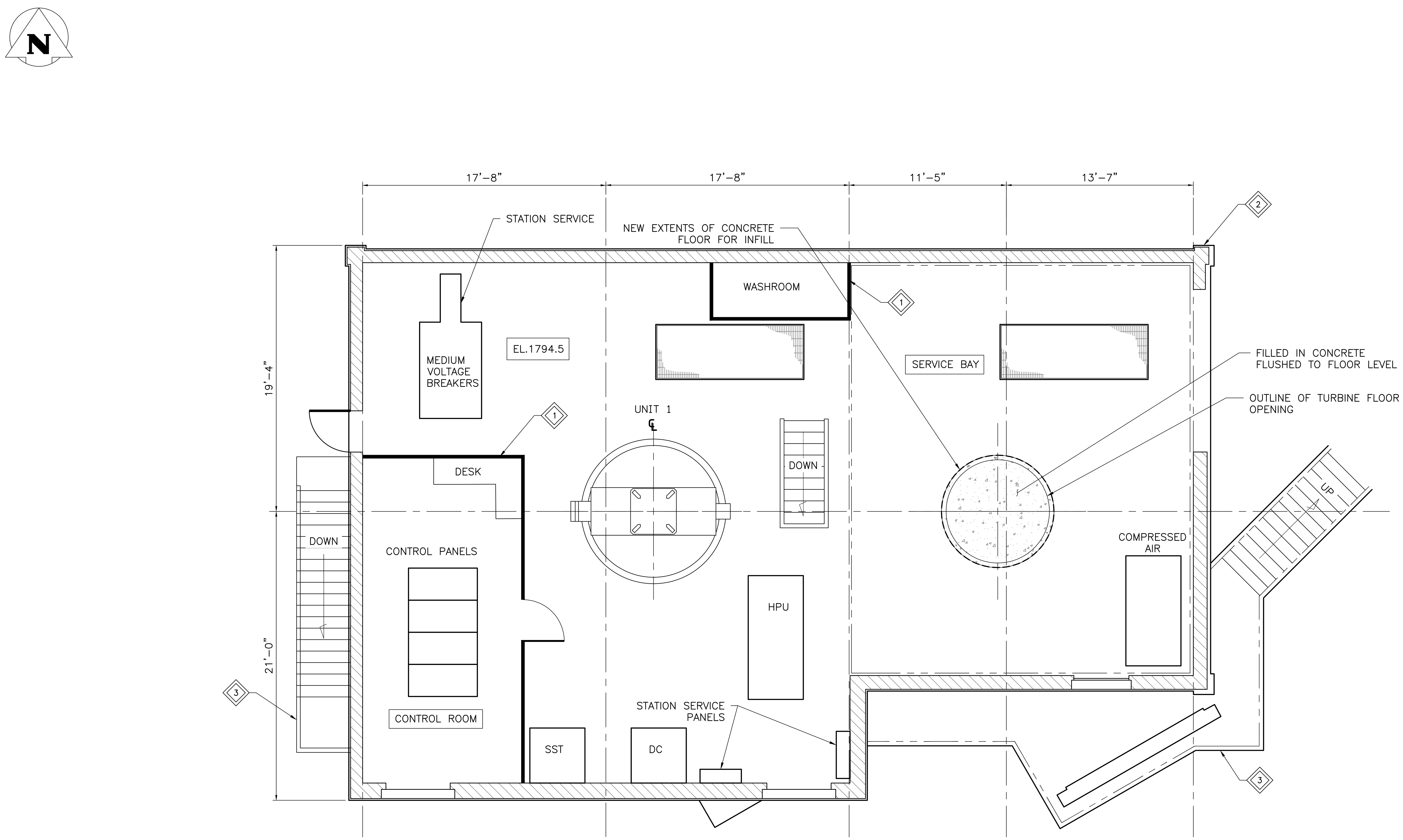
9.2 CAPITAL COST ESTIMATE STATEMENT OF LIMITATIONS

The cost estimates included with this report have been prepared by KGS Group using its professional judgment and exercising due care consistent with the level of detail required for the stage of the project for which the estimate has been developed. These estimates represent KGS Group's opinion of the probable costs and are based on factors over which KGS Group has no control. These factors include, without limitation, site conditions, availability of qualified labour and materials, present workload of the Bidders at the time of tendering and overall market conditions. KGS Group does not assume any responsibility to the Client, in contract, tort or otherwise in connection with such estimates and shall not be liable to the Client if such estimates prove to be inaccurate or incorrect.

FIGURES

FIGURE 1
TIME SPENT (%) IN FLOW RANGE (M^3/S) – OVERALL





TURBINE GENERATOR ARRANGEMENT PLAN

5 0 5 10 FT.

SCALE: 1/4"=1'-0" (24" X 36")

NOTES:

1. ONLY MAJOR EQUIPMENT LAYOUT IS SHOWN.
2. ALL EQUIPMENT IS NEW UNLESS LABELED AS EXISTING

KEY NOTES:

1. NEW ROOM
2. NEW POWERHOUSE SUPERSTRUCTURE
3. EXISTING TO REMAIN

LEGEND:

SST	STATION SERVICE TRANSFORMER
DC	DIRECT CURRENT
HPU	HYDRAULIC POWER UNIT

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
B	16/07/25	ISSUED FOR DESIGN REPORT	DAG	JCL
A	16/05/10	ISSUED FOR DESIGN REPORT	DAG	JCL

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

YUKON ENERGY

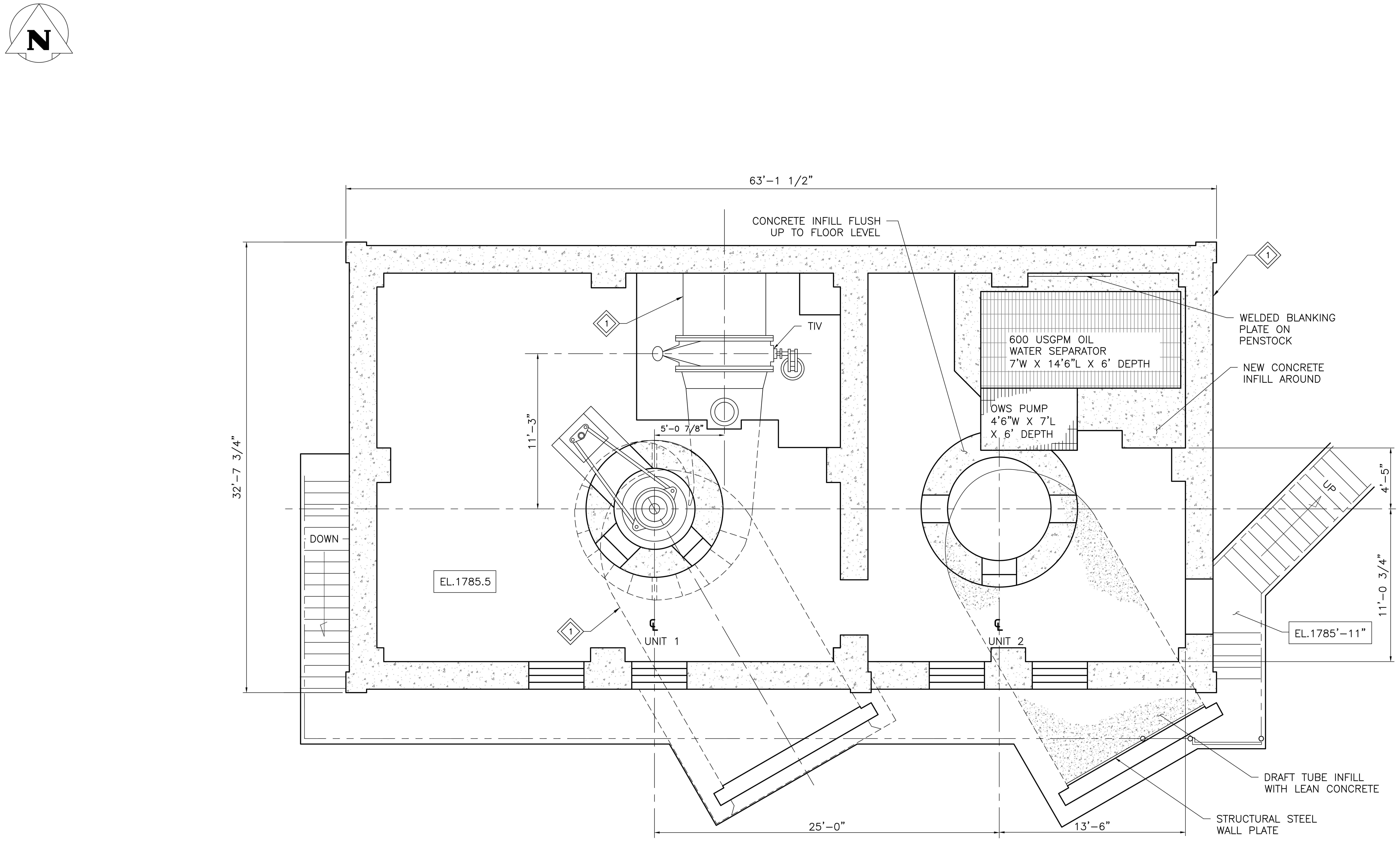
MAYO A FUTURE OPTIONS
OPTION 1 – REPLACE THE FACILITY

POWERHOUSE PLAN
MAIN FLOOR LAYOUT

JULY_2016 | FIGURE 2 | REV: B

FileName: U:\FMS\16-1404-002\16-1404-002_FIGURE 2.dwg - Tab: Rev B Plotted By: cabellanosa 16/07/22 [Fri 2:44pm]
11"x17" PLOT SCALE: 1:2

11x17



NOTES:

1. ONLY MAJOR EQUIPMENT LAYOUT IS SHOWN.
2. ALL EQUIPMENT IS NEW UNLESS LABELED AS EXISTING

KEY NOTES:

1 EXISTING TO REMAIN

LEGEND:

OWS OIL WATER SEPARATOR

TIV TURBINE INLET VALVE

TURBINE ARRANGEMENT BASEMENT PLAN

5 0 5 10 FT.

SCALE: 1/4"=1'-0" (24" X 36")

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
B	16/07/25	ISSUED FOR DESIGN REPORT	DAG	JCL
A	16/05/10	ISSUED FOR DESIGN REPORT	DAG	JCL

REVISIONS / ISSUE

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YUKON ENERGY

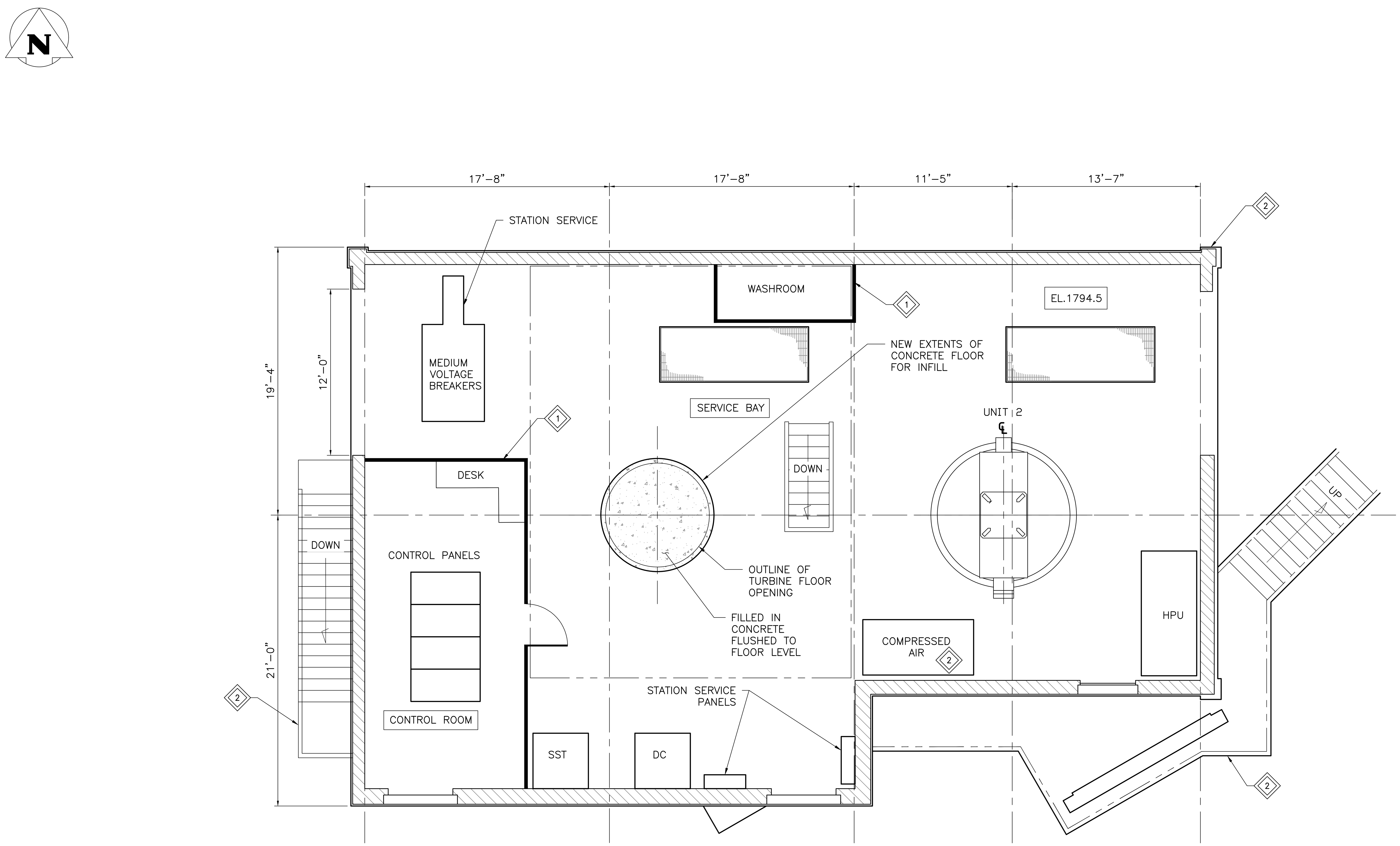
MAYO A FUTURE OPTIONS
OPTION 1 – REPLACE THE FACILITY

POWERHOUSE PLAN
BASEMENT LAYOUT

JULY_2016 | FIGURE 3 | REV: B

11x17

FileName: U:\FMS\16-1404-002\16-1404-002_FIGURE 3.dwg - Tab: Rev B Plotted By: cabellanosa 16/07/22 [Fri 2:43pm]
11"x17" PLOT SCALE: 1:2



TURBINE GENERATOR ARRANGEMENT PLAN

5 0 5 10 FT.

SCALE: 1/4"=1'–0" (24" X 36")

NOTES:

1. ONLY MAJOR EQUIPMENT LAYOUT IS SHOWN.
2. ALL EQUIPMENT IS NEW UNLESS LABELED AS EXISTING

KEY NOTES:

- 1 NEW ROOM
- 2 EXISTING TO REMAIN

LEGEND:

SST	STATION SERVICE TRANSFORMER
DC	DIRECT CURRENT
HPU	HYDRAULIC POWER UNIT

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
B	16/07/25	ISSUED FOR DESIGN REPORT	DAG	JCL
A	16/05/10	ISSUED FOR DESIGN REPORT	DAG	JCL

REVISIONS / ISSUE

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YUKON ENERGY

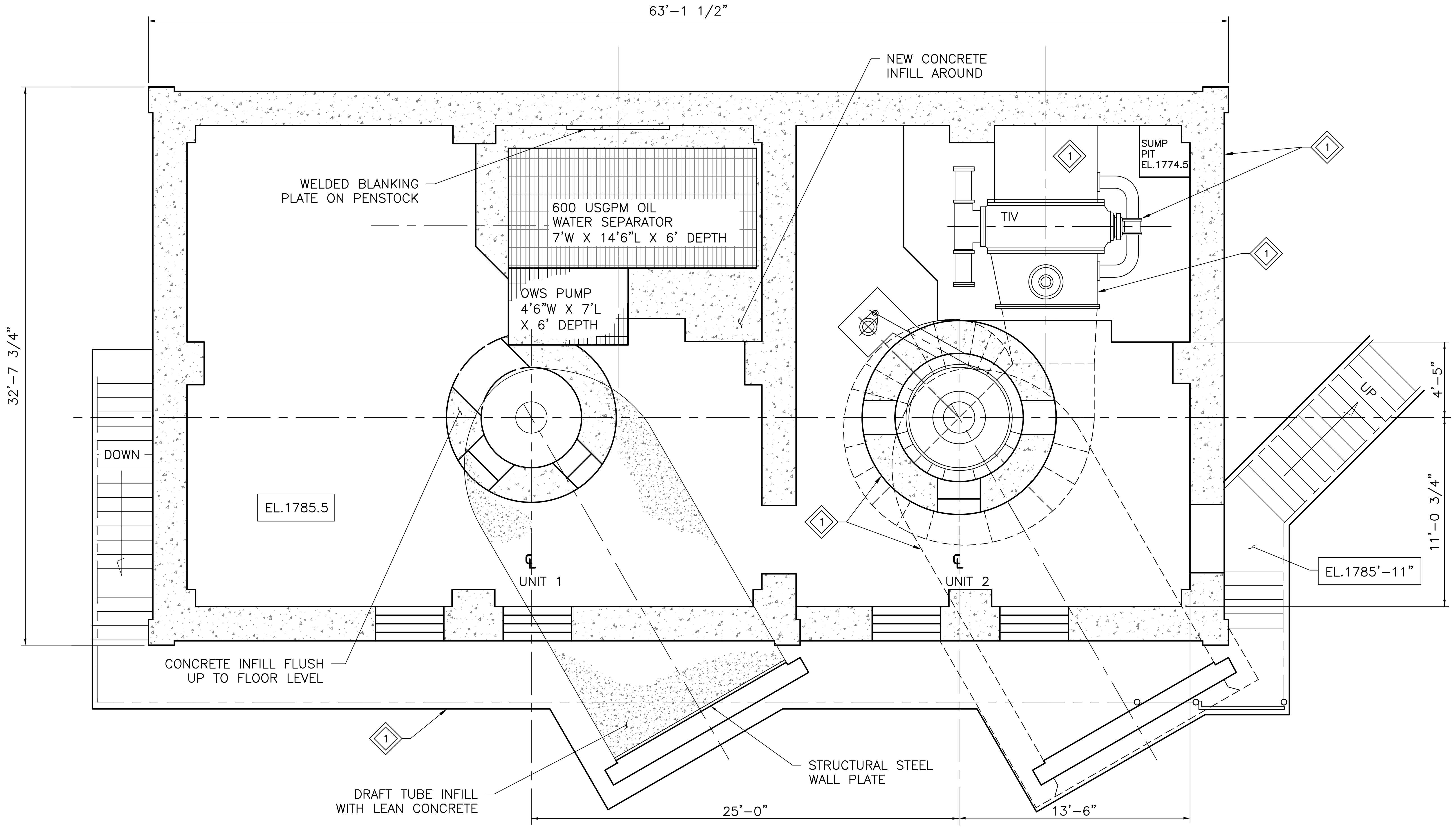
MAYO A FUTURE OPTIONS
OPTION 2 – REFURBISH THE FACILITY

POWERHOUSE PLAN
MAIN FLOOR LAYOUT

JULY_2016 | FIGURE 4 | REV: B

11x17

FileName: U:\PMS\16-1404-002\16-1404-002_FIGURE 4.dwg – Tab: Rev B Plotted By: cabellanosa 16/07/22 [Fri 2:42pm]
11"x17" PLOT SCALE: 1:2



TURBINE ARRANGEMENT BASEMENT PLAN

5 0 5 10 FT.

SCALE: 1/4"=1'-0" (24" X 36")

NOTES:

1. ONLY MAJOR EQUIPMENT LAYOUT IS SHOWN.
2. ALL EQUIPMENT IS NEW UNLESS LABELED AS EXISTING

KEY NOTES:

(1) EXISTING TO REMAIN

LEGEND:

OWS	OIL WATER SEPARATOR
TIV	TURBINE INLET VALVE

NO.	YY/MM/DD	DESCRIPTION	ISSUED BY	CHECK BY
B	16/07/25	ISSUED FOR DESIGN REPORT	DAG	JCL
A	16/05/10	ISSUED FOR DESIGN REPORT	DAG	JCL

REVISIONS / ISSUE

KGS GROUP CONSULTING ENGINEERS

YUKON ENERGY

MAYO A FUTURE OPTIONS
OPTION 2 – REFURBISH THE FACILITY

POWERHOUSE PLAN
BASEMENT LAYOUT

JULY_2016 | FIGURE 5 | REV: B

11x17
FileName: U:\PMS\16-1404-002\16-1404-002_FIGURE 5.dwg – Tab: Rev B Plotted By: cabellanosa 16/07/22 [Fri 2:42pm]
11"x17" PLOT SCALE: 1:2

FIGURE 6
NET PRESENT VALUE (NPV) VS ENERGY BENEFIT ($/MWHR)

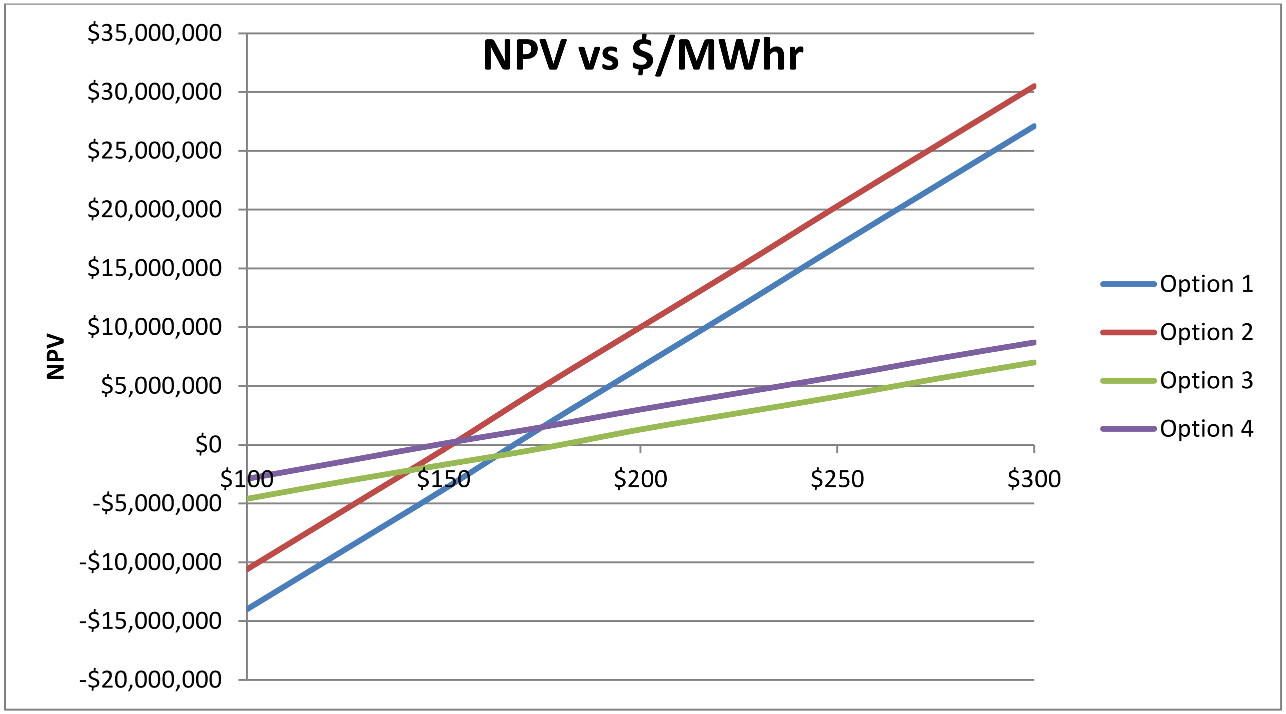
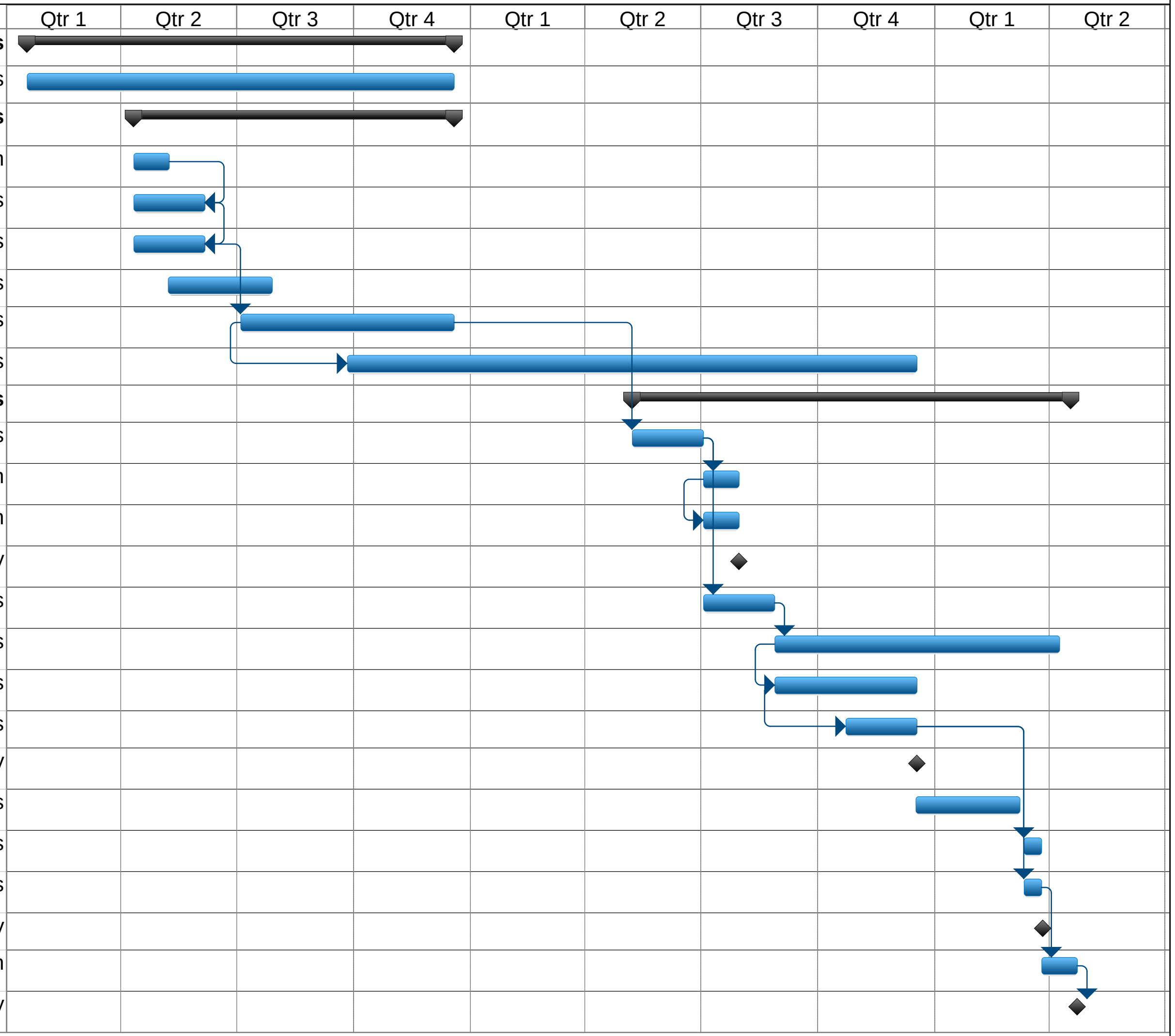


Figure 7: Mayo Hydro Preliminary Schedule - Option 1

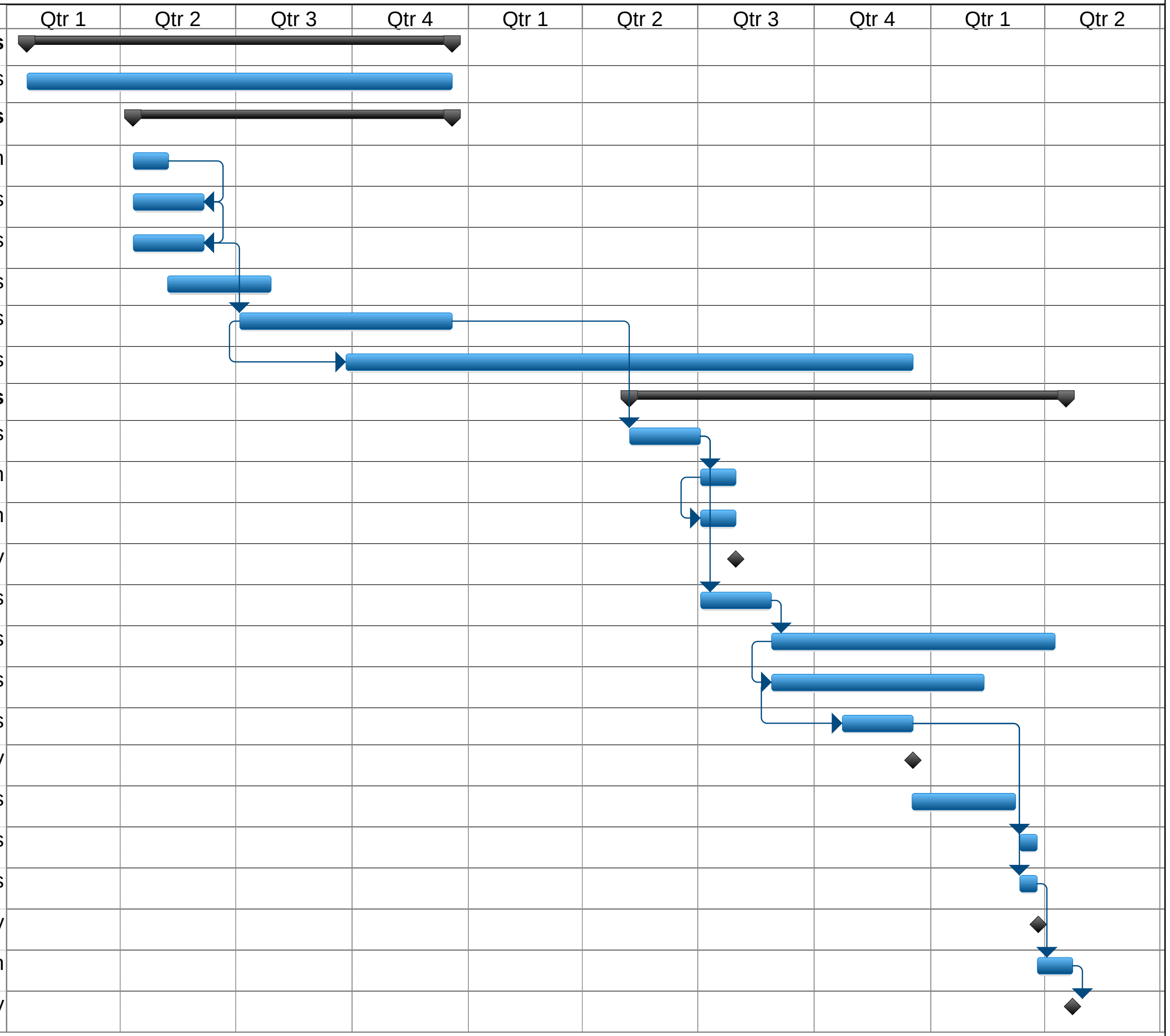
ID	Task Name	Duration
1	**Pre-design Phase**	**240 days**
2	Environmental Approval & Licensing	12 mons
3	**Detailed Design Phase**	**9 mons**
4	Inspection of surge tank and scroll cases	1 mon
5	Refinement of runner study	2 mons
6	Transient Study	2 mons
7	Grid study/electrical parameters	3 mons
8	Drawings and specifications	6 mons
9	T&G Procurement	16 mons
10	**Construction**	**247 days**
11	Mobilization and start-up	2 mons
12	Dewater Mayo Hydro & Mayo B	1 mon
13	Plug unused penstock, blank off TIV	1 mon
14	Rewater Mayo B	1 day
15	Demolition	2 mons
16	Mechanical and Electrical Balance of Plant	8 mons
17	Powerhouse structural work	4 mons
18	Dewater Mayo B and install surge tank, install new TIV	2 mons
19	Rewater Mayo B	1 day
20	Install Turbine and Generator equipment	3 mons
21	Dewater Mayo B	2 wks
22	Commission TIV	2 wks
23	Rewater Mayo B	1 day
24	Commission Turbine and generators	1 mon
25	Commercial Operation	1 day



Date: 18/07/2016 | Summary | Task | Milestone

Figure 8: Mayo Hydro Preliminary Schedule - Option 2

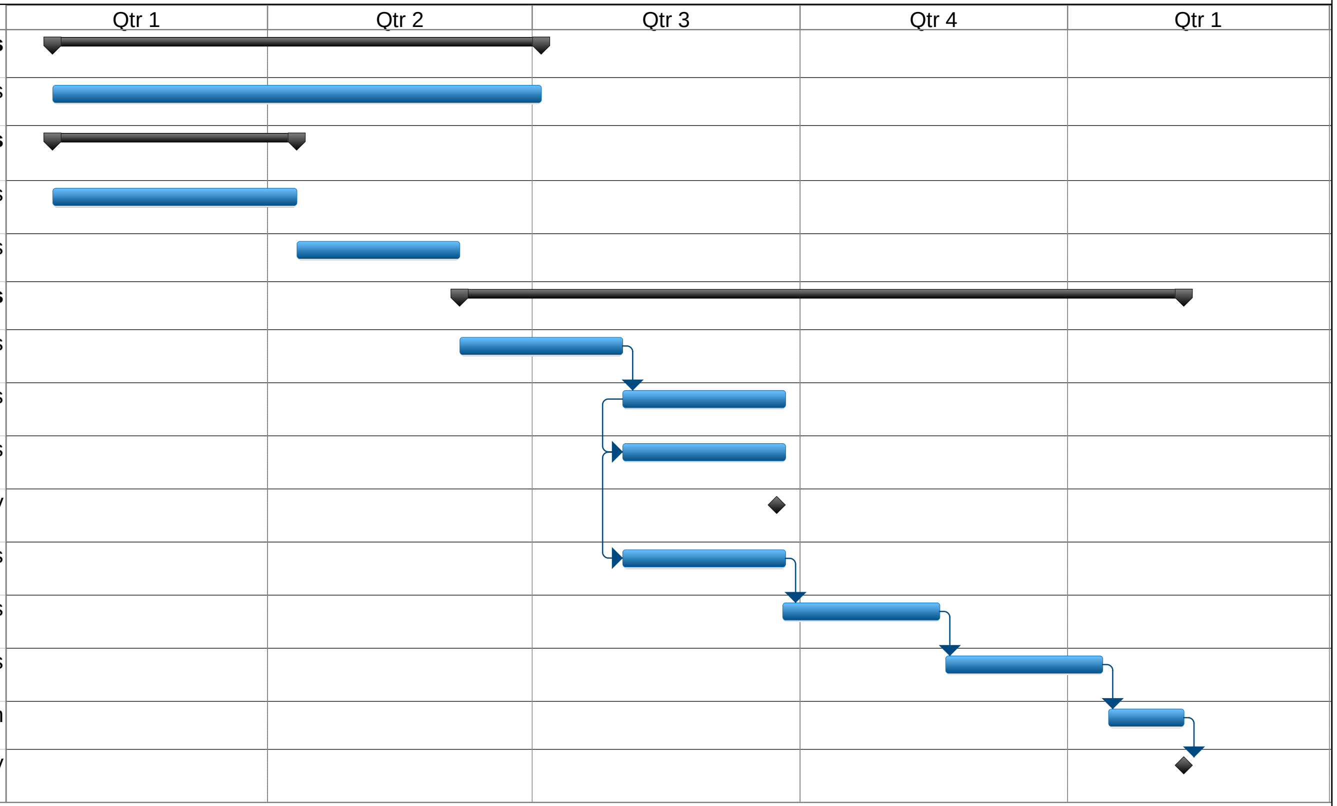
ID	Task Name	Duration
1	**Pre-design Phase**	**240 days**
2	Environmental Approval & Licensing	12 mons
3	**Detailed Design Phase**	**9 mons**
4	Inspection of surge tank and scroll cases	1 mon
5	Refinement of runner study	2 mons
6	Transient Study	2 mons
7	Grid study/electrical parameters	3 mons
8	Drawings and specifications	6 mons
9	T&G Procurement	16 mons
10	**Construction**	**247 days**
11	Mobilization and start-up	2 mons
12	Dewater Mayo Hydro & Mayo B	1 mon
13	Plug unused penstock, blank off TIV	1 mon
14	Rewater Mayo B	1 day
15	Demolition	2 mons
16	Mechanical and Electrical Balance of Plant	8 mons
17	Powerhouse structural work	6 mons
18	Dewater Mayo B and install surge tank, install new TIV	2 mons
19	Rewater Mayo B	1 day
20	Install Turbine and Generator equipment	3 mons
21	Dewater Mayo B	2 wks
22	Commission TIV	2 wks
23	Rewater Mayo B	1 day
24	Commission Turbine and generators	1 mon
25	Commercial Operation	1 day



Date: 18/07/2016 | Summary | Task | Milestone

Figure 9: Mayo Hydro Preliminary Schedule - Option 3

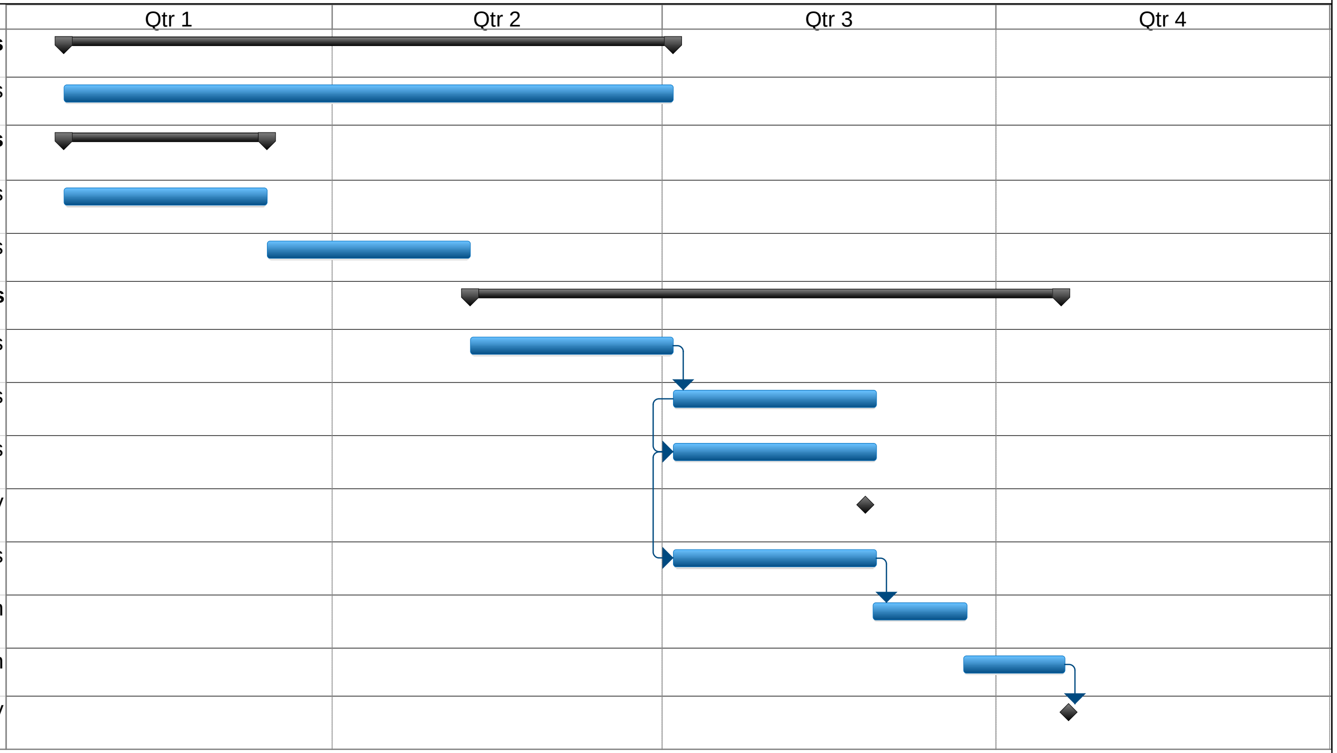
ID	Task Name	Duration
1	**Pre-design Phase**	**120 days**
2	Environmental Approval & Licensing	6 mons
3	**Detailed Design Phase**	**3 mons**
4	Drawings and specifications	3 mons
5	Tender	2 mons
6	**Construction**	**179 days**
7	Mobilization and start-up	2 mons
8	Dewater Mayo Hydro & Mayo B	2 mons
9	Plug tunnel	2 mons
10	Rewater Mayo B	1 day
11	Communication relocation	2 mons
12	Demolition	2 mons
13	Backfill and grade powerhouse and tailrace	2 mons
14	Access barriers	1 mon
15	Project Completion	1 day



Date: 18/07/2016 | Summary | Task | Milestone

Figure 10: Mayo Hydro Preliminary Schedule - Option 4

ID	Task Name	Duration
1	**Pre-design Phase**	**120 days**
2	Environmental Approval & Licensing	6 mons
3	**Detailed Design Phase**	**2 mons**
4	Drawings and specifications	2 mons
5	Tender	2 mons
6	**Construction**	**117 days**
7	Mobilization and start-up	2 mons
8	Dewater Mayo Hydro & Mayo B	2 mons
9	Plug tunnel	2 mons
10	Rewater Mayo B	1 day
11	Communication relocation	2 mons
12	Demolition	1 mon
13	Access barriers	1 mon
14	Project Completion	1 day



Date: 18/07/2016

Summary Task Milestone

APPENDIX A

MAYO HYDRO AND MAYO B GENERATING STATIONS OPTIMIZING PLANT OPERATIONS TESTING RESULTS, MAY 2013

Kontzamanis Graumann Smith MacMillan Inc.

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May 9, 2014

File No. 09-1404-01.02.08.DN300.44.0

Yukon Energy Corporation
P.O. Box 4190
Whitehorse, Yukon
Y1A 3T4

ATTENTION: Mr. Ron Gee
Water Management Engineer

RE: Mayo A and Mayo B Generating Stations
Optimizing Plant Operations Testing Results, May 2013

Dear Mr. Gee:

The Mayo B Hydroelectric Project was designed to operate with a total combined Mayo A and Mayo B flow of 25 m^3/s (19 m^3/s through Mayo B and 6 m^3/s through Mayo A). Yukon Energy Corporation (YEC) has indicated their wish to maximize the capacity of the Mayo complex by increasing these combined flows. The purpose of this letter is to describe the findings of the testing done in May 2013 and the subsequent analysis that was carried out to investigate the extent to which this can be achieved, while ensuring that adequate pressures are maintained in the penstock to Mayo B. Operating the Mayo A and B plants outside of the original design flow conditions can augment energy production; but it also carries increased risk to the penstock unless the acceptable operating conditions are maintained.

The analysis and recommendations are presented in detail in Appendix A.

Recommended maximum Mayo A flows for given Wareham Lake levels and Mayo B flows are presented in the following table:

RECOMMENDED ALLOWABLE MAYO A FLOWS

Wareham Lake Water Level (m)	Mayo A Maximum Flows (m^3/s)						
	One Mayo B Unit Running at Any Flow	Two Mayo B units Running at:					
		8.0 m^3/s Total	10.0 m^3/s Total	12.5 m^3/s Total	15.0 m^3/s Total	17.5 m^3/s Total	20.5 m^3/s Total
573.5	8.7	Wareham Lake below Minimum Level for Operation of 2 Mayo B Units					
573.6	10.0						
573.7	11.2						
573.8	12.3						
573.9	13.3	6.0	6.0	6.0	6.0	6.0	
574.0	14.2	6.0	6.0	6.0	6.0	6.0	
574.1	15.1	6.0	6.0	6.0	6.0	6.0	
574.2	15.9	6.0	6.0	6.0	6.0	6.0	
574.3	16.7	6.0	6.0	6.0	6.0	6.7	6.7
574.4	17.0	6.0	6.0	6.0	6.0	8.3	8.3
574.5	**17.0**	**6.0**	**6.0**	**6.0**	**7.5**	**9.7**	**9.7**

MAXIMUM ALLOWABLE MAYO A FLOWS

The effect of limiting wicket gate openings at Mayo B to 83% was investigated and calculated values for maximum allowable Mayo A flows are presented in Table 4 of Appendix A. The flows shown in that table are theoretically acceptable if the Mayo B wicket gates are limited to 83% or less. However, there is a risk that wicket gate limits which are not physically imposed could be inadvertently removed or defeated in the future, putting the penstock at risk.

The following limits are recommended for pressure levels at the air vent shaft at the tunnel intake:

- Minimum with two Mayo B units in operation: El. 573.4 m
- Minimum with one Mayo B unit in operation: El. 572.9 m

It is recommended that the overall head losses along the intake and conveyance system be monitored and reviewed periodically (suggest minimum of every 3 years) and if/when an event occurs that raises concerns about the integrity of the system, and that the water levels at PI2 and at the air vent shaft be monitored continuously.

If monitoring data shows increased head losses with respect to those obtained during the May 2013 tests, it is recommended to assess the situation and adjust the plant flows to maintain the levels at PI2 stipulated in the plant operational limits. Increased head losses are indication of changes in the conveyance system, possibly debris accumulation or ice blockage at the trashracks or along the tunnel or penstock. These would need to be corrected to restore the allowable flows indicated in this letter.

Other operational conditions at the Mayo plants are recommended to be maintained. These are:

Mayo B Flows:

- Minimum: 4 m^3/s per unit

Mayo A Flows:

- No limits when Mayo B not operated

Levels at PI2 (highest point in the Mayo B penstock):

- Low Alarm: El. 572.5 m
- Low-Low Alarm (Shutdown): El. 572.2 m

In preparing this letter, KGS Group has assumed that YEC will confirm that intake flows in excess of 25 m^3/s are in full accordance with the environmental license for the tunnel intake at Wareham Lake and its trashrack, and that YEC will undertake any regulatory requirements, if necessary, to modify the terms and conditions of the license to allow these flows. This report addresses only the technical aspects of increasing the maximum flow at the plants beyond the design values and the implications with respect to penstock pressures.

This letter has been prepared for Yukon Energy Corporation to whom it has been addressed and any use that a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

Should you have questions regarding this assessment, please contact the undersigned.

Prepared By:

Fuad Curi, P.Eng.
Senior Water Resources Engineer

Approved By:

Gord McPhail, P.Eng.
Senior Specialist Engineer

cc: Lawrence Joudry and Guy Morgan of Yukon Energy Corporation
Rick Martin and Joel Lambert of KGS Group

PROFESSIONAL
YUKON
GORDON D. McPHAIL
TERRITORY
ENGINEER

APPENDIX A

MAYO A AND MAYO B GENERATING STATIONS
OPTIMIZING PLANT OPERATIONS TESTING RESULTS, MAY 2013
DETAILED ANALYSIS AND RECOMMENDATIONS

1.0 BACKGROUND INFORMATION

The operational limits for Mayo B (range of forebay levels and flows) have been revised using data obtained during the first two years of operation of the plant and are summarized in the KGS Group letter: *Mayo B Hydroelectric Project – Operational Conditions for the Mayo B Plant (Ref. 1)*. The conditions indicated in that letter are as follows:

Forebay Levels at Wareham Lake:

- Maximum: El. 574.5 m
- Minimum with two Mayo B units in operation: El. 573.9 m
- Minimum with one Mayo B unit in operation: El. 573.5 m

Mayo B Flows:

- Minimum: 4 m^3/s per unit
- Maximum: 9.5 m^3/s per unit

Mayo A Flows:

- Maximum: 6 m^3/s with two Mayo B units in operation: El. 573.9 m
- No limits when Mayo B not operated

Levels at PI2 (highest point in the Mayo B penstock):

- Low Alarm: El. 572.5 m
- Low-Low Alarm (Shutdown): El. 572.2 m

Levels downstream of the trashracks:

- Minimum with two Mayo B units in operation: El. 573.7 m
- Minimum with one Mayo B unit in operation: El. 573.3 m

The stipulated minimum level at PI2 ensures that at this point the design safety margins will be maintained in all operation conditions considered during the design.

2.0 TEST DATA COLLECTED

The data collected from tests conducted on May 28 and 29 of 2013 allowed the review of the operational limits described in this letter. The recommendations here provided are based on the status of the system during these tests. Conditions could arise in the future that could cause exacerbated head losses at any point in the system. For instance, the trashracks could become severely blocked by debris or, with time, there is algae growth or physical deterioration of the tunnel, or corrosion of the penstock. Should any factor change with time to increase the system head losses observed, the allowable flows presented in this letter would need to be reduced to maintain operation of the plants within the specified limits.

Overall monitoring of pressure levels and the alarms at PI2 is required to allow early detection of conditions within the conveyance system that exceed the specified design conditions. It is recommended that the overall conveyance system head losses be reviewed periodically (every 3 years would be a reasonable guide) and/or if an event occurs that raises concerns about the integrity of the system. The water levels at PI2 and at the trashrack shall continue to be monitored continuously.

2.1 CONVEYANCE SYSTEM FLOWS, PRESSURES AND POWER AT THE PLANTS

The measurements obtained during the tests included flows at Mayo B, Wareham Lake levels, pressures at PI2, pressures at the inlet of the Mayo B turbines as well as generated power and wicket gate openings at the Mayo A and Mayo B turbines. These were obtained for various conditions of flows in Mayo A and Mayo B and are summarized in Table 1.

TABLE 1: SUMMARY OF COLLECTED DATA IN MAY 2013

Time Frame		Average Wareham Lake Level (m)	Average PI2 Level (m)	Average Flow (m^3/s)		Power (MW)		Gate Opening % (Mayo A)		Gate Opening % (Mayo B)		Piezometric head difference Lake - PI2 (m)
From	To			Mayo A	Mayo B	Mayo A	Mayo B	MH1	MH2	MBH1	MBH2	
28/05/2013 8:00	28/05/2013 9:00	574.32	572.98	5.9	17.2	1.6	8.7	0	49	82	80	1.34
28/05/2013 10:31	28/05/2013 11:00	574.33	572.62	6.1	20.6	1.7	9.9	0	52	99	99	1.71
28/05/2013 11:21	28/05/2013 11:30	574.32	572.51	7.2	20.5	1.7	9.8	21	53	99	99	1.82
28/05/2013 11:40	28/05/2013 12:20	574.32	572.32	10.1	20.5	2.7	9.8	47	49	99	99	2.00
28/05/2013 13:20	28/05/2013 14:00	574.30	572.10	12.3	20.5	3.5	9.7	61	57	99	99	2.20
28/05/2013 14:55	28/05/2013 14:55	574.29	572.13	16.8	15.0	4.9	7.4	87	87	73	73	2.16
28/05/2013 15:50	28/05/2013 16:00	574.28	572.83	6.2	18.1	1.7	9.2	0	53	86	86	1.45
28/05/2013 16:30	28/05/2013 17:00	574.28	573.02	5.6	16.5	1.5	8.4	0	47	78	78	1.26
29/05/2013 8:30	29/05/2013 9:00	574.25	572.02	12.7	20.5	3.6	9.7	62	58	99	99	2.23
29/05/2013 9:15	29/05/2013 9:35	574.24	571.75	15.2	20.5	4.5	9.6	75	70	99	99	2.49
29/05/2013 9:44	29/05/2013 9:48	574.24	572.06	12.3	20.6	3.5	9.7	60	56	99	99	2.18
29/05/2013 9:55	29/05/2013 10:05	574.24	572.26	10.0	20.5	2.6	9.8	48	44	99	99	1.98
29/05/2013 10:20	29/05/2013 10:35	574.23	572.84	6.0	17.7	1.6	9.0	0	51	84	84	1.40
29/05/2013 11:50	29/05/2013 12:10	574.23	573.17	16.4	4.6	4.8	2.0	79	76	49	0	1.06
29/05/2013 14:00	29/05/2013 15:00	574.21	572.76	6.4	18.0	1.8	9.1	0	55	86	86	1.45

2.2 WATER LEVEL CHANGES AND HEAD LOSSES AT THE TRASHRACK AND INTAKE

The water level changes between the reservoir and various locations in the intake were measured in order to confirm the estimated head losses in the intake entrance and trashrack. The water levels were measured on site during the tests (at the forebay, the intake gate slot and the air vent shaft) and they form the baseline for this analysis. The measured elevation differentials from the lake to the intake gate slot and the air vent comprise not only intake and trashrack head losses but also what is termed the “velocity head” at each point. The latter is not a head loss but rather corresponds to the kinetic energy in the flow. Both head losses and velocity head were considered in the verifications summarized in Table 2 below. The table shows the level differentials measured during the tests and the corresponding values that were estimated during the design for the location of the air vent, based on the design assumptions for head losses and velocities and the reported conditions at the intake. The table includes a range of values that were calculated during the design. These include the “best estimate” as well as a range of low (optimistic) and high (conservative) head loss values. The best estimate values most closely match the level differences that were measured up to the air vent shaft.

TABLE 2: MEASURED LEVELS AT THE INTAKE OF THE MAYO GS TUNNEL WITH RESPECT TO WAREHAM LAKE

Total Intake Flow [m^3/s]	Mayo A Flow [m^3/s]	Mayo B Flow [m^3/s]	Difference in Level with Respect to Wareham Lake (m)				
			Measured up to the Intake Gate Slot	Measured up to the Air Vent Shaft	Estimated for the Entire Intake Structure		
					Optimistic	Best Estimate	Conservative
26.4	6	20.4	Not measured	0.52	0.49	0.55	0.62
30.4	10	20.4	0.52	0.71	0.65	0.73	0.83
32.8	12.5	20.3	0.60	0.82	0.76	0.85	0.96
35.2	15	20.2	0.73	0.99	0.88	0.98	1.11

Note: These measurements were taken on May 29, 2013, directly by Ron Gee and Joel Lambert. These values are not based on SCADA data.

It must be noted that the measurements summarized in Table 2 were performed with a relatively clean trashrack. Significant debris blockage of the trashrack in the future will increase the measured differences from those observed at the various flows. Any increase in excess of 0.3 m from the intake water levels measured would warrant review of the combined plant operation as well as inspection of the trashrack.

2.3 MAYO B FLOWS

The combined flows at Mayo B were measured by instrumentation and collected through SCADA. The flows at Mayo A are estimated based on the measured power and with relationships used by YEC in the past. These relationships have not been reviewed in detail by KGS Group but result in flows that are within the expected range of values. The recommendations provided in this letter are based on application of those relationships for estimation of Mayo A flows and should be revised if these were modified.

The May 2013 tests results showed that a combined flow of 20.5 m^3/s for the two Mayo B turbines was required to obtain full plant capacity (close to 10 MW). This flow exceeded the maximum of 9.5 m^3/s per unit used in the project design as indicated in the Operational Condition Letter. This greater than expected flow was consistent with the findings of the performance testing conducted by Accusonic which suggest that the efficiency of the turbines and generators would not meet the guaranteed level.

The greater flow needed by Mayo B to produce maximum plant capacity limited the amount of flow that could be concurrently passed through Mayo A while maintaining the pressures in the system above the required minimum values.

The efficiency shortfall of the Mayo B units was rectified by closing the draft tube air admission valves. With the air admission valves closed Mayo B now produces the rated plant capacity closer to the expected flow. YEC has now implemented a wicket gate limit at Mayo of 83% in the plant’s control system software.

3.0 DATA ANALYSIS AND DISCUSSION

3.1 ALLOWABLE MAYO A FLOWS

Based on the data listed in Table 1, a relationship was developed between the Mayo A and Mayo B flows and the resulting pressure head difference between Wareham Lake and PI2. That relationship in metric units is as follows:

Pressure Head Difference = $0.00396\ Q_A^2 + 0.00387\ Q_B^2$

Where: Q_A= Total flow through the Mayo A powerhouse (m^3/s)

Q_B = Total flow through the Mayo B powerhouse (m^3/s)

Figure 1 shows the values of pressure head difference between Wareham Lake and PI2 according to the above relationship, compared with the values obtained from the tests.

As was noted above, it cannot be over-emphasized that the above relationship reflects the conditions found during the tests, including a relatively clean trashrack, and could change if these conditions were altered. For instance, if there is debris or ice blockage at the trashracks, these would need to be cleaned to restore the assumed losses. Otherwise, the relationship would need to be modified.

It must also be noted that at times the levels at PI2 can oscillate within a 0.5 m range. This has been observed (through the instrumentation as well as with direct measurements using a string line and a float) at several instances during the first two years of operation of Mayo B, and occurs even when the Mayo B units are shut off and there is only flow through Mayo A. This fact confirms the need to monitor the water levels at PI2 and to maintain the safe margins reflected in the recommended alarm levels.

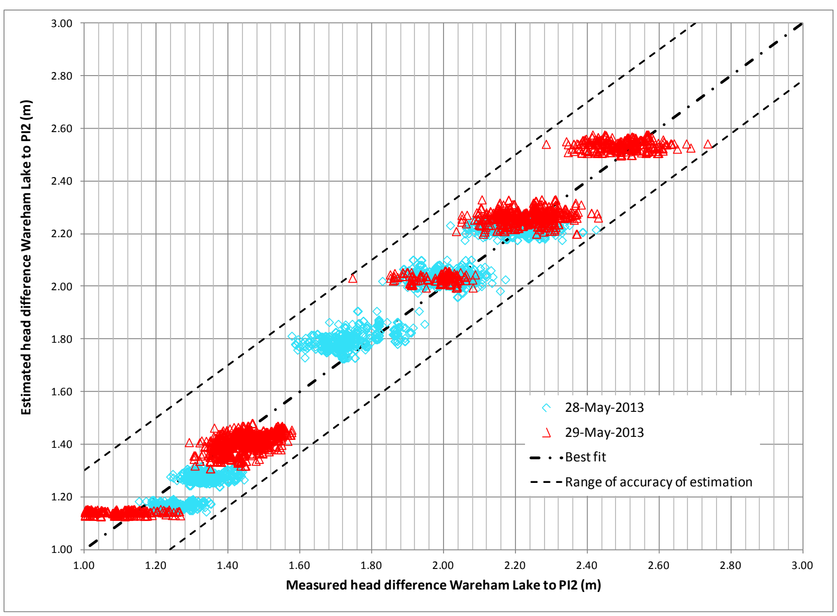

Figure 1: Piezometric Head Difference Wareham Lake to PI2 (estimated vs. measured)

Based on the test results and the relationships derived from them, the maximum allowable flows at Mayo A, for various conditions at Mayo B and Wareham Lake are indicated in Tables 3 and 4. These tables show the amount of water that can be safely directed to Mayo A, given the water level in Wareham Lake and the steady-state flow through Mayo B. The first column in the tables shows the Wareham Lake level and the title row shows the total steady state flow (two units combined) at Mayo B. For example, if Wareham Lake is at El. 574.2 m and Mayo B is operating with a total flow of 12.5 m^3/s, Mayo A can safely be operated up to a maximum of 6.0 m^3/s (Table 3) for unrestricted opening of the Mayo B units. If the wicket gates at Mayo B are physically limited to 83% opening under all operating modes (Table 4), then Mayo A can safely be operated up to a maximum of 8.4 m^3/s.

TABLE 3: ALLOWABLE MAYO A FLOW
IF MAYO B WICKET GATES ARE ALLOWED TO OPEN TO 100%

Wareham Lake Water Level (m)	Mayo A Maximum Flows (m^3/s) with No Limit on Mayo B Wicket Gate Opening						
	One Mayo B Unit Running at Any Flow	Two Mayo B units Running at:					
		8.0 m^3/s Total	10.0 m^3/s Total	12.5 m^3/s Total	15.0 m^3/s Total	17.5 m^3/s Total	20.5 m^3/s Total
573.5	8.7	Wareham Lake below Minimum Level for Operation of 2 Mayo B Units					
573.6	10.0						
573.7	11.2						
573.8	12.3						
573.9	13.3	6.0	6.0	6.0	6.0	6.0	
574.0	14.2	6.0	6.0	6.0	6.0	6.0	
574.1	15.1	6.0	6.0	6.0	6.0	6.0	
574.2	15.9	6.0	6.0	6.0	6.0	6.0	
574.3	16.7	6.0	6.0	6.0	6.0	6.7	6.7
574.4	17.0	6.0	6.0	6.0	6.0	8.3	8.3
574.5	**17.0**	**6.0**	**6.0**	**6.0**	**7.5**	**9.7**	**9.7**

The criteria used for determining the allowable Mayo A flow rates was to maintain a safety margin for the water level at PI2 in the event that Mayo B was loaded from the steady state condition (shown in the title row in the tables) to full load, at the maximum wicket gate opening rate. The shaded areas indicate that the safety margin on the water level at PI2 is less than what was originally adopted for the design (2 m in transient conditions). Mayo B should not be continuously operated in this region, except for when restoring the grid.

Table 3 is based on a full capacity of 10.25 m^3/s for each unit at Mayo B, which is more than the previously stipulated 9.5 m^3/s but corresponds to the test measurements for maximum power at the plant with the draft tube air admission valves open.

Table 4 takes into account a physical limit to the wicket gate opening at Mayo B of 83%. Table 4 can only be used if the wicket gates at Mayo B are limited to a maximum 83% opening.

**TABLE 4: ALLOWABLE MAYO A FLOW
IF MAYO B WICKET GATES LIMITED TO 83%**

Wareham Lake water level (m)	Mayo A Maximum Flows (m^3/s) with Mayo B wicket gates limited to 83% opening						
	One Mayo B Unit Running at any flow	Two Mayo B units Running at:					
		8.0 m^3/s Total	10.0 m^3/s Total	12.5 m^3/s Total	15.0 m^3/s Total	17.5 m^3/s Total	19.5 m^3/s Total
573.5	9.7	Wareham Lake below Minimum Level for Operation of 2 Mayo B Units					
573.6	10.9						
573.7	12.0						
573.8	13.0						
573.9	13.9	6.0	6.0	6.0	6.4	7.3	
574	14.8	6.0	6.0	6.0	8.1	8.9	
574.1	15.6	6.0	6.0	6.7	9.5	10.2	6.0
574.2	16.4	6.0	6.0	8.4	10.8	11.4	7.6
574.3	17.0	6.0	7.0	9.7	11.9	12.4	9.1
574.4	17.0	6.2	8.6	11.0	12.9	13.4	10.4
574.5	17.0	8.0	10.0	12.0	13.8	14.3	11.5

The basis for Tables 3 and 4 includes:

- A rate of Mayo B wicket gate opening limited to 100% per 45 seconds.
- The assumption that Figure 1 represents, and will continue to represent, actual conditions in the Mayo A / Mayo B water conveyance. Increased losses in the water conveyance will invalidate Tables 3 and 4.

The largest factor contributing to the limits shown in Tables 3 and 4 is the potential transient effect of accepting load at Mayo B. The magnitude of this transient effect is less pronounced when the initial steady state flow at Mayo B is closer to its full capacity; as a result, more flow can be passed through Mayo A.

When the initial steady-state flow at Mayo B is near 17.5 m^3/s the head losses in steady state condition increase to the point where the allowable flows at Mayo A need to be reduced to maintain the steady state pressure at PI2 above current alarm levels.

3.2 TRASH RACK HEAD LOSSES

Divers have previously reported that rock rubble is partially blocking the trashrack at the intake by 20% to 30% of the opening. Removing this rubble was not considered prudent as it was not evident to the divers that the removal could be done in safe manner. There was potential that this would lead to further deterioration of the slope adjacent to the intake. The differences in water levels from Wareham Lake to the air vent shaft, shown in Table 2, correspond closely to the values estimated by KGS Group at the design stage, when adjusted to include a 20% blockage in front of the trashracks. The measured and estimated values are shown in Figure 2.

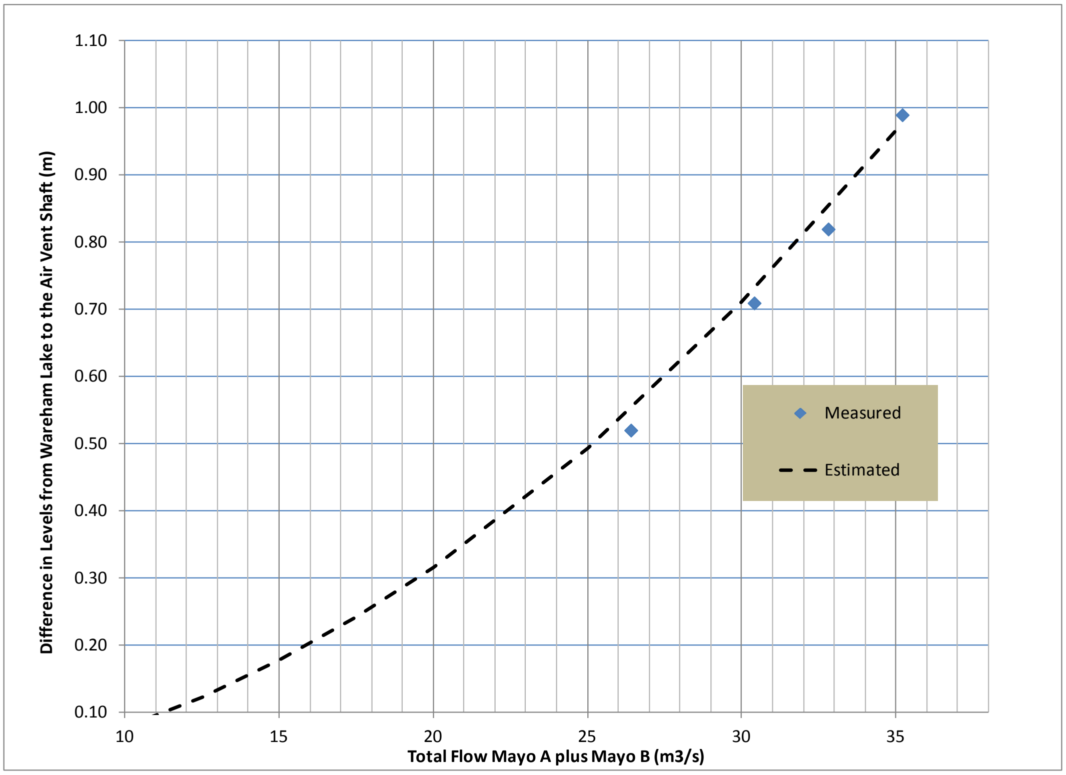

Figure 2: Level Difference between Wareham Lake and Intake Air Vent Shaft

The values provided in Figure 2, and the corresponding minimum levels at PI2, suggest that the following levels at the air vent shaft could be adopted:

- Minimum with two Mayo B units in operation: El. 573.4 m
- Minimum with one Mayo B unit in operation: El. 572.9 m

These are lower than those indicated in Ref.1. The water levels at the air vent shaft are currently collected through SCADA. It is important that these levels and the levels at Wareham Lake are monitored and that YEC maintains a record of the corresponding readings before and after cleaning and/or inspecting the trashracks, as well as a record of the conditions encountered there. This data can then be used as a basis for early detection of debris blockage and for possible future modification to the operational limits.

4.0 RECOMMENDATIONS

KGS Group recommends that the flows through the Mayo A and Mayo B powerhouses be limited to the levels listed in Table 3 as these flow rates provide the design margin of safety on the water levels at the penstock high point vent (PI2) even if the Mayo B wicket limit is not in place. The values listed in Table 4 are only safe if the Mayo B wicket gate opening is limited to 83% or less.

The following limits are recommended for pressure levels at the air vent shaft at the tunnel intake:

- Minimum with two Mayo B units in operation: El. 573.4 m
- Minimum with one Mayo B unit in operation: El. 572.9 m

Other operational conditions at the Mayo plants are recommended to be maintained. These are:

Mayo B Flows:

- Minimum: 4 m^3/s per unit

Mayo A Flows:

- No limits when Mayo B not operated

Levels at PI2 (highest point in the Mayo B penstock):

- Low Alarm: El. 572.5 m
- Low-Low Alarm (Shutdown): El. 572.2 m

It is recommended that the overall head losses along the conveyance system be reviewed periodically (suggest minimum of every 3 years) and if/when an event occurs that raises concerns about the integrity of the system, and that the water levels at PI2 and at the air vent shaft be monitored continuously.

If monitoring data shows increased head losses with respect to those obtained during the May 2013 tests, it is recommended to assess the situation and adjust the plant flows to maintain the levels at PI2 stipulated in the plant operational limits. Increased head losses are indication of changes in the conveyance system, possibly debris accumulation at the trashracks or along the tunnel or penstock. These would need to be corrected to restore the allowable flows indicated in this letter.

5.0 REFERENCES

1. Letter from Gord McPhail (KGS Group) to Guy Morgan (YEC) Re: Mayo B Hydroelectric Project – Operational Conditions for the Mayo B Plant. January 25, 2012.

APPENDIX B

EMAIL: ANDRITZ – FRANCIS TURBINE/GENERATOR REDEVELOPMENT STUDY (APRIL 11, 2016)

From:	Broadhurst Gary
To:	Joel Lambert; Daniel Giesbrecht
Cc:	Taylor Thomas
Subject:	2016.04.11 / YEC / Mayo A GS / KGS - Redevelopment Study / Francis Turbine+Generator Budget Price Request / Q&A"s
Date:	April-11-16 4:41:52 PM
Attachments:	image001.png image002.png

Hi Joel,

Find below our responses to your questions

1. Turbine full load efficiency is 91.7% giving turbine output = 2366 KW. With generator eff = 97% you get generator output = 2295 rather than 2200. Initial offer was rounded down to 2200 KW. Though, same price.
2. There would be cost premiums rather than savings to go with generator voltage of 6.9KV. In addition to extra cost for generator there would also be need for 15KV switchgear rather than 5KV, which would result in cost increase due to change in voltage class. For such small generator outputs, the 4.160 kV voltage is a better solution.

We trust these responses answer your questions appropriately.

Kind regards,
Gary

From: Joel Lambert [mailto:JLambert@kgsgroup.com]
Sent: April-11-16 12:23 PM
To: Broadhurst Gary; Daniel Giesbrecht
Cc: Taylor Thomas
Subject: RE: YEC / Mayo A GS / KGS - Redevelopment Study / Francis Turbine+Generator Budget Price Request

Thank you very much for the budget pricing Gary. This is very useful.

I just have a few questions about this. What would the peak efficiency of the turbine be? You show a 2200 kW generator, but even at 90% turbine efficiency and 97.5% generator efficiency, I get an output slightly above 2200 kW. I am trying to firm up what the output would be to use in the economic analysis.

Also, would changing to a 6900 V generator change the cost significantly?

Regards,
Joel

From: Broadhurst Gary [mailto:Gary.Broadhurst@andritz.com]
Sent: Friday, April 01, 2016 6:23 PM
To: Joel Lambert; RDerksen@kgsgroup.com
Cc: Taylor Thomas
Subject: RE: YEC / Mayo A GS / KGS - Redevelopment Study / Francis Turbine+Generator Budget Price Request

Hi Joel & Rudy,

Andritz Hydro is pleased to provide you with our budget offer as requested for the Mayo A Redevelopment Study.

The turbine runner diameter is 986 mm. Setting elevation is 0.75 M above TWL. Generator would be 600 rpm; 2200 KW 4160 V.

Scope is:

- Vertical Francis turbine with steel spiral case and steel draft tube elbow
- 4160 V Synchronous generator with brushless excitation
- Turbine generator controls including governor function
- 5 KV metal clad switchgear
- DC power system
- 150 KVA Station Service transformer
- Installation advisor
- Commissioning and start-up

Budget price is $3,300,000 Taxes extra DDP site in the Yukon

Attached are the following documents:

- Preliminary turbine hydraulic outline
- Compact Francis Turbine brochure

Your assumption regarding the Andritz Hydro A CAT (Compact Axial Turbine) turbine is correct, as it would probably not be a good fit for the Mayo A GS Redevelopment concept of utilizing the existing powerhouse, because of the need for a deep setting with such a high head. In the event a completely new powerhouse would be considered then it might be applicable to consider our A CAT type turbines.

We trust this budget offer is of service to KGS in performing your Mayo A GS, Redevelopment Study. We'd appreciate if KGS could keep us abreast of developments of your study to YEC.

Kind regards,

Gary BROADHURST, PEng
Regional Sales Director, Western Canada

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Thank you.

From: Joel Lambert [mailto:JLambert@kgsgroup.com]
Sent: March-03-16 9:35 AM
To: Broadhurst Gary
Subject: RE: YEC / Mayo A GS / KGS - Redevelopment Study / Francis Turbine+Generator Budget Price Request

Hi Gary,

Here are a few drawings for the Mayo A Powerhouse and one of the site. Feel free to explore other options, but do not feel obliged to “optimize” at this stage. The deadlines are quite short so it doesn’t leave much time.

I did not look at this in detail, but I would have thought that a Kaplan or your CAT turbines would have needed a much deeper setting than the existing substructure would allow. I strongly suspect that a francis machine will win out, but I have been wrong before.

Best regards,
Joel

From: Broadhurst Gary [mailto:Gary.Broadhurst@andritz.com]
Sent: Wednesday, March 02, 2016 10:45 AM
To: Joel Lambert
Cc: 'Michael Tilbrook'; Duflon Pierre
Subject: RE: YEC / Mayo A GS / KGS - Redevelopment Study / Francis Turbine+Generator Budget Price Request

Hi Joel,

We’d appreciate obtaining some of the existing Mayo A powerhouse drawings as we’d like to explore the possibility of other turbine types such as Kaplan or our Compact Axial Turbines (CAT).

Cheers,
Gary

Gary BROADHURST, PEng
Regional Sales Director, Western Canada

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gary.broadhurst@andritz.com
www.andritz.com

From: Broadhurst Gary
Sent: March-01-16 5:09 PM
To: 'Joel Lambert'
Cc: 'Michael Tilbrook'
Subject: RE: YEC / Mayo A GS / KGS - Redevelopment Study / Francis Turbine+Generator Budget Price Request

Hi Joel,

Thank-you for reaching out to Andritz Hydro regarding your Mayo A Redevelopment Study.

We'll endeavour to provide you with a budgetary estimate for a new vertical Francis turbine and generator for the Mayo A project. As you mentioned a horizontal Francis turbine & generator perhaps could be considered if we had more details regarding existing powerhouse.

I look forward meeting you during my next trip to Winnipeg or perhaps if you are coming thru / to Vancouver.

Kind regards,
Gary

Gary BROADHURST, PEng
Regional Sales Director, Western Canada

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Thank you.

From: Joel Lambert [mailto:JLambert@kgsgroup.com]
Sent: March-01-16 2:16 PM
To: Broadhurst Gary
Cc: 'Michael Tilbrook'
Subject: Mayo A - New unit pricing

Hi Gary,

As we discussed on the phone yesterday, I would like to get some pricing on a new for the Mayo A facility at Yukon Energy. We are currently conducting a study to help YEC determine what to do with the facility (Replace, refurbish, remove, etc.). For various reasons, we are looking at removing the two existing units and installing a single unit.

Also, we have a very short timeline for this work, therefore, I would not have time for you to prepare a very detailed estimate, but any opinion on pricing that you could provide in the next two weeks would be very helpful.

The details of the installation is:

Arrangement: Vertical Francis. We could consider a horizontal arrangement, but that would require extensive concrete changes and I think it would be cost prohibitive.
Gross Head: 36.8 metres
Net Head: 34.6 metres
Max Q: 7.6 cms
Setting (centerline of distributor): 0.76 metres above TWL
Inertia constant (H): minimum of 2
All ancillary equipment (switchgear, transformers, cabling, etc.) will be replaced, therefore, use whatever generator voltage is optimal.
There is a surge chamber a short distance from the powerhouse. Existing water starting time is on the order of 1 second (assuming that both units react in tandem).

I mention the setting above as the hope is to reuse the same powerhouse substructure for both the “Replace” and the “Refurb” options. A report I have from about 15 years ago lists the spiral case as being in poor condition, so for this stage of the project, we will assume that the spiral case, stay ring, and discharge ring all need to be replaced.

If possible, I would be interested in pricing for a complete package, including:

- Turbine
- Generator
- TIV
- Governor/HPU
- Unit P&C

If certain items are not available, just let me know.

Best regards,
Joel Lambert, P.Eng.
Senior Mechanical Engineer
KGS Group
865 Waverley Street
Winnipeg, Manitoba, R3T 5P4
Phone: 204.896.1209 ext 245
Direct: 204.478.3245 Cell: 204.770.6411
Fax: 204.896.0754

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Thank You.

APPENDIX C

MAYO HYDRO DETAILED DIRECT COSTS

			OPTION 1: Replace		OPTION 2: Refurbish		OPTION 3: Greenfield		Option 4: Make Safe	
ITEMS	**Unit**	**Unit Cost (2016 $)**	**Quantity**	**Cost (2016 $)**	**Quantity**	**Cost (2016 $)**	**Quantity**	**Cost (2016 $)**	**Quantity**	**Cost (2016 $)**
SITEWORK				**$120,000**		**$120,000**		**$60,000**		**$60,000**
Clearing	-	-		-		-		-		-
- Misc.	ha	$20,000	0	$0	0	$0	0	$0	0	$0
Dewatering Allowance	months	$15,000	4	$60,000	4	$60,000	4	$60,000	4	$60,000
Access road maintenance	months	$5,000	12	$60,000	12	$60,000	0	$0	0	$0
SLOPE STABILIZATION				**$1,897,000**		**$1,897,000**		**$0**		**$0**
Powerhouse/Surge Slope										
- Phase 1: Mapping/Survey/Assessment	LS	$80,000	1	$80,000	1	$80,000	0	$0	0	$0
- Phase 2: Bench cut/ Flatten Top Slope / New Rock Support	LS	$1,700,000	1	$1,700,000	1	$1,700,000	0	$0	0	$0
Tailrace										
- Gabion Basket Repair	LS	$80,000	1	$80,000	1	$80,000	0	$0	0	$0
Access Road Alignment										
- Repair of the shoulder area where gully has formed near the sub-station	LS	$12,000	1	$12,000	1	$12,000	0	$0	0	$0
- Surface grading and minor granular fill placement	LS	$25,000	1	$25,000	1	$25,000	0	$0	0	$0
DECOMISSIONING AND DEMOLITION				**$799,000**		**$497,000**		**$1,040,000**		**$290,000**
Demo Mobilization/Demobilization	LS	$150,000	1	$150,000	1	$150,000	1	$150,000	0	$0
Powerhouse Superstructure Removal	LS	$250,000	1	$250,000	0	$0	1	$250,000	0	$0
Surge Tank Removal (includes improving access)	LS	$300,000	1	$300,000	1	$300,000	1	$300,000	0	$0
TG and Assoicated Equipment Removal	per unit	$60,000	2	$120,000	2	$120,000	2	$120,000	0	$0
Selected Concrete Demolition	m^3	$3,200	20	$64,000	10	$32,000	0	$0	0	$0
Blanking Plate	LS	$5,000	1	$5,000	1	$5,000	0	$0	0	$0
Plug Tunnel										
- Rock Excavation (from tunnel)	m^3	$1,000	0	$0	0	$0	10	$10,000	10	$10,000
- Rock Support	m^2	$260	0	$0	0	$0	25	$7,000	25	$7,000
- Concrete	m^3	$3,300	0	$0	0	$0	25	$83,000	25	$83,000
Backfill Powerhouse and Tailrace	m^3	$100	0	$0	0	$0	2000	$200,000	1500	$150,000
Secure Powerhouse (remove ladders, weld hatches)	LS	$10,000	0	$0	0	$0	0	$0	1	$10,000
Block Powerhouse Road and Signage	LS	$10,000	0	$0	0	$0	1	$10,000	1	$10,000
Hazardous Materials Disposal Allowance	LS	$10,000	6	$60,000	4	$40,000	6	$60,000	2	$20,000
REHABILITATION				**$1,014,000**		**$1,559,000**		**$0**		**$20,000**
New Roofing	LS	$106,000	0	$0	1	$106,000	0	$0	0	$0
Modernize Crane (allowance)	LS	$50,000	0	$0	1	$50,000	0	$0	0	$0
Concrete work for Generator / OWS Install	m^3	$3,300	40	$132,000	20	$66,000	0	$0	0	$0
Seismic Improvements										
- Anchoring Design and Install Allowance	LS	$800,000	1	$800,000	1	$800,000	0	$0	0	$0
- Bracing Design and Install Allowance	LS	$175,000	0	$0	1	$175,000	0	$0	0	$0
Lean Concrete Infill	m^3	$1,000	18	$18,000	18	$18,000	0	$0	0	$0
Asbestos Encapsulation (roof)	LS	$20,000	0	$0	1	$20,000	0	$0	1	$20,000
New Overhead Door	LS	$63,000	0	$0	1	$63,000	0	$0	0	$0
Concrete Remediation Allowance	LS	$53,000	1	$53,000	1	$53,000	0	$0	0	$0
Insulation Upgrade	LS	$160,000	0	$0	1	$160,000	0	$0	0	$0
Diving Inspection (Draft Tube Concrete / Guides)	LS	$11,000	1	$11,000	1	$11,000	0	$0	0	$0
Additional fall restraint measures	LS	$11,000	0	$0	1	$11,000	0	$0	0	$0
Repair Flashing, weather stripping, wall penetrations	LS	$10,625	0	$0	1	$11,000	0	$0	0	$0
Repoint Block Walls	LS	$15,000	0	$0	1	$15,000	0	$0	0	$0
NEW STRUCTURES				**$1,062,000**		**$266,000**		**$0**		**$0**
Powerhouse										
- Superstructure steel (based off building volume)	m^3	$120	1,450	$174,000	0	$0	0	$0	0	$0
- New Powerhouse Crane	LS	$100,000	1	$100,000	0	$0	0	$0	0	$0
- New Monorail Crane for Draft Tube Gates	LS	$30,000	1	$30,000	0	$0	0	$0	0	$0
- Steel Cladding	m^2	$450	670	$302,000	0	$0	0	$0	0	$0
- Architectural Finish	LS	$200,000	1	$200,000	0	$0	0	$0	0	$0
- Control Room	LS	$10,000	0	$0	1	$10,000	0	$0	0	$0
- Tailrace steel deck w/ guard rail	LS	$11,000	1	$11,000	1	$11,000	0	$0	0	$0
Surge Tank										
- Superstructure steel (based off tank volume)	m^3	$120	500	$60,000	500	$60,000	0	$0	0	$0
- Steel Cladding	m^2	$450	350	$158,000	350	$158,000	0	$0	0	$0
- Mechanical and Electrical	LS	$26,500	1	$27,000	1	$27,000	0	$0	0	$0
TURBINE AND GENERATOR				**$4,416,000**		**$3,142,000**		**$0**		**$0**
New Turbine, generator, governor, switchgear, DC system, SST (supply)	per unit	$3,550,000	1	$3,550,000		$0	0	$0	0	$0
New Turbine, generator, governor, switchgear, DC system, SST (Install)	per unit	$600,000	1	$600,000		$0	0	$0	0	$0
Refurbish Turbine	per unit	$492,000		$0	1	$492,000	0	$0	0	$0
New Generator (Includes Excitation and Install)	per unit	$2,100,000		$0	1	$2,100,000	0	$0	0	$0
New Turbine Inlet Valve (TIV)	per unit	$250,000	1	$250,000	1	$250,000	0	$0	0	$0
New Governor	Each	$209,000		$0	1	$209,000	0	$0	0	$0
Cooling Water Sediment Separator and Replace Shaft Seal	Each	$15,938	1	$16,000	1	$16,000	0	$0	0	$0
Sandblast, Inspect, Paint Stay Ring and Spiral Case	Each	$74,200		$0	1	$75,000	0	$0	0	$0
ELECTRICAL & MECHANICAL BALANCE OF PLANT				**$3,976,000**		**$4,389,000**		**$575,000**		**$575,000**
Mechanical Balance of Plant				$308,000		$327,000		$0		$0
Electrical Balance of Plant				$3,388,000		$3,782,000		$575,000		$575,000
TOTAL DIRECTS				**$13,284,000**		**$11,870,000**		**$1,675,000**		**$945,000**

APPENDIX D

ECONOMIC ASSESSMENTS

Assumptions:			
1	Capacity	2.3	MW
2	Annual Capacity Factor		
3	Annual Energy Production	10.43	GW.h
4	Annual Fuel Costs per MW.h	$0.00	
5	Annual O and M Costs per MW.h	$7.10	(Reference Project: Pehonan Estimated costs)
6	Annual CAPEX Costs per MW.h	$1.15	(Reference Project: Tazi Twé Estimated costs)
7	Capacity Cost	32,000	x1000$
8	Principal Payment	492	x1000$ (Using even principle payments method)
9	Project Life	65	Years
10	Nominal Interest Rate	5.45%	(From YEC)
11	Escalation Rate	2.0%	(From YEC)

Result Summary			
1	Total Energy Production	205,300	MW.h
2	Total Loan Payments	31,762	x1000$
3	Total Operating Cost (Fuel & O & M)	2,073	x1000$
4	Total CAPEX Cost (major maintaince)	335	x1000$
5	Total Cost	34,170	x1000$
6	Levelized Cost	16.64	Cents/KW.h
		166.44	Dollars/MW.h

Calculation Details

Year	Energy Production (MW.h)		Unpaid Balance	Loan Payments ($000) Current Value		Fuel & O & M ($000)	CAPEX ($000)	Total ($000)	
	Current Value	Present Value	Current Value	Principal	Interest	Current $ Value	Current $ Value	Current $ Value	Present $ Value
0									
1	8,797	8,342	31,508	492	1,731	64	10	2,297	2,178
2	11,759	10,575	31,015	492	1,704	87	14	2,297	2,066
3	13,338	11,375	30,523	492	1,677	100	16	2,286	1,950
4	13,599	10,998	30,031	492	1,650	105	17	2,264	1,831
5	13,832	10,609	29,538	492	1,623	108	18	2,242	1,719
6	14,064	10,229	29,046	492	1,596	112	18	2,219	1,614
7	14,194	9,790	28,554	492	1,570	116	19	2,196	1,515
8	14,307	9,358	28,062	492	1,543	119	19	2,173	1,422
9	14,420	8,944	27,569	492	1,516	122	20	2,150	1,334
10	14,537	8,551	27,077	492	1,489	126	20	2,128	1,251
11	14,588	8,137	26,585	492	1,462	129	21	2,104	1,174
12	12,962	6,857	26,092	492	1,435	117	19	2,063	1,091
13	11,784	5,911	25,600	492	1,409	108	18	2,027	1,017
14	11,776	5,602	25,108	492	1,382	110	18	2,002	953
15	11,625	5,244	24,615	492	1,355	111	18	1,976	892
16	11,488	4,915	24,123	492	1,328	112	18	1,951	834
17	9,614	3,900	23,631	492	1,301	96	15	1,905	773
18	9,614	3,699	23,138	492	1,274	97	16	1,880	723
19	9,614	3,508	22,646	492	1,248	99	16	1,855	677
20	9,614	3,326	22,154	492	1,221	101	16	1,831	633
21	9,614	3,154	21,662	492	1,194	103	17	1,806	593
22	9,614	2,991	21,169	492	1,167	106	17	1,782	554
23	9,614	2,837	20,677	492	1,140	108	17	1,758	519
24	9,614	2,690	20,185	492	1,113	110	18	1,733	485
25	9,614	2,551	19,692	492	1,087	112	18	1,709	454
26	9,614	2,419	19,200	492	1,060	114	18	1,685	424
27	9,614	2,294	18,708	492	1,033	117	19	1,661	396
28	9,614	2,176	18,215	492	1,006	119	19	1,637	370
29	9,614	2,063	17,723	492	979	121	20	1,612	346
30	9,614	1,957	17,231	492	952	124	20	1,588	323
31	9,614	1,855	16,738	492	926	126	20	1,564	302
32	9,614	1,760	16,246	492	899	129	21	1,541	282
33	9,614	1,669	15,754	492	872	131	21	1,517	263
34	9,614	1,582	15,262	492	845	134	22	1,493	246
35	9,614	1,501	14,769	492	818	137	22	1,469	229
36	9,614	1,423	14,277	492	792	139	23	1,446	214
37	9,614	1,349	13,785	492	765	142	23	1,422	200
38	9,614	1,280	13,292	492	738	145	23	1,398	186
39	9,614	1,214	12,800	492	711	148	24	1,375	174
40	9,614	1,151	12,308	492	684	151	24	1,352	162
41	9,614	1,091	11,815	492	657	154	25	1,328	151
42	9,614	1,035	11,323	492	631	157	25	1,305	140
43	9,614	981	10,831	492	604	160	26	1,282	131
44	9,614	931	10,338	492	577	163	26	1,259	122
45	9,614	883	9,846	492	550	166	27	1,236	113
46	9,614	837	9,354	492	523	170	27	1,213	106
47	9,614	794	8,862	492	496	173	28	1,190	98
48	9,614	753	8,369	492	470	177	29	1,167	91
49	9,614	714	7,877	492	443	180	29	1,144	85
50	9,614	677	7,385	492	416	184	30	1,122	79
51	9,614	642	6,892	492	389	187	30	1,099	73
52	9,614	609	6,400	492	362	191	31	1,077	68
53	9,614	577	5,908	492	335	195	32	1,054	63
54	9,614	547	5,415	492	309	199	32	1,032	59
55	9,614	519	4,923	492	282	203	33	1,010	55
56	9,614	492	4,431	492	255	207	33	988	51
57	9,614	467	3,938	492	228	211	34	966	47
58	9,614	443	3,446	492	201	215	35	944	43
59	9,614	420	2,954	492	174	220	36	922	40
60	9,614	398	2,462	492	148	224	36	900	37
61	9,614	378	1,969	492	121	228	37	878	35
62	9,614	358	1,477	492	94	233	38	857	32
63	9,614	340	985	492	67	238	38	835	30
64	9,614	322	492	492	40	242	39	814	27
65	9,614	305	0	492	13	247	40	793	25

Assumptions:			
1	Capacity	2.3	MW
2	Annual Energy Production	10.43	GW.h
3	Annual Fuel Costs per MW.h	$0.00	
4	Annual O and M Costs per MW.h	$7.10	(Reference Project: Pehonan Estimated costs)
5	Annual CAPEX Costs per MW.h	$1.15	(Reference Project: Tazi Twé Estimated costs)
6	Capacity Cost	28,600	x1000$ (2011 Est. Cost with Contingencies)
7	Principal Payment	440	x1000$ (Using even principle payments method)
8	Project Life	65	Years
9	Nominal Interest Rate	5.45%	(From YEC)
10	Escalation Rate	2.0%	(From YEC)

Result Summary			
1	Total Energy Production	205,300	MW.h
2	Total Capital Cost	28,387	x1000$
3	Total Operating Cost (Fuel & O & M)	2,073	x1000$
4	Total CAPEX Cost (major maintaince)	335	x1000$
5	Total Cost	30,795	x1000$
6	Levelized Cost	15.00	Cents/KW.h
		150.00	Dollars/MW.h

Calculation Details

Year	Energy Production (MW.h)		Unpaid Balance	Loan Payments ($000) Current Value		Fuel & O & M ($000)	CAPEX ($000)	Total ($000)	
	Current Value	Present Value	Current Value	Principal	Interest	Current $ Value	Current $ Value	Current $ Value	Present $ Value
0									
1	8,797	8,342	28,160	440	1,547	64	10	2,061	1,954
2	11,759	10,575	27,720	440	1,523	87	14	2,064	1,856
3	13,338	11,375	27,280	440	1,499	100	16	2,056	1,753
4	13,599	10,998	26,840	440	1,475	105	17	2,036	1,647
5	13,832	10,609	26,400	440	1,451	108	18	2,017	1,547
6	14,064	10,229	25,960	440	1,427	112	18	1,997	1,453
7	14,194	9,790	25,520	440	1,403	116	19	1,977	1,364
8	14,307	9,358	25,080	440	1,379	119	19	1,957	1,280
9	14,420	8,944	24,640	440	1,355	122	20	1,937	1,201
10	14,537	8,551	24,200	440	1,331	126	20	1,917	1,128
11	14,588	8,137	23,760	440	1,307	129	21	1,897	1,058
12	12,962	6,857	23,320	440	1,283	117	19	1,859	983
13	11,784	5,911	22,880	440	1,259	108	18	1,825	915
14	11,776	5,602	22,440	440	1,235	110	18	1,803	858
15	11,625	5,244	22,000	440	1,211	111	18	1,780	803
16	11,488	4,915	21,560	440	1,187	112	18	1,757	752
17	9,614	3,900	21,120	440	1,163	96	15	1,714	695
18	9,614	3,699	20,680	440	1,139	97	16	1,692	651
19	9,614	3,508	20,240	440	1,115	99	16	1,671	610
20	9,614	3,326	19,800	440	1,091	101	16	1,649	571
21	9,614	3,154	19,360	440	1,067	103	17	1,627	534
22	9,614	2,991	18,920	440	1,043	106	17	1,606	500
23	9,614	2,837	18,480	440	1,019	108	17	1,584	467
24	9,614	2,690	18,040	440	995	110	18	1,563	437
25	9,614	2,551	17,600	440	971	112	18	1,541	409
26	9,614	2,419	17,160	440	947	114	18	1,520	382
27	9,614	2,294	16,720	440	923	117	19	1,499	358
28	9,614	2,176	16,280	440	899	119	19	1,477	334
29	9,614	2,063	15,840	440	875	121	20	1,456	312
30	9,614	1,957	15,400	440	851	124	20	1,435	292
31	9,614	1,855	14,960	440	827	126	20	1,414	273
32	9,614	1,760	14,520	440	803	129	21	1,393	255
33	9,614	1,669	14,080	440	779	131	21	1,372	238
34	9,614	1,582	13,640	440	755	134	22	1,351	222
35	9,614	1,501	13,200	440	731	137	22	1,330	208
36	9,614	1,423	12,760	440	707	139	23	1,309	194
37	9,614	1,349	12,320	440	683	142	23	1,288	181
38	9,614	1,280	11,880	440	659	145	23	1,268	169
39	9,614	1,214	11,440	440	635	148	24	1,247	157
40	9,614	1,151	11,000	440	611	151	24	1,227	147
41	9,614	1,091	10,560	440	588	154	25	1,206	137
42	9,614	1,035	10,120	440	564	157	25	1,186	128
43	9,614	981	9,680	440	540	160	26	1,165	119
44	9,614	931	9,240	440	516	163	26	1,145	111
45	9,614	883	8,800	440	492	166	27	1,125	103
46	9,614	837	8,360	440	468	170	27	1,105	96
47	9,614	794	7,920	440	444	173	28	1,085	90
48	9,614	753	7,480	440	420	177	29	1,065	83
49	9,614	714	7,040	440	396	180	29	1,045	78
50	9,614	677	6,600	440	372	184	30	1,025	72
51	9,614	642	6,160	440	348	187	30	1,005	67
52	9,614	609	5,720	440	324	191	31	986	62
53	9,614	577	5,280	440	300	195	32	966	58
54	9,614	547	4,840	440	276	199	32	947	54
55	9,614	519	4,400	440	252	203	33	927	50
56	9,614	492	3,960	440	228	207	33	908	47
57	9,614	467	3,520	440	204	211	34	889	43
58	9,614	443	3,080	440	180	215	35	870	40
59	9,614	420	2,640	440	156	220	36	851	37
60	9,614	398	2,200	440	132	224	36	832	34
61	9,614	378	1,760	440	108	228	37	813	32
62	9,614	358	1,320	440	84	233	38	795	30
63	9,614	340	880	440	60	238	38	776	27
64	9,614	322	440	440	36	242	39	758	25
65	9,614	305	0	440	12	247	40	739	23

Assumptions:			
1	Capacity	2.3	MW
2	Annual Energy Production	7.18	GW.h
3	Annual Fuel Costs per MW.h	$0.00	
4	Annual O and M Costs per MW.h	$7.10	(Reference Project: Pehonan Estimated costs)
5	Annual CAPEX Costs per MW.h	$0.00	
6	Project Life	10	Years
7	Nominal Interest Rate	0	(From YEC)
8	Escalation Rate	0	(From YEC)

Option 3 - Demolition and Return to Greenfield

Result Summary			
1	Total Energy Production	57,278	MW.h
2	Total Capital Cost	4,000	x1000$
3	Total Operating Cost (Fuel & O & M)	458	x1000$
4	Total CAPEX Cost (major maintaince)	0	x1000$
5	Total Cost	4,458	x1000$

Option 4 - Abandon in Situ

Result Summary			
1	Total Energy Production	57,278	MW.h
2	Total Capital Cost	2,300	x1000$
3	Total Operating Cost (Fuel & O & M)	458	x1000$
4	Total CAPEX Cost (major maintaince)	0	x1000$
5	Total Cost	2,758	x1000$

Calculation Details										
Year	Energy Production (MW.h)		Capital ($000)		Operating ($000) (Fuel & O & M)		CAPEX ($000) (Major Maintaince)		Total ($000)	
	Current Value	Present Value	Current $ Value	Present $ Value	Current $ Value	Present $ Value	Current $ Value	Present $ Value	Current $ Value	Present $ Value
0										
1	4,539	4,304			33	31			33	31
2	4,722	4,246			35	31			35	31
3	4,999	4,264			38	32			38	32
4	6,038	4,884			46	38			46	38
5	8,277	6,348			65	50			65	50
6	9,697	7,052			78	56			78	56
7	9,949	6,862			81	56			81	56
8	10,179	6,658			85	55			85	55
9	10,412	6,458			88	55			88	55
10	10,544	6,202			91	54			91	54

APPENDIX E

EMAIL: AISHIHIK RERATE STUDY (APRIL 13, 2015)

The following correspondence from Yukon Energy Corporation was used as a basis for a Present Value analysis of the Mayo A Future Options. The attached email contains assumptions provided by Yukon Energy Corporation to analyze the benefit of an increase in capacity ($/MW), and the benefit of an increase in annual energy ($/GWh). The information was provided for the Aishihik Rerate and Assessment Project and is assumed to be applicable to the analysis of Mayo A.

Ariane Adriano

From: Hector Campbell <Hector.Campbell@yec.yk.ca>
Sent: April-13-15 11:45 AM
To: Ron Gee
Cc: Joel Lambert; Goran Sreckovic; Lawrence Joudry; Bill Haydock; Guy Morgan
Subject: RE: Aishihik rerate study,
Attachments: TAB-2012-05-08-Business Case Templates.xlsm

Joel,
You should assume the following:
1/ benefit of an increase in capacity - $2.5M per MW based on avoided capital cost of new natural gas generation.
2/ benefit of an increase an annual energy - $200,000 per GWh based on avoided operating (i.e. variable cost) cost of natural gas.

It would be worthwhile doing some sensitivity analysis based on capacity benefits of between $1M (high speed diesel gensets) and $10M (wind or higher cost new hydro).
Similarly for energy benefit going from $100,000 (best possible natural gas operating cost) to $300,000 (diesel operating cost).

For paybacks longer than 5 years, we use discounted payback – see attached economic spreadsheets – use 5.2% as YEC's discount rate.

Note that both of the larger turbines (AH1 and AH2) at Aishihik have had their generators rewound in the 1990's that would allow a modest increase in capacity to be an option or part of an option (combination of capacity and efficiency gains) with rerunnering.
The units were rewound in different years by different vendors resulting with different ratings on the new insulation. I can't recall the final revised generator ratings. I believe one was increased to about 16 MVA and the other one to about 16.5 MVA from their original 15.5 MVA ratings.

Goran/Lawrence/Bill/Guy – any comments?

Hector Campbell P. Eng., M.B.A.
Director, Resource Planning & Regulatory Affairs
Telephone: 867-393-5331 | Mobile: 867-334-7070
YUKON ENERGY
your needs power what we do

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From: Ron Gee
Sent: April-10-15 3:51 PM

To: Hector Campbell
Cc: Joel Lambert
Subject: FW: Aishihik rerate study,

Hector,
I am away for a couple weeks starting Monday. I was wondering if could respond to the question below by sending any answer you have to Joel Lambert of KGS. Please copy me so that I can stay in the loop.

Thanks.

Ron Gee P. Eng.
Hydrological & Civil Engineer
Telephone: 867-393-5305 | Mobile: 867-334-6908
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your needs power what we do

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SM-YEC-20141008MYEC-20141008

From: Ron Gee
Sent: April-09-15 9:17 AM
To: hector.campbell@yec.yk.ca
Subject: FW: Aishihik rerate study,

Hector,
Would you be able to answer the question below. It pertains to a study being performed on the potential rerunnering of the Aishihik turbines.

From: Joel Lambert [mailto:JLambert@kgsgroup.com]
Sent: April-09-15 9:14 AM
To: Ron Gee
Subject: FW: Aishihik rerate study,

Hi Ron,

The original question I sent is below. This is the value that YEC assigns to the additional energy produced by the new runner.

Say for example that the upgrade costs $1,000,000 and that the uprated machine produces an additional 2 GWhr/year. If the value of energy is $300,000 / GWhr, the simple payback would be 3.3 years. The value of energy may depend greatly if it reduces diesel consumption or not. Presumably it will since Aishihik has a lot of storage.

If it helps, we can have a call to discuss further. If so, I would likely include someone else from KGS that has a lot of experience in these matters.

Regards,
Joel

From: Joel Lambert [mailto:JLambert@kgsgroup.com]
Sent: March-31-15 2:26 PM
To: 'Ronald Gee (ron.gee@yec.yk.ca)'
Subject: Aishihik rerate study,

Hi Ron,

What value of energy should we be using in our payback calculations for the Aishihik Rerate Study? Presumably this would be a $/GW-h value.

Regards,
Joel Lambert, P.Eng.
Senior Mechanical Engineer
KGS Group
865 Waverley Street
Winnipeg, Manitoba, R3T 5P4
Phone: 204.896.1209 Cell: 204.770.6411
Fax: 204.896.0754