ATCO Electric
YUKON

2023-2024 General Rate Application (GRA)

Fish Lake 2 Power Station Design

2023-2024 Business Case #39

Executive Summary

1. Fish Lake 2 (FL2) Plant is a Francis hydro turbine-generator that was installed in 1954 and produces electricity on the Yukon Integrated System (YIS), which helps displace thermal generated sources and offsets AEY's purchased power from Yukon Energy Corporation (YEC). There have been various upgrades to the infrastructure and equipment since installation. Recently, engineering evaluations have been prepared due to observed failures and known issues.

2. This site has seen increasing downtime and maintenance and a long-term asset recapitalization plan is necessary. A comprehensive condition assessment of FL2 was completed by BBA Engineering in 2022. The objective was to thoroughly document the current condition, present recommendations to extend the life and optimize performance of FL2.

3. There are safety and reliability risks with ongoing operation of this facility that need to be addressed, and many components have reached end of life. The report contains three options:

(1) Targeted Safety Improvement:

(a) Address immediate safety and reliability risks with reinforced foundations and building, modernize governor and brake systems, and update control and switchgear to current standards.

(2) Full Replacement:

(b) Demolish the existing facility and replace with an entirely new power station in place.

(3) Optimized Replacement

(c) Demolish the existing facility and replace with an entirely new power station and a bottom-end penstock to increase hydraulic power.

4. The recommendation is to proceed further with feasibility studies of Option 2, a full replacement of PL2. This will result in a project estimate (Class 3 -20/+30) for

evaluation. Currently it is estimated (+/-50 percent) to require $6.54 million in capital investment.

Background

5. FL2 suffered a catastrophic failure in 2016 because of a grid outage and was out of service until 2019 due to repairs. The extent of damage was primarily due to a lack of functional equipment protections. Upon inspection, it was determined that foundation settlement is contributing to the reliability problems being observed. Engineering investigations thereafter (Maven Consulting, ONEC Engineering) determined several components are at end of life and helped to identify existing safety risks.

6. BBA Engineering compiled all past issues identified, conducted their own inspection for current condition, clarified component lifespans and functionality, and presented priced options to extend and optimize the operation of this asset and mitigate immediate safety and reliability concerns. Please refer to Attachment 1.[1]

7. There are hazards inherent in continued operation of this equipment that need to be addressed to protect personnel including open rotating parts, unpredictable forces from manual braking, unreliable mechanical protection and control devices, inability to isolate equipment from water, and arc flash boundary plus shock potential.

8. Furthermore, many components of the facility have reached end of life and require immediate investment.

- The sub-structure is not adequate for the seismic and environmental conditions present and does not meet current code requirements.
- There are no spare parts and the very specialized skillset required for ongoing maintenance of the hydraulic governor is not readily available. The governor's mechanical protections cannot be tested offline, and the machine's manual operation comes with inherent hazards that are no longer common practice.

[1] BBA Engineering Report.

- The PLC and protection relays are obsolete and the commutator condition requires replacement. Switchgear does not meet limits of approach guidelines.
- The building frame shows signs of deterioration and age and needs to be retrofitted for adequate envelope protection and structural stability.

9. Refer to Business Case #39 Attachment 1, the BBA Engineering Report for details.

Project Description

10. An engineering consultant with proficiency in electrical, mechanical, controls/automation, civil, structural disciplines will be engaged to prepare a Front-End Engineering Design (FEED) and Design Basis Memorandum (DBM). Design expertise is required in hydro-turbines and utility power generation.

11. After review and approval by necessary stakeholders, a detailed engineering work package will be created along with cost and schedule estimates. This will define the project to a level of accuracy necessary for regulatory approvals and construction funding authorization.

Project Schedule and Costs

Table 1: Project Costs
($000)

	Cost		
Project Development Tasks	**2023**	**2024**	**Total**
Geotechnical Assessment	50	-	50
Penstock and Hydraulic Evaluation	50	-	50
Environmental and Water Studies	50	50	100
DBM/FEED	150	-	150
Permitting	-	50	50
Detailed Engineering	-	327	327
Project Management	50	50	100
Contingency (10%)	35	50	85
Total	**385**	**527**	**912**

12. Line-item costs are based upon BBA's estimates, experience at AEY, and the expected complexity of this project.

Business Drivers and Benefits

13. The Fish Lake waterway and power production facilities are regulated by the Yukon Water Board, which issued AEY a type A water licence to operate (HY12-065 – expires 2038). The production of power from this site offsets purchase power from YEC and during winter months offsets higher cost and higher GHG emitting diesel/LNG power due to the grid being at capacity.

14. AEY would like to optimize the generation of power at this site while ensuring lifecycle costs are minimized and that operation of this facility meets or exceeds industry standards. The 69-year-old facility has reached the end-of-life and requires significant investment.

15. AEY is addressing the following immediate concerns in 2023 as separate small sustaining capital projects, to mitigate urgent personnel hazards and continue operating the equipment over the short-term with increased oversight:

- Replace wicket gates and wear rings;
- Upgrade protection relays; and
- Install UPS battery bank for TIV.

Evaluation of Viable Alternatives

16. Refer to the BBA Engineering report, Attachment 1, for description of lifecycle options, and their respective capital and O&M costs along with forecasts for annual generation. The options can be summarized as follows:

1. Targeted Safety Improvements – 490 kW (rated 596 kW):
    a. Reinforce and stabilize foundation, retrofit and reinforce building;
    b. Replace governor and servomotor and water brake and exciter;
    c. Modernize controls; and
    d. Replace other components as they reach the end-of-life.
2. Full Replacement – 620 kW:
    a. Demo entire plant; and
    b. Rebuild new hydro-turbine generator power plant, re-using and penstock/TIV.

3. Optimized Replacement – 635 kW:
   a. Demo entire plant;
   b. Replace section of penstock to reduce capacity restriction; and
   c. Rebuild new hydro-turbine generator power plant.

17. A fourth option of demolishing the turbine/generator and solely use the penstock and TIV for water resource management pursuant to YWB conditions was not explored in the report. This would eliminate the generation of power from this site, and therefore increase the overall cost burden of the remainder of Fish Lake infrastructure that AEY is obligated to manage. However, due to continued use of the inadequate foundation to anchor the penstock and electrical auxiliaries, the ongoing reliability and safety of this option is not clear.

18. Please refer to Business Case #39 Attachment 1, Appendix D[2] from the engineering report, which compares capital and O&M costs related to the three alternatives as well as the energy production.

Table 2: Relative Risk Evaluation:

	1	**2**	**3**	**4**
Option	**Upgrade**	**Replace**	**Upsize**	**Penstock Water Control**
Scope	Modifications to existing facility to address end-of-life and safety concerns – continued risks due to proximity of MV switchgear	Demolish and replace in-site with modern turbine generator plant.	Demolish and replace near-site with modern turbine generator plant – optimizing hydraulic constraints.	Demolish all equipment except TIV in existing structure, to solely manage water levels – continued risks due to settlement
Capex				
Scope Creep				
Maintenance Obligation				
Reliability				
Safety				
Generation Capacity / Efficiency				
Permitting				
Construction Impact (land, water)				

Green = Low, Orange = Medium, Red = High

[2] Business Case #39 Attachment 1, Appendix D, PDF page 87.

Recommendation

19. Proceed with design for a full replacement of the power station (Option 2). This will result in a project estimate (Class 3) for investment authorization of full execution. Currently, it is conceptually estimated to require $6.54 million in capital. This would take several years of planning and construction and is anticipated to require regulatory approval(s).

20. In addition, the financial support in the alternatives section shows the capital cost is about the same as the safety replacement and saves on the end-of-life replacements required in the next 20-years on the systems not replaced under Option 1. There is also a projected savings on maintenance costs of $45,000 per year.

ATCO Electric Yukon

Fish Lake 2 Condition Assessment

Fish Lake, YT

Technical Report

Condition Assessment and Options Analysis

BBA Document No.-Rev.: 7035002-000000-40-ERA-0001-R00

May 24, 2023

FINAL

1050 West Pender Street, Suite 800.
Vancouver, BC V6E 3S7
T +1 604.661.2111 **F** +1 604.683.2872
BBA.CA

PERMIT TO PRACTICE
BBA ENGINEERING LTD
SIGNATURE
Date 2023-05-26
PERMIT NUMBER PP589
Association of Professional
Engineers of Yukon

Electrical Section Prepared by:
Ken Walton, C.Tech.
ASTTBC No. 13749

Mechanical Section Prepared by:
Kate Ross, P.Eng
EGBC No. 50419

PROFESSIONAL
2023-05-25
YUKON
MINA SHAHRAKI
TERRITORY
ENGINEER

PROFESSIONAL
YUKON
N. HAWLEY
TERRITORY
ENGINEER
2023-05-24

Civil Section Prepared by:
Mina Shahraki, P.Eng.
APEY No. 3254

Verified by:
Nick Hawley, P.Eng.
APEY No. 2756

BBA Document No.-Rev.: 7035002-000000-40-ERA-0001-R00

REVISION HISTORY

Revision	Document Status – Revision Description	Date
R00	Final	2023-05-24

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. Executive Summary

ATCO contracted BBA Engineering Ltd. (BBA) to perform an independent, high-level condition assessment of the hydro unit at ATCO's Fish Lake 2 Generating Station. The generating unit's rated capacity is 812kVA and 596 kW; however, in its current condition, it is limited to 480 kW of generation.

The main objectives of this report are to:

- Review maintenance records, report on the site inspection during overhaul, and report on interviews with maintenance and operations staff;
- Document the present condition of the electrical equipment (generator, medium voltage switchgear and cables) and the mechanical equipment (turbine TIV, governor, lubrication system and cooling system), and any equipment that would not be replaced in a unit upgrade or that is already planned to be replaced;
- Estimate the remaining lifespan of equipment and cost to replace;
- Estimate the cost and benefits to upgrade the existing units with either two units or one single unit;
- Determine the predicted output (GWh/year) using historical flow data;
- Prepare a business case for three options:
  a) Completing targeted safety updates on critical equipment, and replacing other equipment at end-of-life with like-for-like equipment;
  b) Replacing existing building and hydro unit with a brand-new unit with the same installed capacity as existing (1.35 m^3/s);
  c) Replacing existing building and hydro unit with a brand-new unit, but with a higher installed capacity (1.42 m^3/s).

While the plant has been very well maintained over the years, there are significant safety hazards inherent to continued operation that must be addressed. This includes the age and condition of governor and other control and protection equipment, as well as the current layout of electrical and control equipment. These are outlined in more detail in Section 5.1.5.

Many components of the facility have already reached end-of-life condition and spare parts are no longer readily available. In particular, the building structure and foundation require significant upgrades, as they do not meet current seismic loading standards. Spare parts for the governor and protection / control equipment are no longer readily available, and the ongoing maintenance of the governor requires a very specialized skillset which is not readily available. It is not acceptable to continue operating the station as-is considering the significant safety and operational risks.

It is recommended that ATCO Electric Yukon complete a full replacement of the Fish Lake 2 powerhouse and generating unit. This is the only viable option to proceed with that reduces safety risks, prevents the risk of future outages, and provides increased generation capacity to ATCO Electric Yukon. The possibility of installing an optimized unit should also be further considered.

The results of this study are summarized in Appendix D.

2. Introduction

The existing Fish Lake 2 Hydro Plant is located just outside of Whitehorse, Yukon, and was constructed in 1954. It consists of a single-storey wooden frame building with wooden roof truss, housing a 596-kW turbine, generator, and all associated mechanical and electrical generation equipment.

ATCO Electric Yukon contracted BBA Engineering Ltd. (BBA) to perform an independent, high-level condition assessment of the Fish Lake 2 Generating Station. ATCO's driver for this assessment was to identify and forecast on-going costs and compare with the cost of replacement of the unit, either with a similar sized unit or larger.

This Condition Assessment is intended to build on (not repeat) previous condition assessments carried out by Maven and ONEC in 2017.

The main objective of this report is to document the present condition of the unit and the associated systems. In addition, the report presents a high-level implementation schedule that prioritizes the improvements identified, as well as an option for full replacement and optimization of the water resource within the limits of the current water license.

3. Condition Assessment of Fish Lake 2

The condition assessment aims to qualitatively determine the present condition of the unit and the associated system, and to evaluate the best approach to improve the safety, reliability, and availability of the systems. No testing of equipment was completed as part of this condition assessment.

The improvements identified are intended to support determinations by ATCO as to which upgrades are worthy of pursuing for the purpose of increasing the overall safety and reliability of the generating station. The scope of BBA's condition assessment includes the generating unit, powerhouse structure, powerhouse foundations, as well as the relevant plant auxiliary equipment. The penstock and TIV (replaced in 2017) were specifically excluded from this condition assessment.

BBA performed a high-level condition assessment of the following systems:

- Generator and turbine;
- Governor, including hydraulics;
- Bearings and lubrication systems;
- MV switchgear and Protection and Control (P&C) equipment;
- Generator step up transformer.

In addition to the site visit, ATCO provided the following documents for reference:

- Maven, Fish Lake #2 Assessment and Recommendation Report, Nov 4, 2016, including addendum dated March 9, 2017;
- ONEC, Engineering Condition Assessment, Fish Lake #2 Hydro Plant Assessment, October 20, 2016;
- American Governor inspection report;
- Electrical test data.

3.1. Site Visit Conditions

A BBA team of three engineers visited the site on October 12 and 13, 2022. The team was comprised of:

- Senior Mechanical Engineer – Nick Hawley;
- Senior Electrical and Automation Technologist – Ken Walton;
- Senior Civil Engineer – Mina Shahraki.

The BBA team was escorted by Rob Williamson, Trevor White, and Dale Kates from ATCO. The annual inspection of the unit was underway while they were on site. At the time of the visit, the weather was sunny and dry.

3.2. Fish Lake Maintenance History and Observations

Figure 1: Turbine and Generator

The Fish Lake 2 generator is a horizontal, 812 kVA, 1200 RPM, 2300V, 3 phase Westinghouse generator with an 800 BHP (600kW), 200 ft head Gilkes Francis hydro turbine. The unit was installed in Fish Lake 2 in 1954. It is presently 68 years old and maximum output is reported to be 480kW.

3.2.1. Plant History

Following a major failure the unit was out of service for effectively 4.5 years. The original outage started on July 18, 2016. The failure was due to a grid outage and a lack of protection on the Fish Lake 2 unit. AC power was lost at the station, which prevented the TIV from closing. In addition, the wicket gates did not fully close, which meant water continued to pass through the turbine. During this event, the unit either went into overspeed or reverse rotation. Significant bearing damage and leakage from the water brake was discovered after this event. A piano wire alignment was completed in 2019 – using the scroll case centerline. The thrust pedestal was decked then angularly shimmed, indicating that the foundation along with the scroll case is falling into the creek. This is likely connected to general subsidence of the foundations around the unit base. This would have resulted in eventual bearing wipe, regardless of the overspeed / reverse rotation event.

The Fish Lake 2 unit was returned to service on November 5, 2018, for 9 days. Since then, it was only operational for a few hours in 2019, and several days in 2020. The unit was fully returned-to-service on January 24, 2021. The unit has been in service for nearly two years at the time of this inspection.

Several major equipment repairs and replacements have occurred in the past 23 years.

- 2000: Generator stator was re-wound and P&C was replaced;
- 2010: Turbine shaft was replaced;
- 2010: Journal and thrust bearings on the turbine were re-metalled;
- 2010: Original runner, constructed from bronze, was replaced with a stainless-steel runner. The original Gilkes casting was used to fabricate the new runner;
- 2011: The original wicket gates were replaced;
- 2012: A new generator step up transformer was installed;
- 2014: DC Generator re surface, Generator major clean and re-varnish;
- 2016: Unit misalignment correction by shimming bearing pedestal;
- 2016: Runner cavitation repairs completed;
- 2016: The journal and thrust bearings on the turbine were re-metalled (again);
- 2017: Wicket gate cavitation repairs completed;
- 2018: Runner reprofiled – trailing edges were "sharpened" and balanced;
- 2020: Runner cavitation repairs completed (again);
- 2022: Wicket gate cavitation repairs completed (again).

One of the major ongoing issues with the unit is misalignment of the turbine / generator due to foundation subsidence. This issue was first discovered in 2016, when the misalignment was measured at 0.002" vertically over 1' horizontally. The bearing pedestal was shimmed to correct the misalignment. This should have moved the runner off centre from the crown and band seals; however, measurements taken in 2022 show the runner to be well centred.

3.2.2. Turbine as Found Condition

3.2.2.1. Turbine Maintenance Summary

Crews at Fish Lake 2 complete the following **daily checks** on the existing unit:

- Recording instrumentation readouts;
- Checking belts and brushes;
- Identifying and reporting oil leaks (these occur very rarely).

It is estimated that these daily checks take approximately 1 hour per day, 7 days per week.

Crews at Fish Lake 2 also complete a **bi-monthly inspection**:

- Looking for anything unusual;
- Topping up oil in bearings / governor;
- Completing maintenance on belts and sliprings.

It is estimated that this inspection takes 5 hours, once every two months.

Finally, each year, crews at Fish Lake 2 complete a **one to two-month overhaul**. This includes the following tasks:

- Strip down and inspect bearings (#1 (Exciter inboard), #2 (Generator), #3 (Turbine and thrust) ,#4 (exciter outboard));
- Remove Draft Tube elbow;
- Remove and inspect wicket gates and runner;
- Replace gaskets – governors, bearings;
- Grease wicket gate bushings;
- Governor Giljet brake overhaul;
- Governor overhaul (every 3 years);
- Seals, measure gaps, inspect and ensure no alignment issues:
  a) shaft, crown, band;

b) WG Bushings;

c) Packing.

- Change bearing oil;
- Generator air gap measure;
- Clean generator;
- Brushgear – change out bi-annually;
- Exciter commutator inspection, pick up;
- Skim/clean commutator 5 years;
- Vacuum breaker check;
- Intake gate valve check;
- Electrician – 2 weeks:
  a) Check all connections;
  b) Insulation test rotor and stator;
  c) Inspect CB, measure contact wear;
  d) Protection relay settings check with secondary injection.
- Future:
  a) DC battery bank MTCE (2023).

It is expected that this annual overhaul takes two people approximately one month of full-time work over a period of two months.

3.2.2.2. Turbine Observations:

Runner

The turbine condition is "average" with the following concerns:

- Runner is showing frosting or cavitation on the suction sides, signifying that the flow is a little too high (as max output is below rated O/P this means head is lower than rated head – it is 6% below rated head);
- Stay vanes are very rough, high friction losses, misshaped leading edges;

- Wicket gates show signs of leakage past lower wear rings, the upper gap could not be seen but measured 0.0015" to 0.014". The worst areas being the trailing edges. Post visit/annual maintenance TW informs us that the gap is now reduced to 0.4mm;
- Lower wear ring (Bronze) is in poor condition (to be repaired along with replacement of wicket gates soon);
- Scroll case surfaces are very rough (likely original casting issue), brushing with a wire brush would remove corrosion, but not overall roughness. This could be another cause of low output;
- Minimal leakage into headcover past shaft seal (crown seal likely good too);
- Runner drain holes were enlarged as recommended in 2016;
- Band seal – turbine band showed no signs of damage or leakage;
- A 0.5mm clearance on the band seal – all round;
- Scroll case is buried in it's own anchor block not attached to the unit base so with settlement occurring it will soon be impossible to align the scroll case and bearings any further;
- Crown seal clearance – unknown;
- Draft tube was in good condition and submerged correctly.

Runner cavitation repairs being required every 6 years points to issues in terms of the original design. The rated peak efficiency of the unit was 84%, however it runs 6% off rated head so will likely have only ever been 82%. The USBR/USACE recommend assuming a deterioration of 1% every 10 years, being 70 years old means a reduction to 75% +/-5% today. At 480 kW output, the efficiency was calculated to be 67% using recorded data. This is within typical boundaries for a unit of this size and age. This indicates that flow is restricted to 0.8 m^3/s, while the turbine nameplate points to a max flow of around 1.1 m^3/s at full gate opening (the penstock flow meter reads 1200 L/s at 480 kW).

Flow restriction can be caused by:

- Gates not opening to full gate (confirmed not to be the case);
- High leakage past the runner seals (likely);
- Rough surfaces in the water passages (scroll case, stay vanes, wicket gates);
- A small penstock diameter, which creates high frictional losses, therefore reducing available net head and flowrate.

Bearings, lubrication, and Shaft

The bearing, lubrication, and shaft is in reasonable condition with the following concerns:

- #3 Turbine journal bearing – very slight wear on upper shells;
- #3 Turbine journal bearing shaft – slight grooving;
- #3 Michel bearing – significant scoring, requires repair;
- #3 Michel bearing thrust ring (gen side) – smooth;
- #3 Michel bearing thrust ring (turb side) – smooth;
- #3 Turbine bearing pedestal – requires sealing from outside air (getting in through base);
- #2 Generator journal bearing – very good condition;
- #2 Generator journal bearing shaft – good condition;
- #1 Exciter journal Bearing – best condition;
- #1 Exciter journal Bearing shaft – good condition;
- #4 (Exciter) bearing – smooth;
- The turbine bearing oil turns black after a year's operation, the shaft and thrust pads require annual buffing;
- Vibration – no issues (#1 = 0.81mm/s, #2 = 2.07mm/s, thrust 0.64 mm/s) #2 has the highest load, these readings are consistent across the years and across operating range;
- Winding temps = 42 – 45 deg C;
- Bearing temps #1 = 58, #2 = 65, Thrust = 46 deg C, #4 = 29 deg C.

Giljet Brakes/Flywheel

The Giljet brake is an original component that was supplied with the turbine. This brake uses a Pelton wheel and water jet to slow and stop the turbine. The brake was repaired in 2016 when the bucket undercut was rebuilt. While the brake works well it will require ongoing repairs to the bucket. It is driven by the governor, which at this time has no off-the-shelf spare parts and which requires specialist maintenance (see "Governor" section for details). This could be replaced by a standard disk brake to reduce maintenance. In addition, applying the brake is a hazardous activity for workers to undertake as it requires the manual application of a snipe.

WG servomotor, swing ring, and links/pins

During the inspection the servomotor was not opened but based on reports from crews has minimal leakage. The servomotor ram has a damper which is oil-filled, but which is not regularly inspected.

The swing ring and wicket bushings are all in good condition. Bushing tolerances are tight.

Wicket gate links and friction devices are also in good condition. In the past 10 years, only one has required fixing due to a large wooden block passing through the penstock.

Governor

The governor is the original Gilkes flyball governor with two spool valves: pilot valve and distributor valve. This governor requires manual intervention onsite to start or stop the unit and does not have the functionality for remote control. The control includes permanent and temporary droop – adjusting these requires a very specific skill set.

The governor is in acceptable condition with the following concerns:

- Oil is water cooled and very low pressure (60psi), governor oil stays clean, year on year;
- Oil requires periodic top-ups;
- Flyballs are belt driven from the turbine shaft (safety hazard);
- The unit is never operated in frequency keeping mode or in isolation;
- Crew reports that the governor has multiple leaks (subsequently fixed by American Governor in 2022 visit);
- Greasing of pivot points and grease nipples as well as top up of oil;
- Multiple oils/lubricants required (gears, cables, Speedo wheel, ballhead, sump, pivot points, links and levers).

The governor requires periodic maintenance from American Governor and has had episodes of "hunting". Maintenance of this equipment is intensive, expensive and requires specialists.

<u>Summarized findings from recent American Governor visit ($21,000):</u>

- Base gaskets leaking;
- Tubing leaking;
- Servomotor packing leaking;

- Fasteners (bolts) are loosening over time and an "odd British thread" which can't be sourced – tightened and resealed threads (likely not repeatable);
- Pivot points – good condition;
- Distributing valve bushing – good condition;
- Links and levers – minor wear;
- Ballhead – good condition;
- Speed signal comes from belt on main shaft;
- Cannot repressurize governor unless unit is running;
- No spare parts available worldwide (except potentially from Gilkes in the UK, but will need to be custom made).

Crane – Monorail system

The monorail system in the powerhouse should be rated to lift the maximum load of the generator rotor and shaft, which is approximately 3,500lb. In 2016 the capacity of the monorail was assessed to be only 850lbs. The supporting columns are in very poor condition (see Section 3.3 for further detail).

Observations

Figure 2: Runner Suction Side Cavitation (expansion too severe)

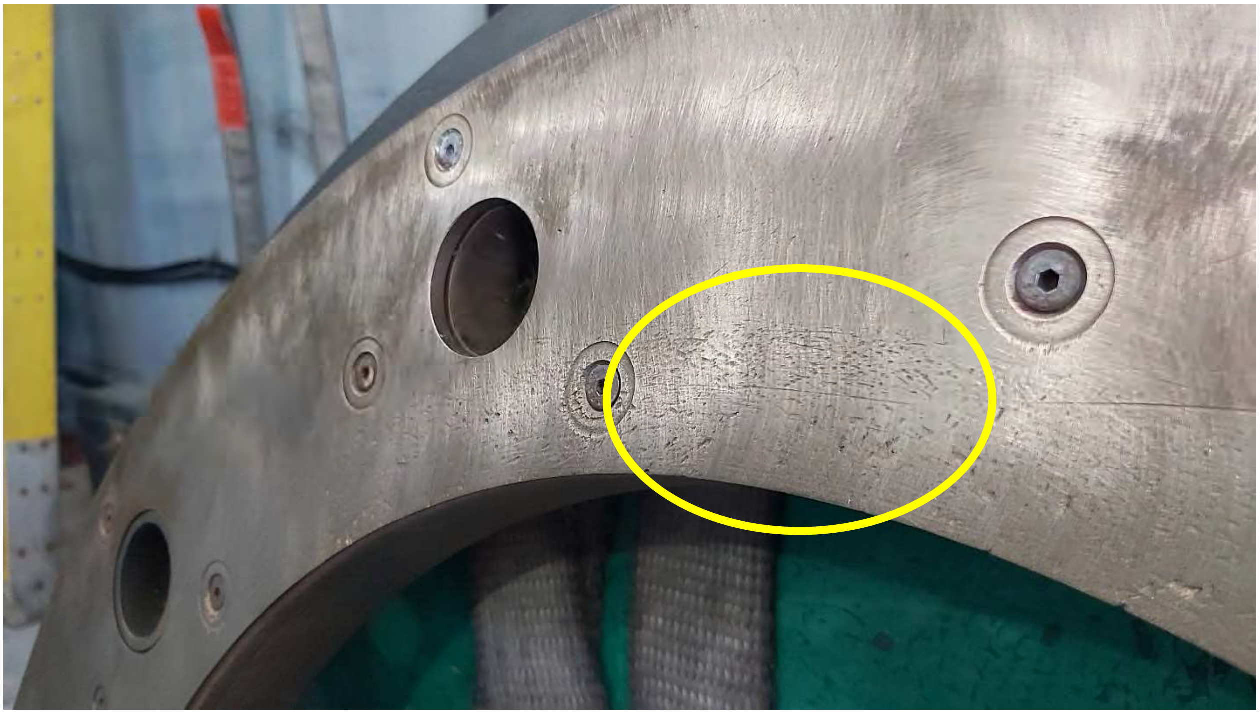


Figure 3: Lower Wear plate and Band seal Damage (Cavitation)

Figure 4: Wicket Gate Damage

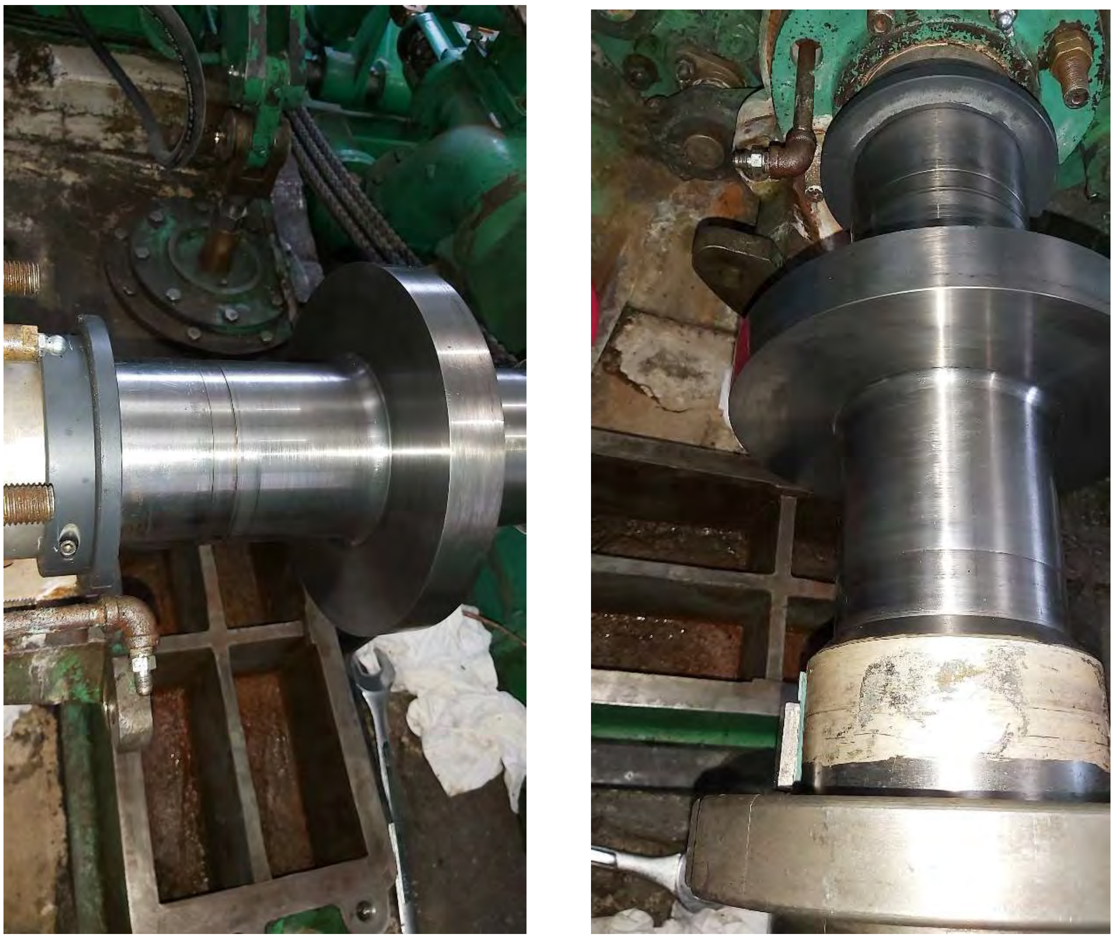


Figure 5: Turbine Journal Bearing Shaft Scoring

Figure 6: Turbine Journal Bearing Minor Wear

Figure 7: Thrust Pad Damage

Figure 8: Turbine Bearing Pedestal Hole to Ground

Figure 9: Scroll Case and Stay Vane High Friction Condition

Figure 10: Brake/Flywheel Damage

Figure 11: Gilkes Governor Belt Drive (Speed Indication)

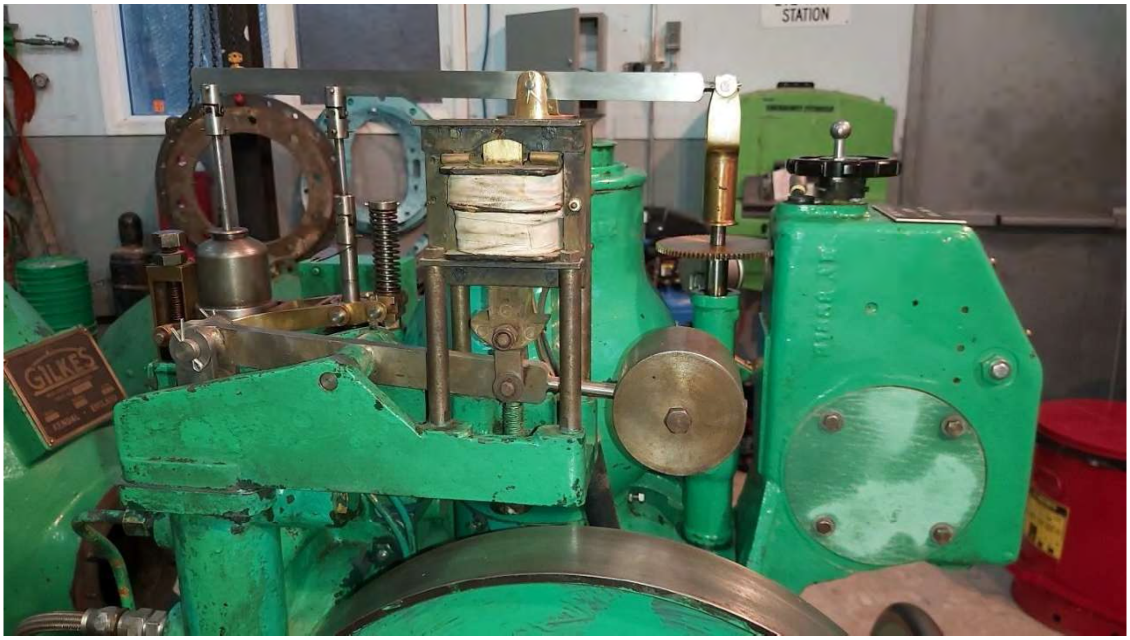


Figure 12: Gilkes Governor Head LHS

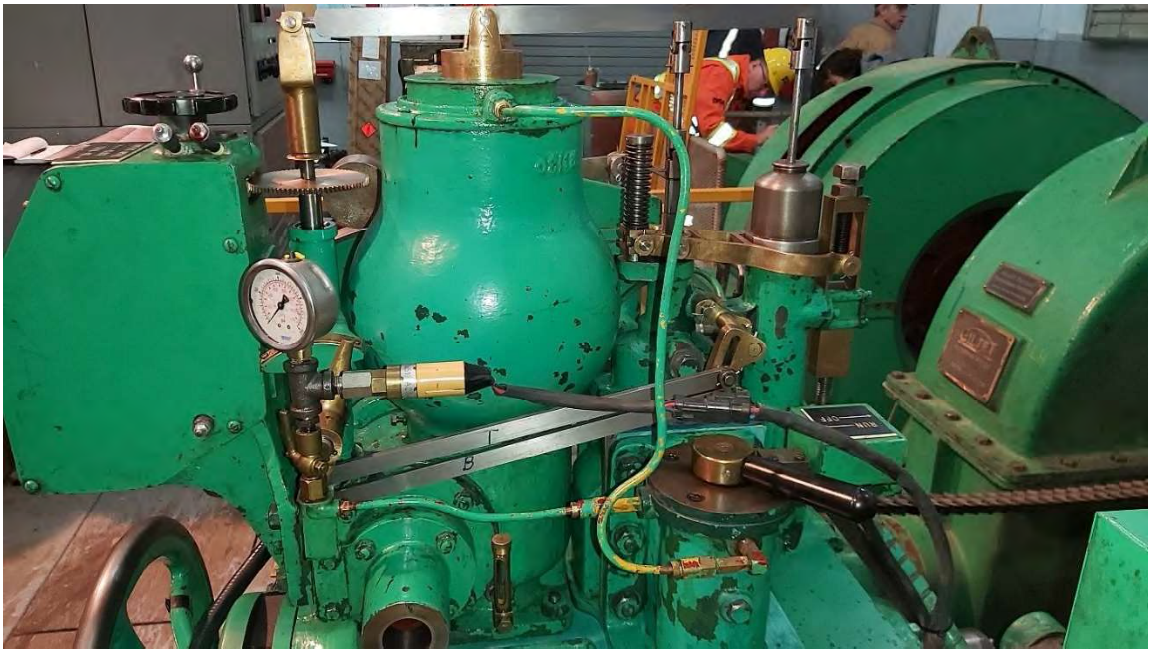


Figure 13: Gilkes Governor Head RHS

3.2.3. Generator

The generator was originally manufactured by Westinghouse in 1954, with a rating of: 812kVA, 600kW, 2300V, 203A, 0.8PF, 1200RPM. It was subsequently re-wound in 2000. Unfortunately, due to water conveyance losses, the generator is only able to obtain about 480kW maximum output.

The generator output leads are connected through a 4160V, 400A, 3-phase vacuum circuit breaker located in the powerhouse, and then to a 1.5MVA, 24.94kV (Gnd Wye) – 2.4kV (Delta) transformer located outside the powerhouse.

Excitation power is produced by a Westinghouse direct coupled DC generator rated: 612kW, 125V, 52A DC, manufactured in 1954, and a Basler SR4A AVR.

For the following, the estimated life span of electrical equipment is based on Table 2 in: *Replacements, Units Service Lives, Factors December 2005, prepared by, US Department of Energy, US Department of the Interior, Western Area Power Administration & US Bureau of Reclamation.*

3.2.3.1. Generator Maintenance Summary

Several major repairs and tests have occurred on the generator in the past 23 years.

- 2000 – Generator was re-wound (as stated in the Maven Report);
- 2014 – DC generator commutator was machined;
- Stator polarization index readings (PI) supplied by ATCO for stator insulation testing from 2010, 2011, 2012 and 2017 show a good average PI reading of 5.055;
- A rotor pole drop test in 2017 recorded no issues within the rotor poles themselves. Each of the voltage drop results across the six poles was less than 10% of the average which is good.

3.2.3.2. Generator observations

Largely, the generator appears to be in relatively good condition based on a visual inspection. Both the rotor and stator appear to have a significant buildup of carbon dust with more on the end closest to the brush gear. Some stator core air slots at the air gap are approximately 20-30% plugged with dirt and carbon dust (observations were made before any cleaning).

Stator core air slots in general appear to be straight and the laminations are tight and look uniform with no evidence of bowing, buckling, or waving. The collector ring and end turns appear to be lashed tightly and are in good condition with no discoloration, dusting, cracking of the insulation, or flaking of the grading paint.

According to the Maven Report the stator was rewound in 2000 and appears to still be in good condition. Contributing to the condition is no doubt the fact that the generator has been operated approximately 25% below its maximum nameplate rating for most of its life.

Figure 11: Generator Windings

Figure 12: Stator and End Turns with Carbon Dust Buildup

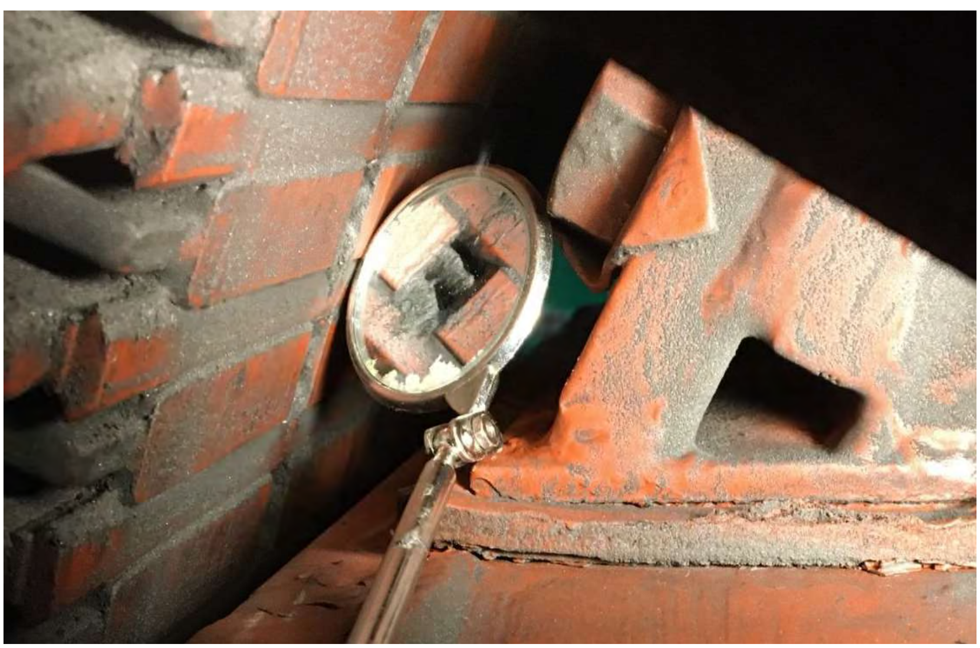


Figure 13: Inspection Partially Obstructed Stator Slot

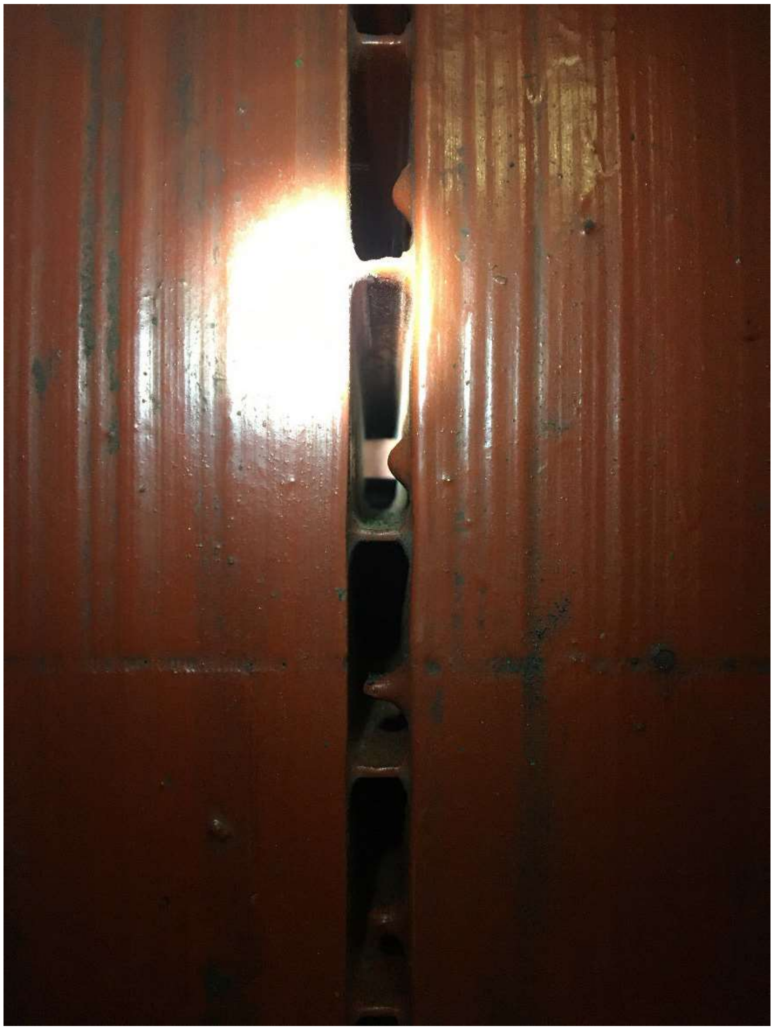


Figure 14: Stator Air Slots on Outside

The rotor field leads are tight and don't show any signs of movement or deterioration.

The main slip rings are smooth but have some streaking. The brush holder is solidly mounted and holds four brushes per ring. The frequency of brush change out needs to be confirmed by ATCO. BBA recommends cleaning to remove the streaking.

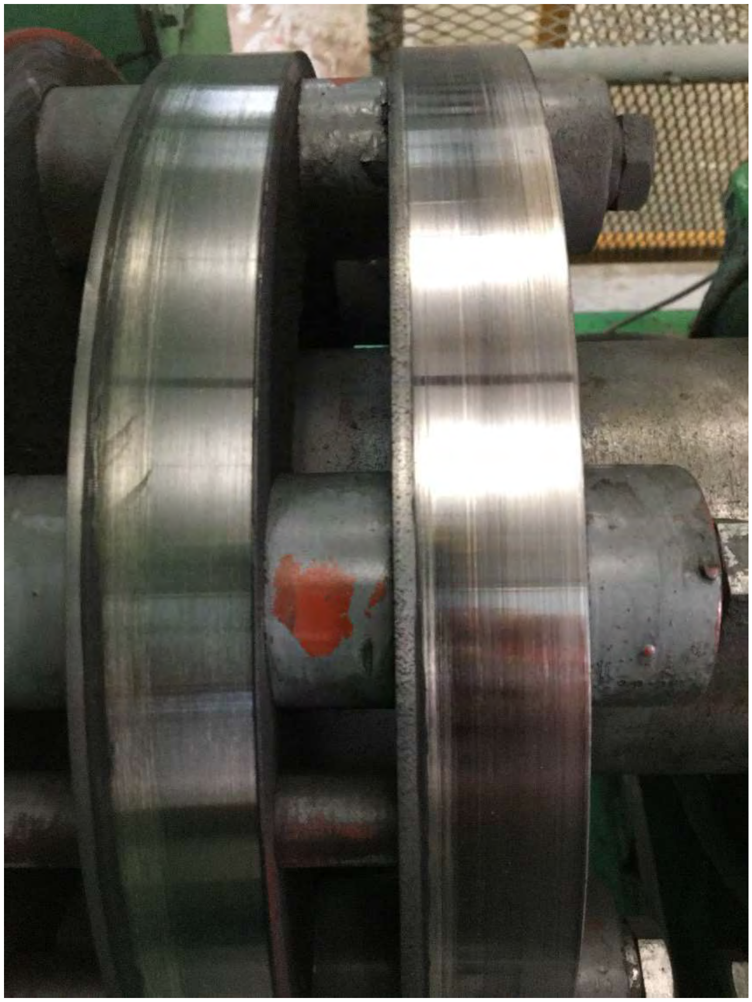


Figure 15: Main Slip Rings

The direct coupled rotary DC generator used to supply power to the generator field, would generally have a lifespan of about 40 years before requiring a full rehabilitation. This unit is nearly 69 years old and although the commutator was resurfaced in 2014 (per the Maven report) there is no evidence that it has had a complete overhaul.

Visual observation of the commutator shows that a noticeable groove is wearing under one set of brushes and that a resurfacing is needed yet again (last time was in 2014). There appears to be enough copper on the commutator for it to be resurfaced a couple of more times, but this is dependant on how much longer the unit is in service and the grove worsens.

The Maven Report suggests that different brush densities and adjustment of the brush holders be further investigated. In addition, each time the commutator needs resurfacing the work needs to be synchronised with a suitable unit outage window.

To eliminate brush and commutator maintenance and extend life, the removal of the DC generator and replacement with a new static exciter should be considered. This would tie in nicely with a P&C upgrade.

Figure 16: DC Generator Commutator

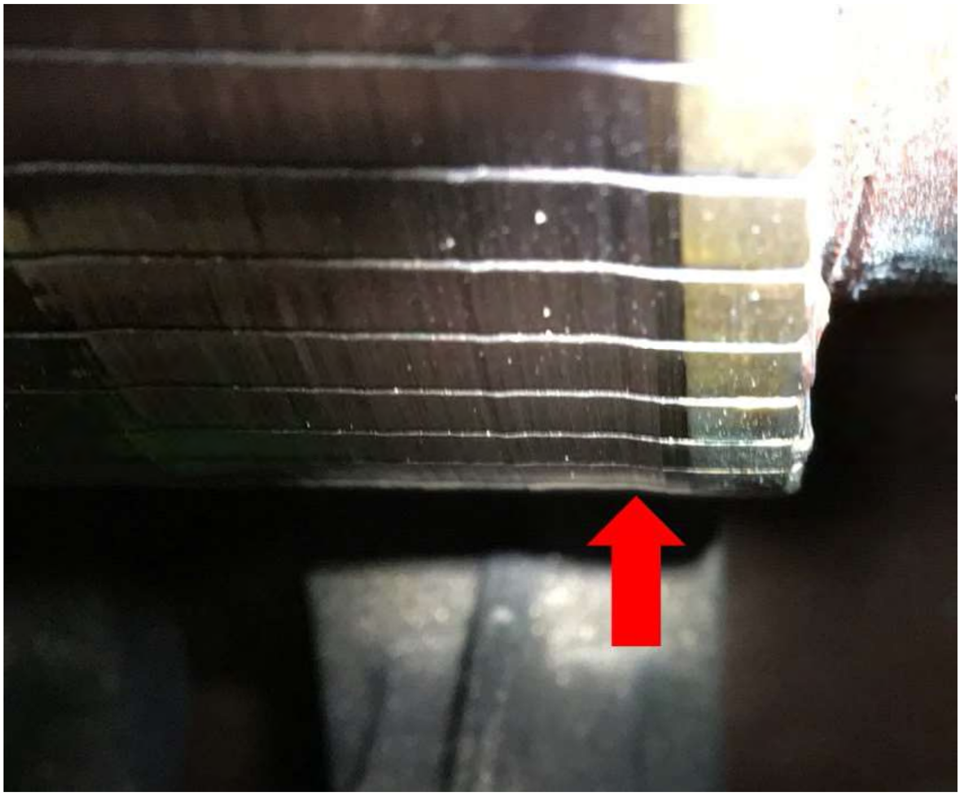


Figure 17: Groove Worn in Commutator

Figure 18: Commutator Remaining Surface (~3 to 4mm)

3.2.4. Generator Switchgear and P&C

The switchgear and P&C are in a combined cabinet with a 4kV vacuum circuit breaker in the bottom compartment, CTs and PTs in behind and the P&C components isolated from the MV gear in their own cabinet above. It is worth noting that this equipment appears to have been installed in approximately 1999 and is now 23+ years old.

The position and location of the generator controls adjacent to the running equipment and directly above the generator circuit breaker poses somewhat of a safety risk to the operator.

Figure 19: P&C and SWGR Panel

3.2.4.1. P&C observations

The GE series 90-30 PLC used for the unit control is obsolete and is no longer supported by GE. Spare parts will become an issue. To upgrade the CPU to a newer RX3i model would require the existing PLC application program to be manually converted.

The generator protection consisting of the Basler BE3-GPR generator protection relay and BE1-87G differential protection relays are obsolete and at end of life. These old analog relays have no event capturing capability to aid in locating faults, or built-in self monitoring like modern digital protective relays.

The Quickpanel HMI is not as useful to operators as a larger HMI with data logging and event historizing capability.

A modern P&C and SCADA system would provide historization and event recording of many analog and discrete signals aiding in alarm and trip event troubleshooting. Not only could this data be available locally, but it could also be uploaded to corporate servers for diagnosing issues remotely before going to site. In addition, a modern P&C and SCADA system would provide the option for complete remote monitoring and control, which would optimise unit operation and maximize revenue.

3.2.4.2. Medium Voltage (MV) Switchgear observations

The circuit breaker (CB), potential transformers (PTs), and current transformers (CTs) were inaccessible during the site visit due to the electrical isolation and limits of approach, however, there is a discussion on their condition in the Maven Report.

Both the vacuum CB and instrument transformers (PTs and CTs) have a practical 35-year life span with good maintenance.

The generator CB is located underneath the control cabinet, posing a potential safety risk to the local operator due to the possibility of an arc-flash while operating. There is no arc-flash warning label identifying the incident energy.

3.2.5. MV cables

The MV cables appear to have been replaced since the original installation, most likely in 1999 when the new switchgear was installed.

Figure 20: MV Cables Under Generator

3.2.5.1. MV cable observations

Cables from the generator phase outputs to the 4kV switchgear, are located in dry, concrete, trenches and are composed of 6 x 1 conductor 4/0, 7500V, tray cable, 1 per phase for main leads and 1 per phase for neutral (phase neutrals are tied together in the switchgear after the neutral CT's).

The cables appear to be in satisfactory condition for 23 years age, and the insulation test results supplied, although at a reduced voltage, appear to be satisfactory. Typically, power cables have a 40-year life span. These cables should continue to be tested every couple of years to monitor for any issues.

3.2.6. Generator Transformer

The generator step up transformer is a 1500kVA, ONAN, 60Hz, 3Ph, 24940 Grd Wye/14400X 12470 GrdY/7200 – 2400 Delta, with 4-2.5% (+2, -2) taps. The transformer is connected to a 12kV distribution line and is grounded. The transformer was installed in 2012 and the industry standard life span is approximately 40 years.

There does not appear to be any oil level, temperature, or other monitoring on the transformer and since the transformer was energized, limits of approach were respected and access was restricted to visual only from the outside.

No oil test data was provided. BBA recommends oil sampling be performed at a minimum, every 2 years.

In the eventuality that the generator was to be replaced with a similar sized unit, the transformer should be reused. It would be prudent though, to add some basic instrumentation such as a core temperature RTD and connect to the PLC for monitoring and alarming.

3.2.7. Equipment Grounding and Bonding

The Maven Report identified a lack of grounding of the major equipment. It was observed that the main pieces of equipment such as the generator and exciter end frame, bearing pedestals, water brake and governor have now been individually tied with a ground conductor to a central ground point. It was not possible to see where the central ground point was exactly located or make a visual assessment as it appears to be inside the MV switchgear. BBA would recommend a fall of potential test to check the ground connection to earth.

3.3. Powerhouse Structural and Foundation Assessment

3.3.1. Introduction

A condition assessment of the Fish Lake 2 generating station building and foundation was completed to assess its suitability for continued use. This section of the report aims to summarize findings and provide recommendations for the upgrades required to make the powerhouse suitable for continued use as a power generating facility.

The building is a single-storey wooden frame building with wooden roof truss hosting a turbine/generator. The building layout is shown Figure 21 below.

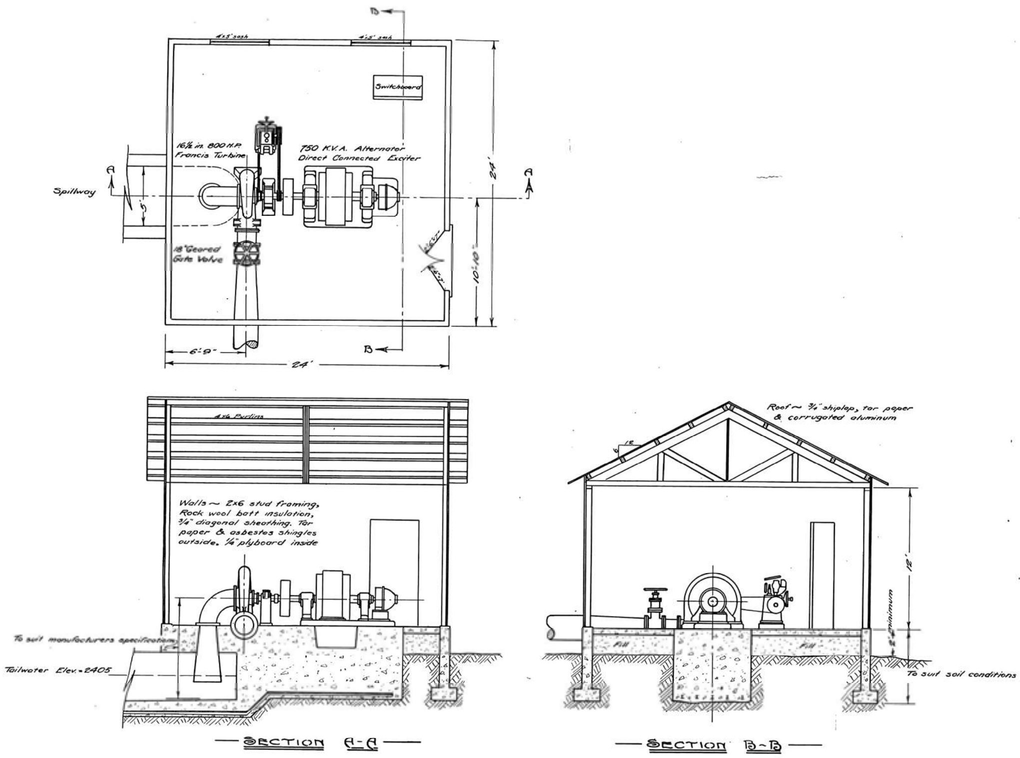


Figure 21: Powerhouse building

3.3.2. Code requirements

Currently, the governing code is the National Building Code of Canada 2015, but the building was presumably designed to NBCC 1954. To complicate matters further, NBCC 2020 was published late last year, but has yet to be formally adopted by any Canadian jurisdiction.

3.3.3. Available Information and Assumptions

There are a limited number of drawings available, which mainly consist of the general arrangement of the powerhouse. Record drawings of the building, concrete, rebar, and later updates to the building including monorail columns were not available. In addition, no geotechnical information was available for the area beneath and surrounding the facility.

Based on the site inspection and limited reports and drawings, the building substructure is comprised of concrete strip and single footings. On the perimeter, a concrete pony wall extends up beyond the floor level by about 4 inches. The attic insulation consists of 2" of paper faced fiberglass batt installation with approximately 6" of blown-in cellulose over top.

The foundation for the turbine and generator assembly is comprised of a concrete mass block with some non-reinforced trenches and walls surrounding the equipment.

The superstructure consists of wooden frame building and trusses with 2x4 suspended ceiling joists and a 3/8" painted plywood celling.

As a stand-by power station, Fish Lake 2 is a post-disaster life-line facility. The National Building Code of Canada 2015, which is currently in effect, requires the main structural system of post-disaster structures to be designed for a 50 year return period wind load and seismic load calculated with an importance factor of 1.5.

Since the facility was built in 1954 it is assumed that design was done based on 1954 code.

3.3.4. Structure Assessment

3.3.4.1. Building Substructure

The visible concrete portions of the building substructure (pony walls, floors, and trenches) appear to be poor condition. Several floor cracks were identified, and differential settlement was observed between the concrete block and slab on grade. The height difference between the concrete slabs varies from 0.5in to 3in Figure 22.

Without further geotechnical investigation, it is difficult to assess the cause of settlement beneath the powerhouse foundation. The indicators of settlement are generator shaft misalignment and floor cracking. As it stands, there only seems to be local settlement around the bearing and generator slabs but not the whole concrete block. Determining the cause of this settlement will require further testing. Without any intervention, the building foundation will continue to settle unevenly.

The main service trench running around the generator was inspected. Hammer testing showed very loose and degraded concrete (Figure 23).

Vertical "cracks" are visible at the pony wall locations (Figure 28).

Several cracks were observed on the floor on and around the monorail columns (see Figure 28).

Figure 22: Differential settlement between the concrete block and slab on grade


Loose and decomposed

Figure 23: Loose and degraded concrete under the block concrete and inside the trench

Figure 24: 1 in wide crack on the floor and settlement between the block concrete and building slab

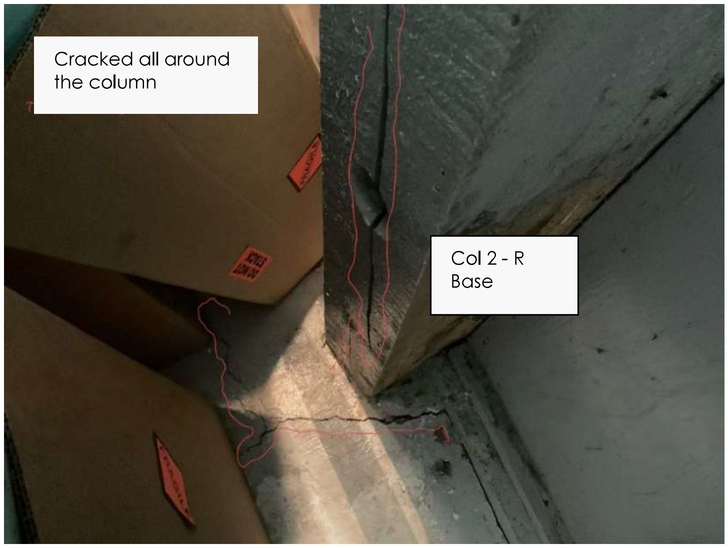


Figure 25: several cracks on the pony walls and column bases

Figure 26: degraded concrete on tailrace walls

Figure 27: Differential settlement outside and inside the building

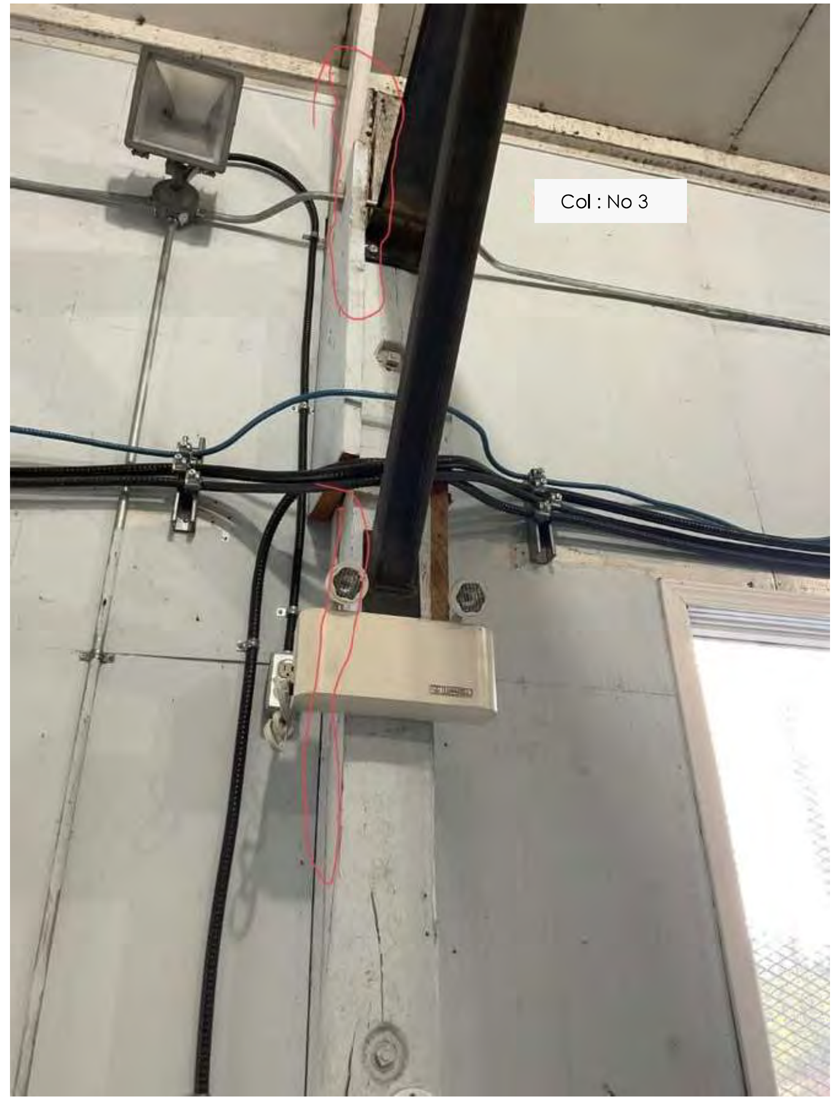
3.3.4.2. Building Superstructure

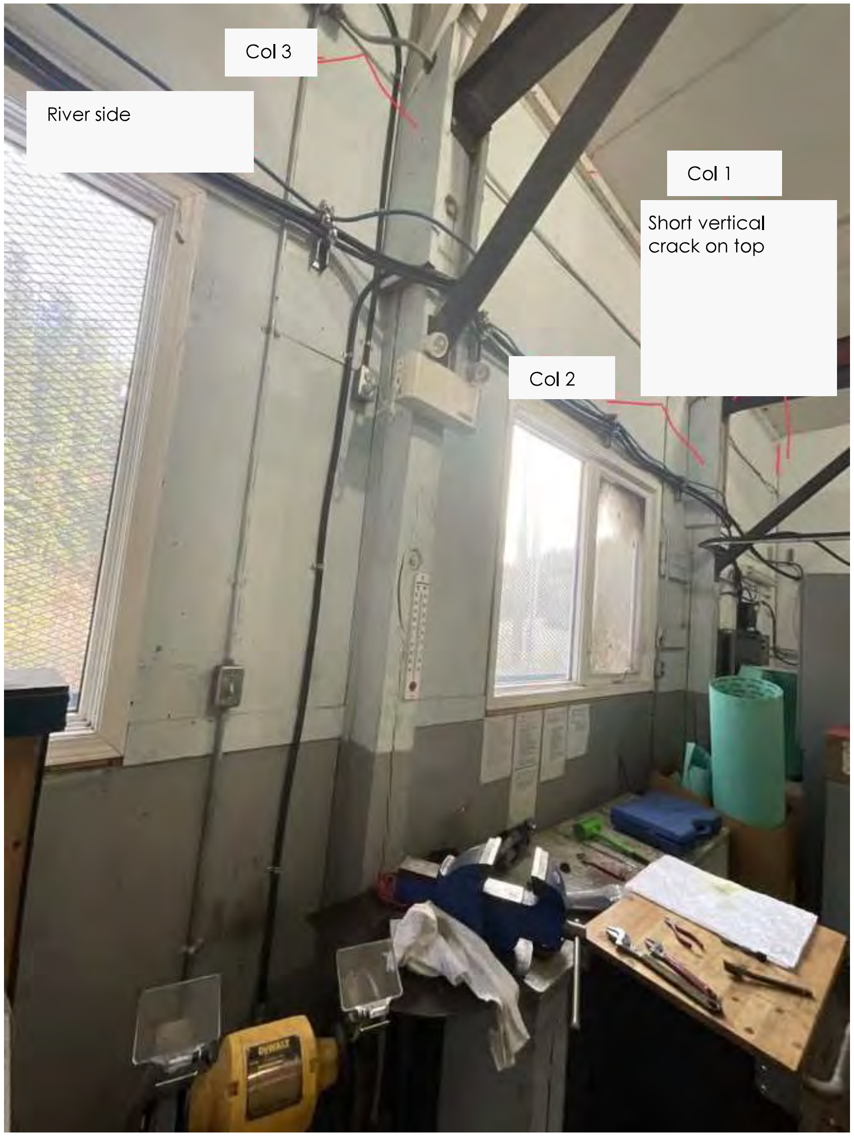
During the inspection the building envelope columns and studs were not visible, and the roof truss was not inspected due to the access; however, several major continuous cracks were observed on the monorail support columns.

The general visual inspection of the visible structural elements shows that the wooden structure is not in fair condition. The wooden structure is not expected to have any lateral capacity during any seismic event. These structural elements must be retrofitted or replaced.

The following photographs show several vertical continuous cracks and column separation gaps.


Col 3
Vertical crack
All around


Col : No 3

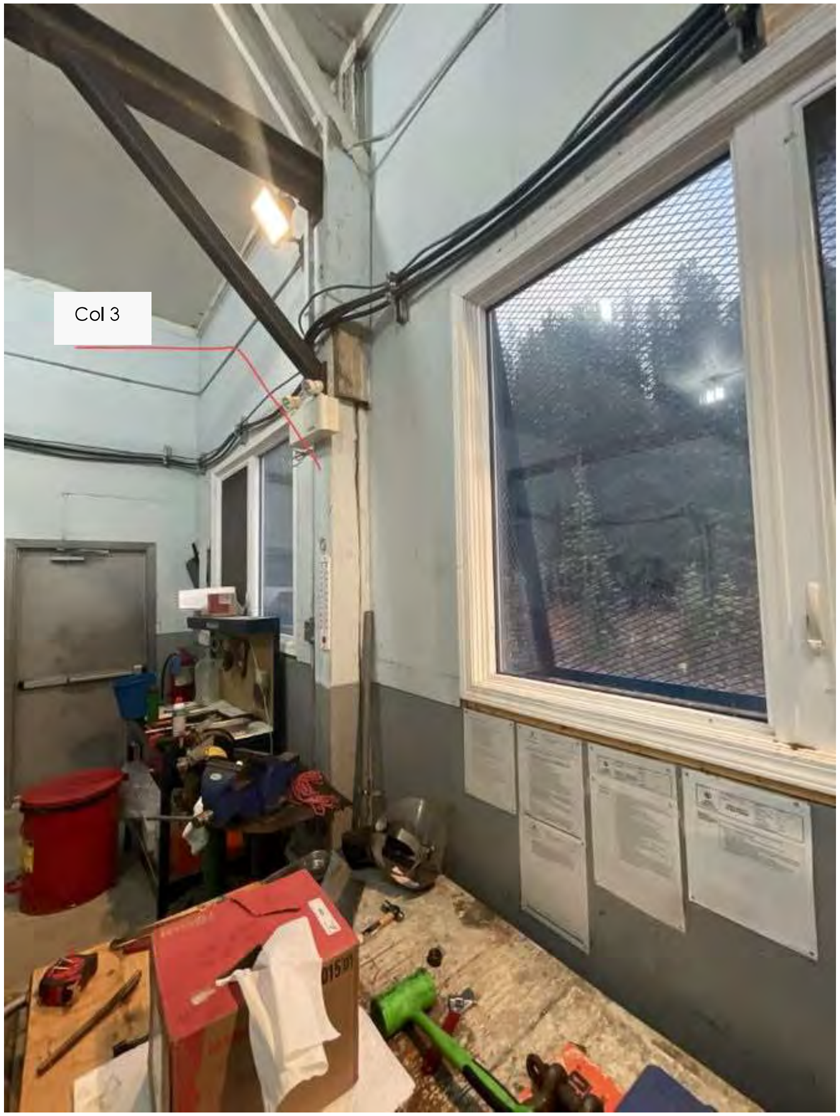

Col 3
River side
Col 1
Short vertical crack on top
Col 2

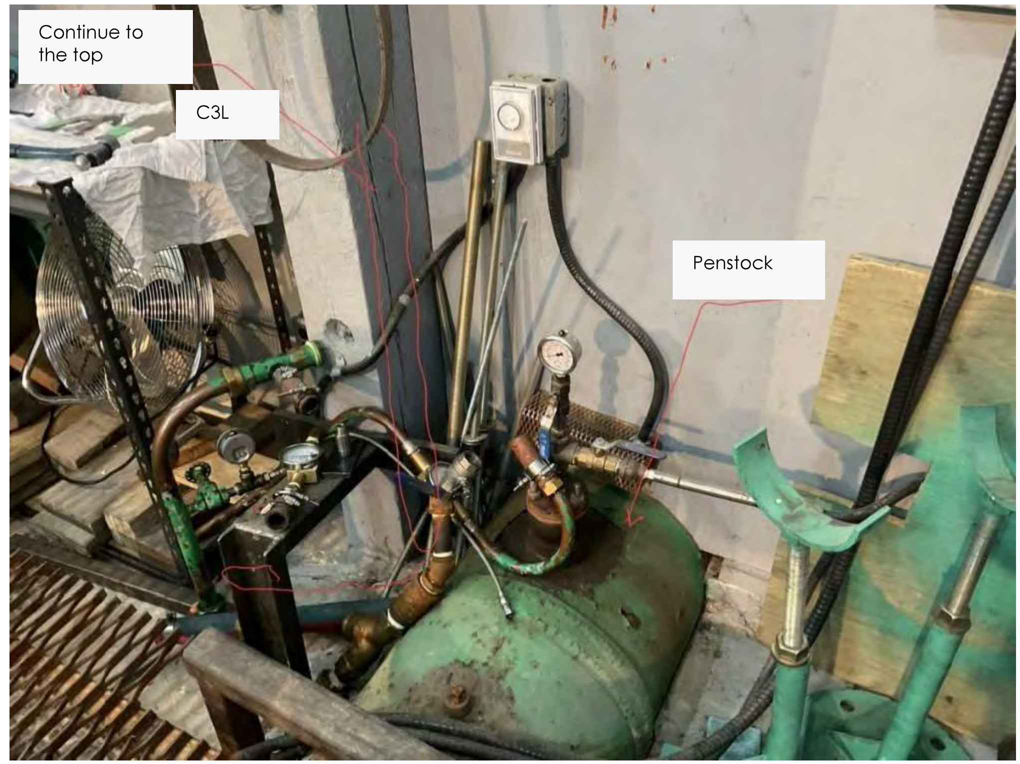

Col 2 R


Col 3 R
Vertical wide cracks 0.5 in all around
Col 2 R


Bolted to the main column but separation visible at the top

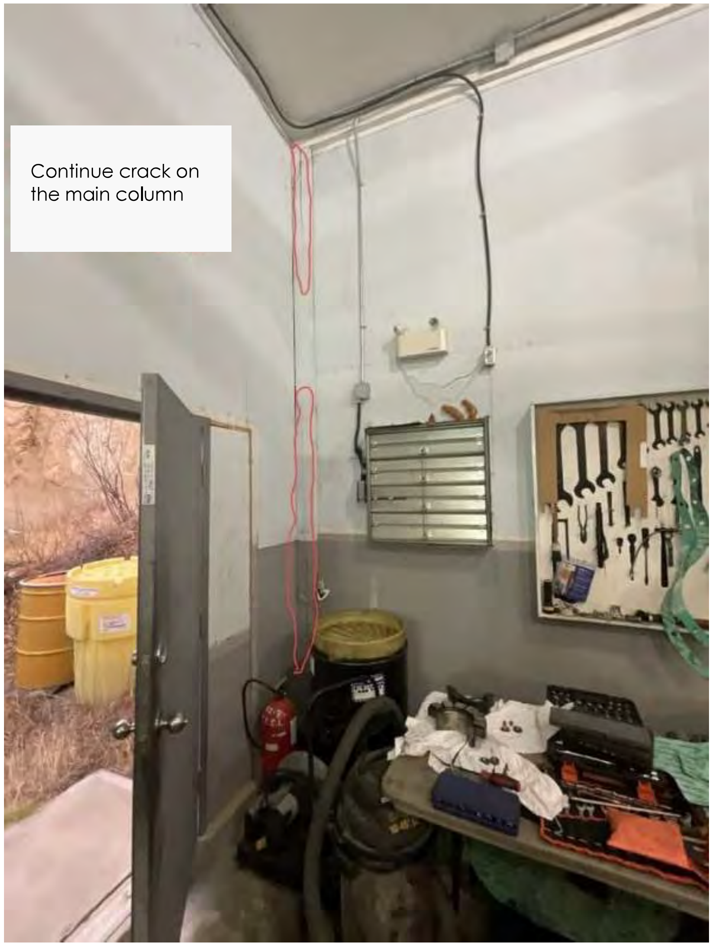

C3L
C2L


Col 3


Continue to the top
C3L
Penstock


Col 2
left


Separation between wall and column.
Col no 1, left site (looking at river)



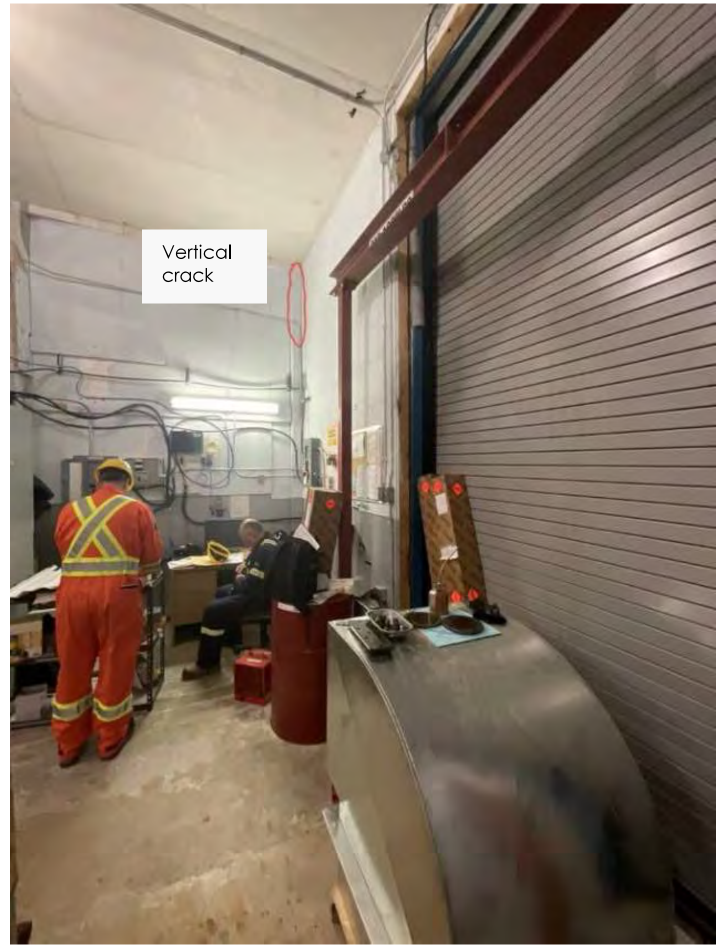


Figure 28: Cracks on main columns

Figure 29: Missing handrails

3.3.5. Environmental loads

The NBCC design loading that was likely used when the Fish Lake 2 structure was designed is as shown below.

Table 1: Environment from NBCC 1965

Snow		
Ground snow load (1/30 years)	1.3 kPa	
Outside temperature		
January	2.5%	–41°C
January	1.0%	–43°C
July	2.5% dry	24°C
July	2.5% wet	16°C
Precipitation		
15 minutes (1/10 years)	5 mm	
1 day	38 mm	
Total annual	279 mm	
Wind load		
Gust speed (1/30 years)	115.9 km/hr	
Velocity pressure (1/30 years)	0.67 kPa	
Seismic data		
Earthquake factor	2	

For reference, the design loading as shown in NBCC 1970, 1990, and 2010, respectively, is listed as shown below.

Table 2: Environment from NBCC 1970

Snow		
Ground snow load (1/30 years)	1.3 kPa	
Outside temperature		
January	2.5%	−41°C
January	1.0%	−43°C
July	2.5% dry	24°C
July	2.5% wet	16°C
Precipitation		
15 minutes (1/10 years)	5 mm	
1 day	38 mm	
Total annual	279 mm	
Wind load		
Hourly wind pressure (1/10 years)	0.28 kPa	
Hourly wind pressure (1/30 years)	0.34 kPa	
Hourly wind pressure (1/100 years)	0.42 kPa	
Seismic data		
Earthquake R-factor	4	

Table 3: Environment from NBCC 1990

Snow		
Snow load, Ss (1/30 years)	1.7 kPa	
Rain load, Sr (1/30 years)	0.1 kPa	
Outside temperature		
January	2.5%	−41°C
January	1.0%	−43°C
July	2.5% dry	25°C
July	2.5% wet	15°C

Precipitation	
15 minutes (1/10 years)	8 mm
1 day	31 mm
Total annual	261 mm
Wind load	
Hourly wind pressure (1/10 years)	0.28 kPa
Hourly wind pressure (1/30 years)	0.34 kPa
Hourly wind pressure (1/100 years)	0.42 kPa
Seismic data	
Za	2
Zv	4
Zonal Velocity Ratio v	0.20

Table 4: Environment from NBCC 2010

Snow, rain, and depth of frost		
Snow load, Ss (1/50 years)	1.8 kPa	
Rain load, Sr (1/50 years)	0.1 kPa	
Outside temperature		
January	2.5%	−41°C
January	1.0%	−43°C
July	2.5% dry	25°C
July	2.5% wet	15°C
Elevation		
Whitehorse	655 m	
Precipitation		
15 minutes (1/10 years)	8 mm	
1 day (1/50 years)	43 mm	
Total annual	170 mm	
Wind load		
Hourly wind pressure (1/50 years)	0.38 kPa	

Seismic data – 5% damped horizontal spectral accelerations and horizontal PGA with 2% probability of being exceeded in 50 years for Site Class C	
Sa (0.2)	0.22
Sa (0.5)	0.15
Sa (1.0)	0.10
Sa (2.0)	0.060
Peak Ground Acceleration (PGA)	0.11

Finally, the current NBCC design loading is as shown below.

Table 5: Environment from NBCC 2015

Snow, rain, ice, and depth of frost		
Snow load, Ss (1/50 years)	2.0 kPa	
Rain load, Sr (1/50 years)	0.1 kPa	
Equivalent radial ice thickness (10m above ground, open terrain, 1/50 years)	10 mm (as per Figure 1 from CSA S37)	
Frost depth	To be finalized	
Design temperature		
January	2.5%	−41°C
January	1.0%	−43°C
July	2.5% dry	25°C
July	2.5% wet	15°C
Site Properties		
Whitehorse Elevation	655 m	
Site Specific Elevation	642m (masl)	
Precipitation		
15 minutes (1/10 years)	8 mm	
1 day (1/50 years)	43 mm	
Total annual precipitation	275 mm	
Wind load		
Hourly wind pressure (1/10 years)	0.29 kPa	
Hourly wind pressure (1/50 years)	0.38 kPa	

Seismic data – 5% damped horizontal spectral accelerations and horizontal PGA with 10% probability of being exceeded in 50 years for Site Class C	
Sa (0.2)	0.165
Sa (0.5)	0.140
Sa (1.0)	0.100
Sa (2.0)	0.056
Peak Ground Acceleration (PGA)	0.073

As shown in Table 1 through Table 5, the NBCC requirements for design loading have become more stringent over the years. Based on a simple comparison of design code and current code requirements, it seems unlikely that the structure has adequate lateral load capacity for earthquake loads.

3.3.6. Summary of Building Condition

A formal detailed capacity analysis of the structure cannot be carried out due to the lack of dimensional information for the pre-engineered building components; however, the visual inspection indicates that this building has reached its end-of-life state.

Based on a simple comparison of NBCC code requirements, it is unlikely that the structure in its current condition will meet NBCC seismic loading requirements.

An upgrade would normally be "triggered" only by a change in building usage or if major alterations to the building were planned. Most owners of a post-disaster facility will undertake an upgrade if such an evaluation identifies a deficiency, and we recommend that this be done for the Fish Lake 2 plant.

There are no records of the subsurface conditions directly below the plant. Considering the apparent problems with foundation cracks, which may be due to vibration, this lack of geotechnical information is a source of considerable risk for all options,

3.3.7. Recommendations and Next Steps

Given that Fish Lake 2 is a post-disaster facility, it is recommended to complete upgrades to the building structure and foundations as soon as is reasonably practicable to extend the useful life of the building for another 40 years.

There are two upgrade options to consider: retrofitting the existing building structure and foundations or replacing the building structure entirely and upgrading existing building foundations.

Retrofitting the existing structure and foundations would comprise re-establishing and upgrading the cross-bracing in the long building direction. Additionally, the portal frames may be inadequate to carry the required lateral loads, even if reinforced. This could be addressed by providing improved roof cross bracing down the length of the building and tying this into new transverse bracing panels. These transverse bracing panels would probably require micro-pile foundations. The cost of such upgrades is outlined in Section 5.1.3.

Replacing the building structure would require installing a new prefabricated building. The existing foundation would have to be replaced as well.

Prior to continuing with preliminary design, a detailed dimension survey of the existing superstructure would be required. Furthermore, while the evaluation was carried out to evaluation level loads, an upgraded detailed design should be carried out to full current load requirements.

Regardless of which option is progressed, it is recommended that a geotechnical investigation be carried out to evaluate the static and dynamic properties of the subsoil as a part of the preliminary design phase. This investigation should be comprised of:

- Two exterior boreholes drilled as close to the building as possible;
- In-situ tests would likely comprise standard penetration tests and sampling for classification tests;
- Cross-hole or down-hole geophysical tests to determine the low-strain shear modulus of the soils.

4. Summary of Equipment Condition

The notes are taken verbatim during the site visit and can be found in Appendix B.

4.1. Turbine

- The runner is steel and relatively new, however, it cavitates and likely has a relatively short life expectancy (8 years). Cavitation repair is required every two years until replacement in 2026;

- The bronze wicket gates require replacement with steel wicket gates immediately, and will likely need replacement every 10 years;
- The upper and lower wear rings require replacement now and likely in 10 years;
- The shaft and lubrication systems appear to be in good condition and low maintenance;
- Annual maintenance is required on white metal bearings, which entails scraping bearing pads every year. This is unusual. Generally, babbitt metal bearings last forever, until vibration caused by another issues triggers a bearing wipe and the need to re-metal. Based on the current condition it should be assumed that a full re-metalling of all bearings will be required every 10 years;
- The brake system is likely what is causing the bearing failures and should be replaced with a simple truck brake system and controls;
- Water seals appear to be low maintenance;
- The governor and its associated Giljet brake are high maintenance and obsolete, they should be replaced as soon as possible.

4.2. Generator

- It is recommended that the generator is given a good and thorough cleaning, both the rotor and stator, including air slots;
- Continue testing and monitoring of generator condition;
- Sliprings on the generator require cleaning to remove streaking;
- The commutator on the DC exciter generator needs to be re surfaced. It is recommended to replace this with a static exciter (together with a P&C upgrade).

4.3. Switchgear / P&C

- The Protection and control equipment, although working, is obsolete and spare parts will be hard to find. It is recommended to replace this equipment as soon as possible.

4.4. MV Switchgear

- Although the MV switchgear appears to be in ok condition, the CB and instrument transformers are nearing end of life;

- The generator CB is located underneath the control cabinet, posing a potential safety risk to the local operator due to the possibility of an arc-Flash incident while operating.

4.5. MV Cables

- The MV cables appear to be in ok condition. Continue testing and monitoring of condition.

4.6. Generator Transformer

- It is recommended that oil sampling of the transformer is completed every two years.

4.7. Building Structure and Foundations

- The building structure and foundations reached the end of life state many years ago, and a full replacement is recommended;
- A geotechnical investigation of the area surrounding the current powerhouse is recommended to provide data for the design of a new foundation.

5. Alternatives

5.1. Option 1: Targeted Safety Replacement

5.1.1. Scope of Work

The first option to consider for Fish Lake 2 is to immediately replace any equipment with safety concerns and continue to replace all other equipment as it reaches its end-of-life. The end-of-life for each piece of equipment has been assessed based on the observations documented in Section 3.

The equipment with safety concerns includes the governor and servomotor, as well as the building foundation and structure. The governor and servomotor shall be replaced immediately. In addition, retrofits to the building structure shall also be undertaken to ensure it meets current building and seismic codes. This would likely include reinforcement of the existing building structure, plus installation of micro-pile foundations.

5.1.2. Energy Modelling

A set of historical generating data for Fish Lake 2 between 2016 and 2021 was provided. The data shows the operational parameters of the station over the past several years.

Table 6: Historical Energy Production from Fish Lake 2 Generating Station

Year	Energy Production (GWh/year)
2016	1.961
2017	0.653
2018	0.092
2019	0.001
2020	0.025
2021	1.922

As discussed in Section 3.2, Fish Lake 2 experienced significant downtime between 2017 - 2020. This means that the average energy production per year based on this historical data was 0.776 GWh/year between 2016 and 2021.

It is assumed that by completing the targeted safety upgrades, there will be more reliable operation of the unit. A more realistic estimate of future energy production as end-of-life equipment replacements are completed would only consider the average of 2016 and 2021 energy production, the years in which the unit ran reliably, plus some small gain in energy production on a pro-rata basis. This estimated energy production is approximately 2.1 GWh/year.

As previously discussed, the unit is currently rated to a maximum of 480 kW output, which indicates it is only operating at 67% efficiency. This is low for a unit of this size built recently; however, the original unit was quoted as 75% peak efficiency. Based on the unit's age and accounting for any operation outside of design head / flow would explain this phenomenon.

5.1.3. Life Cycle Plan and Capital Costs

Based on the equipment condition outlined in Section 4.1, the timeline and costs for equipment replacement at Fish Lake 2 are outlined in Table 7 below.

Table 7: End of Life Replacement Cost Based on Condition

Equipment	Manufacture Date	Refurbishment Date	Lifespan (Typical)	Replacement date	Replacement Cost (materials + labour)
Runner	2010	2018	8	2026	$210k
Governor & Servomotor	1954	NA	50	2025	$650k
Wicket gates	2011	2015	8	2023	$82k
Wear rings and seals	1954	NA	8	2023	$50k
Bearings	1954	2021	5	2023	$30k
Lubrication oil system and Shaft	1954	2021	40	2061	$100k
Generator	1954	2000	30	2030	$135k
Rotary Exciter	1954	2014*	50	2004*	$30k
MV Switchgear	~1999	NA	35	2034	$70k
MV Cables	~1999	NA	50	2040	$50k
Protection & Control	~1999	NA	20	2019	$**
Step up Transformer	2014	NA	50	2064	$100k
Giljet Brake	1954	NA	50	2004	$5k
Powerhouse Structure & Foundations	1954	NA	50	2004	$2.225mil

* Commutator resurfaced in 2014. Typical lifespan of original equipment is 50 years.

** Included in Governor and Servomotor replacement cost.

The up-front capital cost of a targeted safety upgrade project is outlined in Table 8 below:

Table 8: Cost Estimate for Targeted Safety Upgrade Project

Components	Cost (CAD)*
	596 kW
Project Management	$415,760
Engineering Design	$424,080
Civil / Structural Equipment Supply – Building Foundation and Structure Upgrades	$2,225,000

Components	Cost (CAD)*
	596 kW
Electrical Equipment Supply – Rotary Exciter	$30,000
Mechanical Equipment Supply – Governor, wicket gates, wear ring & seal, bearings, brake	$817,000
Building Foundation and Structure Labour	$849,450
Mechanical / Electrical Equipment Labour	$236,190
Contingency (30%)	$1,499,240
Capital Cost	$6,496,720

* Assuming an exchange rate of $1.34 CAD = $1 USD

Note that any equipment scheduled for end-of-life replacement in 2023 or earlier has been included in the capital cost estimate. Future replacement expenditures for all equipment past 2023 are outlined in Appendix D.

5.1.4. Ongoing Maintenance Costs

The existing equipment at Fish Lake 2 will require ongoing maintenance until each asset reaches its end-of-life. Some of the maintenance can be reasonably expected to occur on a yearly basis, and other maintenance activities can be reasonably expected to occur at other frequencies. Table 9 outlines the estimated annual labour costs moving forwards for Option 1.

Table 9: Annual Maintenance Costs for Existing Fish Lake 2 Generating Station

Asset	Labour Costs ($100/hr)	Material Costs
Turbine: Runner, wicket gates, seals, scroll case	$15,000	-
Generator: Rotor, stator, P&C	$16,000	-
Governor	$15,000	$5,000

Asset	Labour Costs ($100/hr)	Material Costs
Shaft and bearings	$10,000	-
Brakes	$2,000	-
Daily checks ($80/hr)	$200,000	-
Bi-monthly inspection	$5,000	-
Recurring Annual Cost	$263,000	$5,000

Table 10 below outlines some of the major periodic maintenance activities that will be required at Fish Lake 2 moving forwards for Option 1.

Table 10: Periodic Maintenance Costs for Existing Fish Lake 2 Generating Station

Asset	Frequency	Labour Costs ($100/hr)	Material Costs
Turbine:	-	-	-
1. Runner	8Y	-	$25,000
2. Wicket gates	8Y	-	$10,000
3. Seals	8Y	-	$8,000
4. Water passage	40Y	$3,000	
Rotary Exciter	6Y	$3400	$2,000
Shaft and bearings	5Y		$4,000
Brakes	5Y	$10,000	-

5.1.5. Risks

In its current state, there are a variety of safety and operational risks currently present at Fish Lake 2. Namely, this includes the condition of the building and superstructure, as well as the condition / age of the governor and other control and protection equipment.

As outlined in Section 3.3, the building and superstructure has reached its end-of-life and does not meet current building codes and seismic design standards. In its current condition it poses a risk to workers inside the facility if a seismic event were to occur.

There are a variety of safety risks associated with the governor and associated protection / control equipment. As discussed in Section 3.2.2.2, the governor has no automatic start or stop functionality, and uses a chain belt, which exposes workers to a high-speed rotating piece of equipment. If the governor fails, the unit will go into overspeed, which requires workers to physically arrive on site during a loss of control of water to manually apply the Giljet brake using a snipe. Finally, the governor and brake do not have spare parts readily available due to their age. Completing any repair work would require fabrication of custom parts, adding significant cost to an overhaul or capital project.

Completing targeted safety upgrades on key pieces of equipment partially mitigates the risks outlined above; however, completing immediate upgrades to the building structure and governor does not alleviate a variety of other worker safety and operational risks.

One risk to highlight is the current building layout. The current plant layout does not respect modern equipment spacing, safe egress, or arc flash limits to electrical equipment. Operators are directly exposed to arc flash risk from the circuit breaker when operating the unit. In addition, egress in the event of an electrical or mechanical issue is beside the generator. A new unit inside of a new powerhouse would respect current safe work clearances to electrical and mechanical equipment and would put operators in a safe location for operating the generator and CB including a safe egress away from the equipment, reducing the risk of serious injuries or fatalities.

In addition, the overhead hoist, only rated to 850lbs, is not usable for a generator re-wind or other major overhaul work. It will likely not be usable unless major structural upgrades or a structural replacement of the building is completed. A new building could have an appropriately sized monorail crane for future overhaul work.

Another risk associated with the aging equipment is that the switchgear and P&C equipment do not have spare parts readily available due to obsolescence. This means that failure of critical components could cause additional significant delays in returning the unit to service.

This option shows that there is a significant capital cost expenditure required to make the station safe, without any significant gains in generation capacity or reduction in maintenance outage duration / frequency to offset this expenditure. It also will not address some of the electrical risks inherent to the current layout of electrical equipment inside the existing powerhouse.

5.2. Option 2: Full Replacement

5.2.1. Scope of Work

The second option to consider is a total replacement of the Fish Lake 2 power station.

This would include the following scope of work:

- Removal and replacement of the existing building frame and cladding structure with a new prefabricated building:
  a) Demolition of existing building structure, and replacement with a new pre-fabricated structure;
  b) Replacement of the existing building foundation;
  c) Installation of a new jib crane;
  d) Refer to Appendix A drawings.
- Removal and replacement of mechanical equipment between the downstream flange of the existing TIV, and the downstream edge of the embedded draft tube:
  a) Turbine, governor, generator assemblies;
  b) Refer to Appendix B drawing.
- Removal and replacement of automation and electrical equipment up to but not including the existing generator transformer:
  a) Exciter, switchgear, P&C panels;
  b) Refer to Appendix C drawing.

This assumes that the replacement building structure would be in the same location as the existing building structure.

5.2.2. Energy Modelling for New Unit

A significant percentage of the benefit resulting from replacement of the Fish Lake 2 hydro station is due to the increased efficiency that ATCO Electric Yukon will see by using a modern turbine / generator.

As shown in Section 5.1.2, Fish Lake 2 experienced significant downtime between 2017 and 2020. Therefore, the penstock flow data provided was not an accurate representation of the total available flow during this time. To estimate what the theoretical available flow would have been during this time, the sum of the penstock flow and the spillway flow up to a maximum capacity of 1.35 m^3/s was considered.

Using this flow, the penstock losses and expected installation capacity for a new unit were calculated.

Table 11: New Unit Energy Modelling

Generators	New Unit
Maximum flow (cms)	1.35
Net Head (m)	54
Peak generation capacity (kW)	630
Installed capacity (kW)	620
Combined efficiency (%)	87.5
Hydro generation (GWh/y)	3.843

The installed capacity and combined efficiency for the flow and net head were provided by Canyon Hydro. With a more efficient new unit, the annual generation would increase by 205% over the existing unit. A new unit will also operate ~20% more efficiently than the existing unit.

5.2.3. Capital Cost Estimate

The overall project cost to install a new unit at Fish Lake 2 is as follows:

Table 12: Cost Estimate for Replacement Project

Components	Cost (CAD)*
	620 kW
Project Management	$184,570
Engineering Design	$409,685
Civil / Structural Equipment Supply – Prefab Building Frame and Cladding	$1,191,880

Components	Cost (CAD)*
	620 kW
Mechanical / Electrical Equipment Supply – turbine, generator, lube oil unit, HPU estimate, P&C, controller, static exciter	$1,999,360
Building Installation – Demolition, Structure / Frame, Building Services	$849,450
New Unit Installation – Demolition, Turbine/Generator/P&C/Electrical	$393,650
Contingency (30%)	$1,508,785
Capital Cost	$6,537,380

* Assuming an exchange rate of $1.34 CAD = $1 USD

This cost estimate was developed using the actual capital costs from the Fish Lake 1 project, adjusted for inflation since 2016.

5.2.4. Ongoing Maintenance Costs

A new generating station at Fish Lake 2 will require less ongoing maintenance than the existing station. There will still be some annual and periodic maintenance expected over the lifetime of the new assets.

Table 13: Annual Maintenance Costs for New Fish Lake 2 Generating Station

Asset	Labour Costs ($100/hr)	Material Costs
Turbine: Runner, wicket gates, seals, scroll case	$4,000	-
Generator: Rotor, stator, P&C	$4,000	-
Governor	$4,000	-
Exciter	-	-
Shaft and bearings	$2,000	-

Asset	Labour Costs ($100/hr)	Material Costs
Brakes	$500	-
Daily checks ($80/hr)	$200,000	-
Bi-monthly inspection	$4,000	-
Recurring Annual Cost	$218,500	-

Table 14: Periodic Maintenance Costs for New Fish Lake 2 Generating Station

Asset	Frequency	Labour Costs ($100/hr)	Material Costs
Shaft and bearings	1M	$400	-

5.2.5. Project Sequencing and Schedule

The Fish Lake 2 Replacement Project should take about 12 months in total to complete. Table 15 below outlines the design and construction activities and planned durations.

Table 15: Project schedule

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Project Kick-Off	■											
Issue for Tender Design		■	■									
RFP Process & Contractor Award				■	■							
Issue for Construction Design						■	■					
Equipment Procurement						■	■					
Site Mobilization								■				
Removal of Existing Equipment								■				
Civil Foundation Works									■			
Prefab Building Install									■			

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9	Month 10	Month 11	Month 12
Mechanical / Electrical Install										GREEN		
Commissioning										GOLD	GOLD	
Project Close-Out (Record Drawings, Deficiencies)												GOLD

BLUE = Design Activities

GOLD = Joint Activities

GREEN = Construction Activities

5.2.6. Risks

This option will fully mitigate all major safety risks associated with the condition of the powerhouse structure and mechanical / electrical equipment. Given the poor condition of the building structure, it is recommended to spend the money fully replacing the structure rather than completing significant remediation work to the old structure.

This option also increases the energy production from the unit by ~200% and reduces the annual and periodic maintenance costs of the unit, which will help offset the capital cost.

5.3. Option 3: Optimized Replacement

5.3.1. Scope of Work

The scope of work of an optimized replacement would be the same as outlined in Section 5.2.1.

The only difference would be the design of the turbine / generator. Option 2 outlines what the expected power output would be from a new unit sized for the same flow as the current unit (1.35 m^3/s).

Based on historical flow, there is some capacity to divert flow above 1.35 m^3/s through the penstock instead of over the spillway. This could result in increased generation capacity.

BBA completed some analysis to estimate what the energy production and unit rating would look like if some of the spillway flow could be diverted through the penstock.

5.3.2. Energy Modelling for Optimized Unit

The historical flow from the penstock and from the spillway is shown in Figure 30 below.

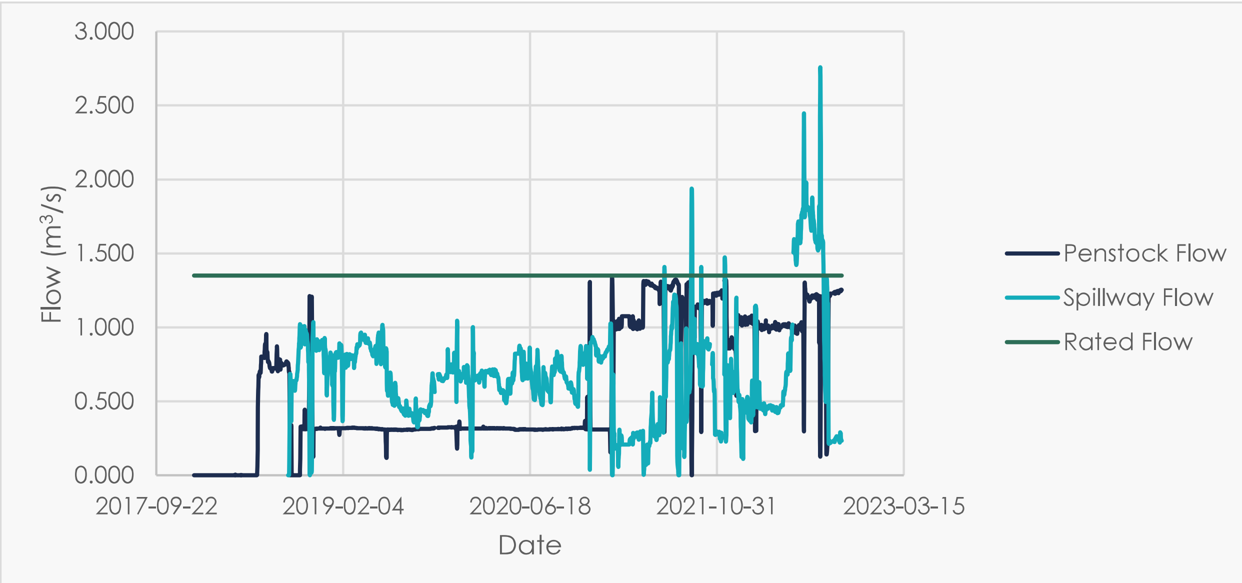


Figure 30: Fish Lake 2 Penstock and Spillway Flow 2018 - 2022

As shown, there is additional flow over the spillway that could be captured and diverted through the penstock.

Daily flow data for 1,734 days between 2018 and 2022 was analyzed. During this period, there were 489 days where the sum of flow through the penstock and flow over the spillway was above the rated flow of 1.35 m^3/s. The maximum flow during this period was 3.20 m^3/s.

Some iterative calculations were completed to assess what the "peak" annual electricity production would be with different flows through the penstock. It was established that the current flow of 1.35 m^3/s was actually very close to the optimal flow, which is 1.42 m^3/s. There are 20 additional days during this 1,734-day period where flow was between 1.35 m^3/s and 1.42 m^3/s and where the additional generation capacity would be reflected.

When the flow was increased above this point, the peak power output of the unit increased, but the head losses through the existing penstock greatly reduced the actual electricity generation on a yearly basis. This proves that the current penstock restricts flow, and this will constrain ATCO's ability to install a unit that is significantly larger unit that what currently exists at Fish Lake 2.

Using the optimized flow, the penstock losses and expected installation capacity for a new unit were calculated.

Table 16: Optimized Unit Energy Modelling

Generators	New Unit
Maximum flow (cms)	1.42
Net Head (m)	53
Peak generation capacity (kW)	645
Installed capacity (kW)	635
Combined efficiency (%)	87.5
Hydro generation (GWh/y)	3.847

BBA provided an updated net head and maximum flow to Canyon Hydro, who provided the installation capacity and efficiency for a slightly larger unit.

As shown, it is possible to get 4 MWh/year more out of the station using a turbine optimized for slightly higher flow through the unit. Unfortunately, there is a significant cost implication (shown in Section 5.3.3) required to get this small gain.

The optimized flow was validated by compiling a flow /duration curve. This data is shown in Figure 31 below:

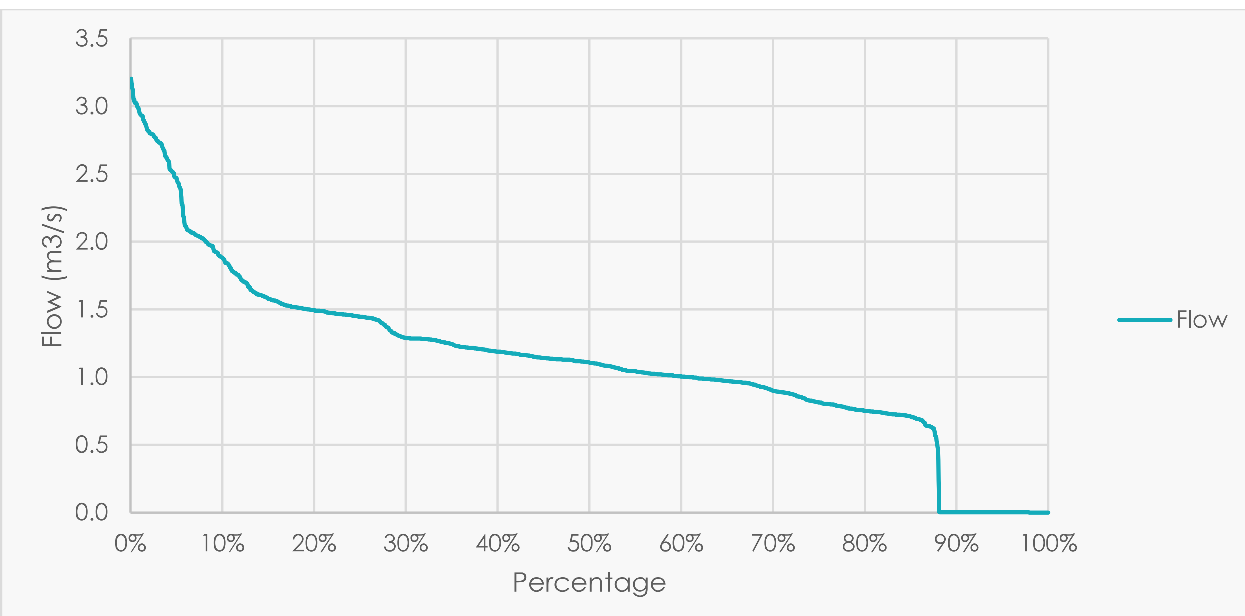


Figure 31: Flow Exceedance Curve for FL2

Generally, a turbine is designed for the point at which the curve flattens out (~15% of flow exceedance); however, in this case it is designed for 20-30% of the flow exceedance to balance cost with generation. The exact rated power though will generally be the nearest that the supplier had to the optimum at the time. The current rated flow (1.35m^3/s) is at approximately 27%, while the optimized flow (1.42m^3/s) is at 28%. Both points sit just to the right of a small "jump" in the data, which indicates that the specified flow for the existing Fish Lake 2 unit is acceptable.

5.3.3. Capital Cost Estimate

The overall project cost to install an optimized unit at Fish Lake 2 is as follows:

Table 17: Cost Estimate for Replacement Project

Components	Cost (CAD)*
	635 kW
Project Management	$184,570
Engineering Design	$409,685
Civil / Structural Equipment Supply – Prefab Building Frame and Cladding	$1,191,880
Mechanical / Electrical Equipment Supply - turbine, generator, lube oil unit, HPU estimate, P&C, controller, static exciter	$2,401,702
Building Installation – Demolition, Structure / Frame, Building Services	$849,450
New Unit Installation – Demolition, Turbine/Generator/P&C/Electrical	$393,650
Contingency (30%)	$1,629,280
Capital Cost	$7,060,217

* Assuming an exchange rate of $1.34 CAD = $1 USD

The project management, engineering, civil / structural tasks, and unit installation costs remain the same; however, the equipment cost for the mechanical / electrical equipment increases by $400k over Option 2. This additional expenditure to install a unit, which is only rated 15 kW higher than the existing unit, adds risk to the project.

A full penstock replacement would need to be completed to significantly increase the rated capacity of the unit. This was not analyzed as part of the scope of this study.

5.3.4. Ongoing Maintenance Costs

Ongoing annual and periodic maintenance costs will be the same as outlined in Section 5.2.4.

5.3.5. Project Sequencing and Schedule

The project sequencing and schedule will be the same as outlined in Section 5.2.5.

5.3.6. Risks

Like with Option 2, this option will fully mitigate the major safety risks associated with the condition of the powerhouse structure and mechanical / electrical equipment. This option does have an extra capital cost to obtain a slightly larger unit, which only increases yearly annual generation by 4 MWh/year. This adds additional cost risk to the project over the full replacement option.

5.4. Risk Comparison

The safety, capital cost, and future forced outage risks for all three options are outlined in Table 18 below:

Table 18: Risk Matrix

	Targeted Safety Replacement	Full Replacement	Optimized Replacement
	596 kW	620 kW	635 kW
Safety Risk	Medium	Low	Low
Capital Cost Risk	Medium	Medium	High
Future Forced Outage Risk	High	Low	Low

As shown, the targeted safety replacement will address some of the most pressing safety risks associated with the operation of the Fish Lake 2 power station; however, it does not fully address all risks present at this time and does not fully remove the risk of future forced outages due to equipment failure.

The full replacement and optimized replacement options will fully address all safety risks at Fish Lake 2 and will greatly reduce the risk of future forced outages. While the optimized replacement option could potentially generate 4 MWh/yr more than the full replacement option, it does come with an additional $500k capital cost, which increases the risk of the project.

6. Conclusions

While the plant has been very well maintained over the years, there are major safety hazards inherent to continued operation that must be addressed. This includes the age and condition of the governor and other control and protection equipment, as well as the current layout of electrical and control equipment. Many components of the facility have already reached end-of-life condition and spare parts are no longer readily available. The building structure and foundations, in particular, have reached their end-of-life condition, and require significant upgrades to meet current NBCC loading requirements. It is not acceptable to continue operating the station as-is considering the significant safety and operational risks.

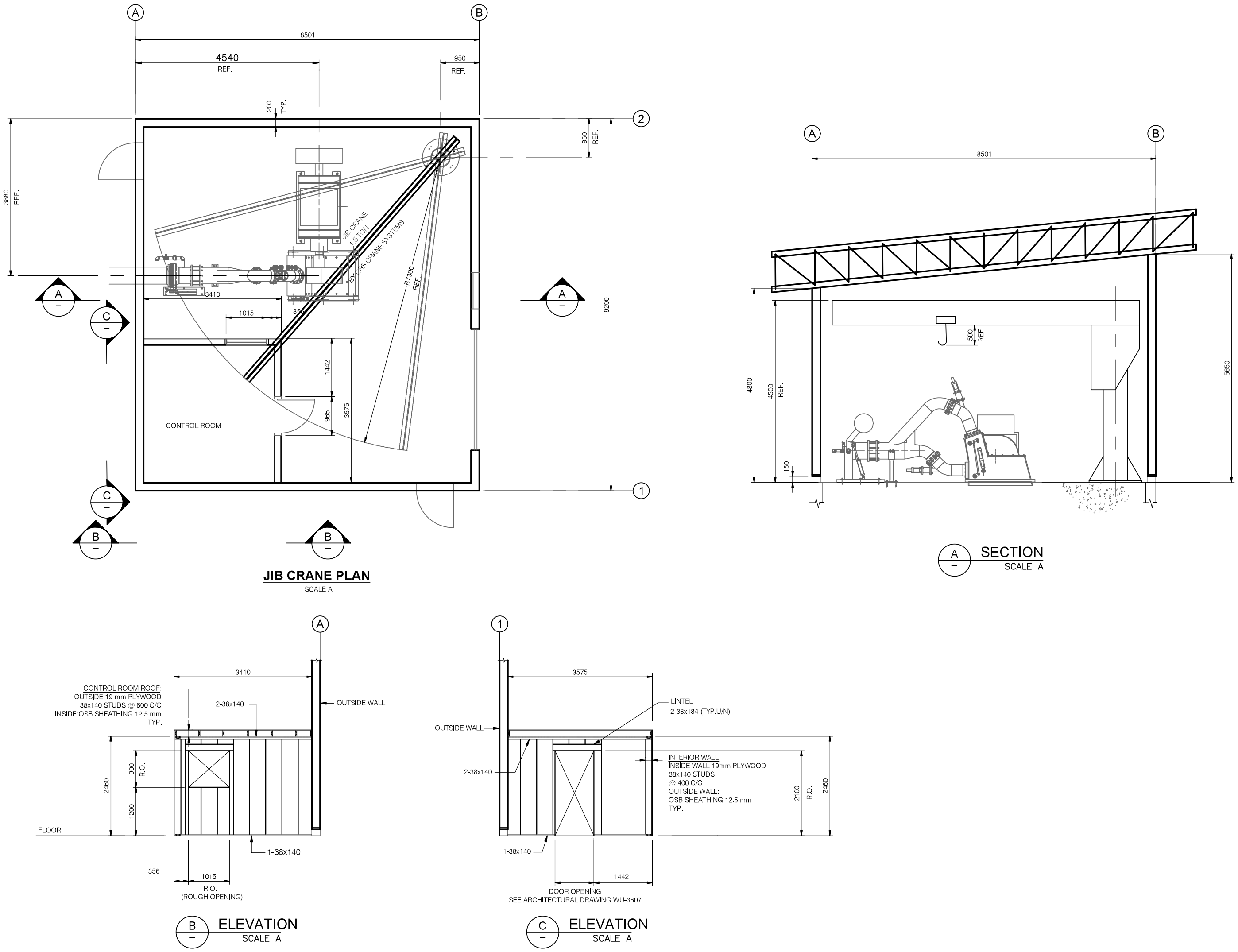
It is recommended that ATCO Electric Yukon complete a full replacement of the Fish Lake 2 powerhouse and generating unit. This is the only viable option to proceed with that reduces safety risks, prevents the risk of future outages, and provides increased generation capacity to ATCO Electric Yukon.

The possibility of installing an optimized unit at Fish Lake 2 should also be explored further, as the additional generation capacity, while small, could potentially justify the additional capital expenditure if rates are high enough.

Appendix A: Civil Conceptual Layout Drawings

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES AND ELEVATIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. THE DESIGN IS CONCEPTUAL ONLY, THE PRELIMINARY/DETAILED DESIGN OF THE POWERHOUSE WILL DEPEND ON RESULTS OF FURTHER GEOTECHNICAL INVESTIGATION AND TURBINE/GENERATOR/ELECTRICAL EQUIPMENT SIZING AND ARRANGEMENT.



PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

SCALE A 1:50 — 1 0.5 0 1 2 3 4 5 m

DRAWING No.	DESCRIPTION	REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
		AA	PRELIMINARY	M.SHAHRAKI	M.SHAHRAKI	2023-03-14

REFERENCE DRAWINGS — REVISIONS

SEAL:

CLIENT: ATCO Electric YUKON

PROJECT: FISH LAKE 2

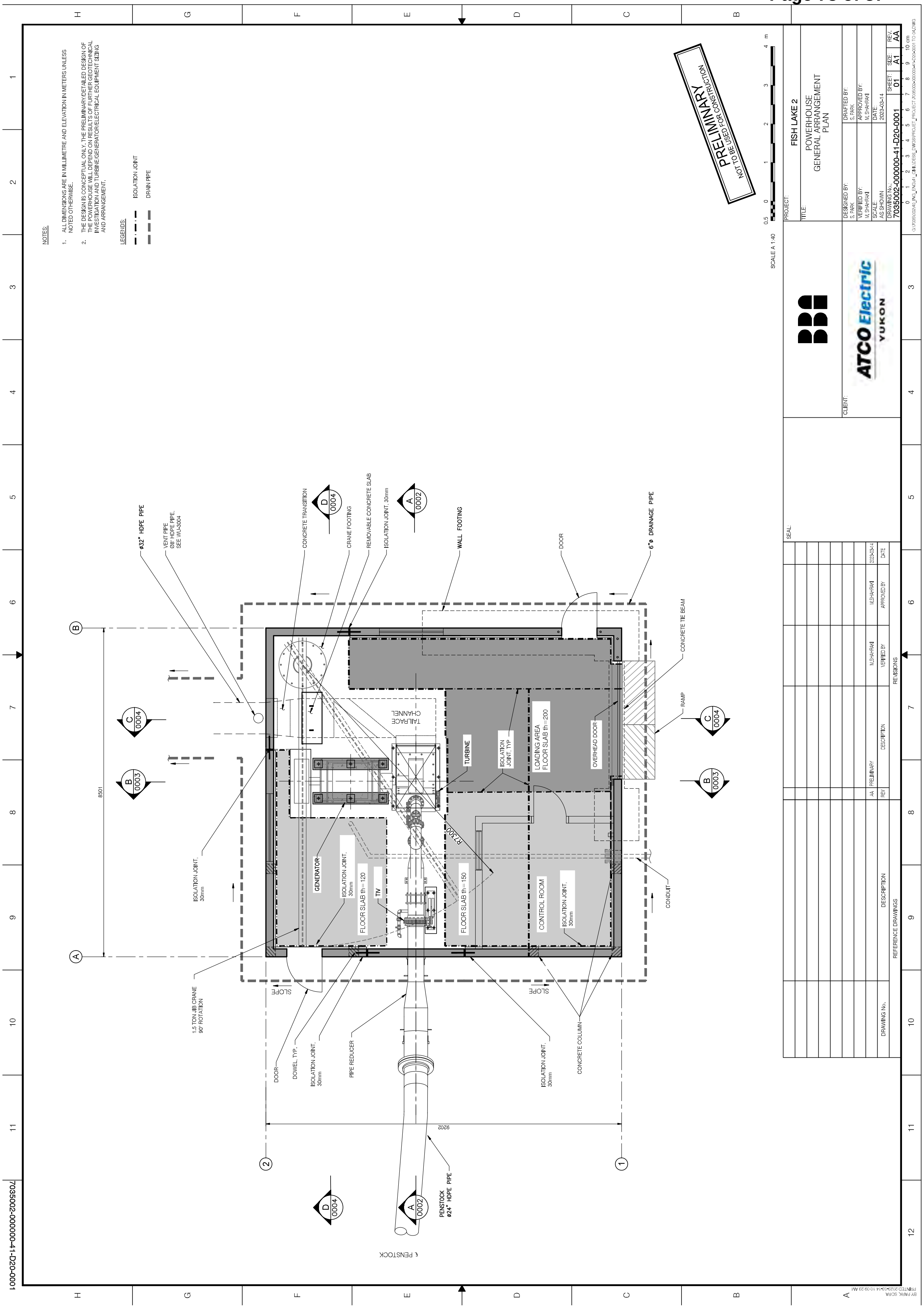
TITLE: POWERHOUSE PLAN & SECTIONS JIB CRANE LAYOUT

DESIGNED BY: S. PARK	DRAFTED BY: S. PARK
VERIFIED BY: M. SHAHRAKI	APPROVED BY: M. SHAHRAKI
SCALE: AS SHOWN	DATE: 2023-03-14

DRAWING No.: 7035002-000000-41-D20-0005 — SHEET: 01 — SIZE: A1 — REV.: AA

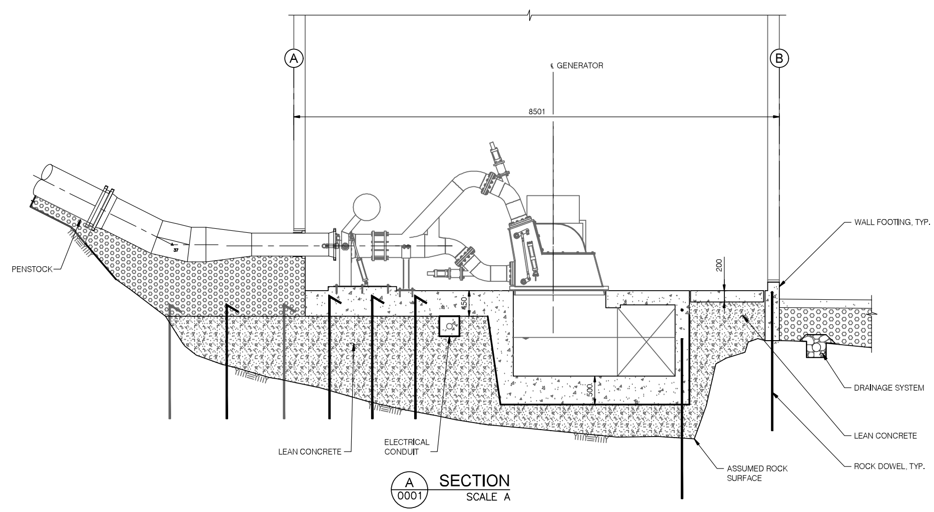
G:\7035002\40_ING_ENG\41_CIVIL\DESS_DWG\03\PROJET_PROJECT\7035002-000000-41-D20-0005.DWG

7035002-000000-41-D20-0005


NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRE AND ELEVATION IN METERS UNLESS NOTED OTHERWISE.
2. THE DESIGN IS CONCEPTUAL ONLY, THE PRELIMINARY/DETAILED DESIGN OF THE POWERHOUSE WILL DEPEND ON RESULTS OF FURTHER GEOTECHNICAL INVESTIGATION AND TURBINE/GENERATOR/ELECTRICAL EQUIPMENT SIZING AND ARRANGEMENT.
LEGENDS:
ISOLATION JOINT
DRAIN PIPE
PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION
SCALE A 1:40
PROJECT:
FISH LAKE 2
TITLE:
POWERHOUSE
GENERAL ARRANGEMENT
PLAN
DESIGNED BY:
S. PARK
DRAFTED BY:
S. PARK
VERIFIED BY:
M. SHAHRAKI
APPROVED BY:
M. SHAHRAKI
SCALE:
AS SHOWN
DATE:
2023-03-14
DRAWING No.:
7035002-000000-41-D20-0001
SHEET:
01
SIZE:
A1
REV:
AA
CLIENT:
ATCO Electric
YUKON
SEAL:
AA
PRELIMINARY
M.SHAHRAKI
M.SHAHRAKI
2023-03-14
REV
DESCRIPTION
VERIFIED BY
APPROVED BY
DATE
REVISIONS
DRAWING No.
DESCRIPTION
REFERENCE DRAWINGS
ø32" HDPE PIPE
VENT PIPE
Ø8" HDPE PIPE,
SEE WLI-3004
CONCRETE TRANSITION
CRANE FOOTING
REMOVABLE CONCRETE SLAB
ISOLATION JOINT, 30mm
WALL FOOTING
DOOR
6"ø DRAINAGE PIPE
CONCRETE TIE BEAM
RAMP
TAILRACE CHANNEL
TURBINE
ISOLATION JOINT, TYP.
LOADING AREA
FLOOR SLAB th=200
OVERHEAD DOOR
GENERATOR
ISOLATION JOINT, 30mm
FLOOR SLAB th=120
TIV
FLOOR SLAB th=150
CONTROL ROOM
ISOLATION JOINT, 30mm
R7500
CONDUIT
ISOLATION JOINT, 30mm
1.5 TON JIB CRANE
90° ROTATION
SLOPE
SLOPE
DOOR
DOWEL, TYP.
ISOLATION JOINT, 30mm
PIPE REDUCER
ISOLATION JOINT, 30mm
CONCRETE COLUMN
8501
9202
PENSTOCK
ø24" HDPE PIPE
℄ PENSTOCK
7035002-000000-41-D20-0001

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRE AND ELEVATION IN METERS UNLESS NOTED OTHERWISE.
2. THE DESIGN IS CONCEPTUAL ONLY. THE PRELIMINARY/DETAILED DESIGN OF THE POWERHOUSE WILL DEPEND ON RESULTS OF FURTHER GEOTECHNICAL INVESTIGATION AND TURBINE/GENERATOR/ELECTRICAL EQUIPMENT SIZING AND ARRANGEMENT.



A 0001 SECTION
SCALE A

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

SCALE A 1:40 — 0.5 0 1 2 3 4 m

REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
AA	PRELIMINARY	M.SHAHRAKI	M.SHAHRAKI	2023-03-14

REVISIONS

DRAWING No.	DESCRIPTION

REFERENCE DRAWINGS

SEAL:

CLIENT: ATCO Electric YUKON

PROJECT: FISH LAKE 2

TITLE: POWERHOUSE GENERAL ARRANGEMENT SECTION SHEET 1 OF 3

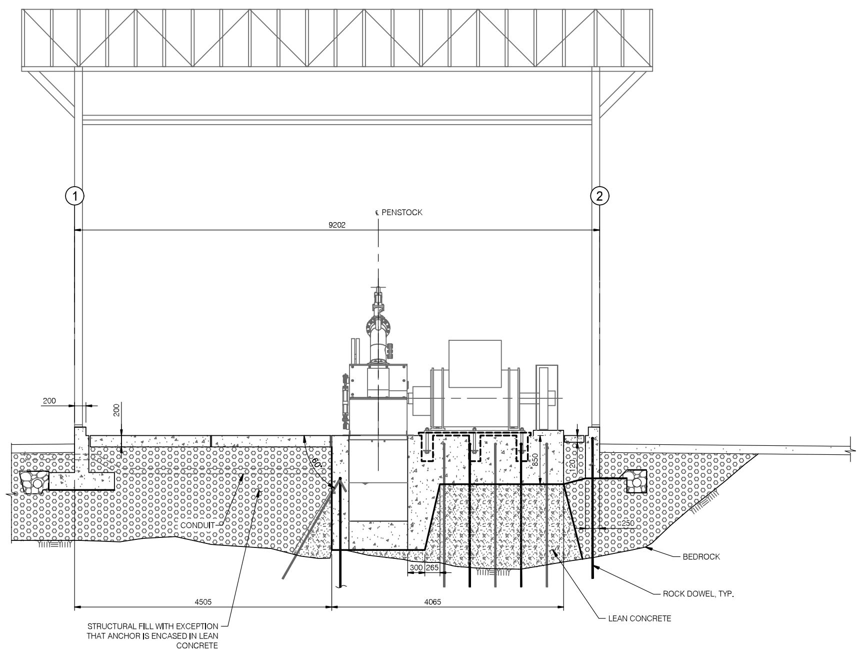
DESIGNED BY: S. PARK	DRAFTED BY: S. PARK
VERIFIED BY: M. SHAHRAKI	APPROVED BY: M. SHAHRAKI
SCALE: AS SHOWN	DATE: 2023-03-14

DRAWING No.	SHEET	SIZE	REV.
7035002-000000-41-D20-0002	01	A1	AA

7035002-000000-41-D20-0002

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRE AND ELEVATION IN METERS UNLESS NOTED OTHERWISE.
2. THE DESIGN IS CONCEPTUAL ONLY. THE PRELIMINARY/DETAILED DESIGN OF THE POWERHOUSE WILL DEPEND ON RESULTS OF FURTHER GEOTECHNICAL INVESTIGATION AND TURBINE/GENERATOR/ELECTRICAL EQUIPMENT SIZING AND ARRANGEMENT.



B / 0001 SECTION
SCALE A

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

SCALE A 1:40

DRAWING No.	DESCRIPTION	REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
		AA	PRELIMINARY	M.SHAHRAKI	M.SHAHRAKI	2023-03-14
REFERENCE DRAWINGS		REVISIONS				

SEAL:

CLIENT: ATCO Electric YUKON

PROJECT: FISH LAKE 2

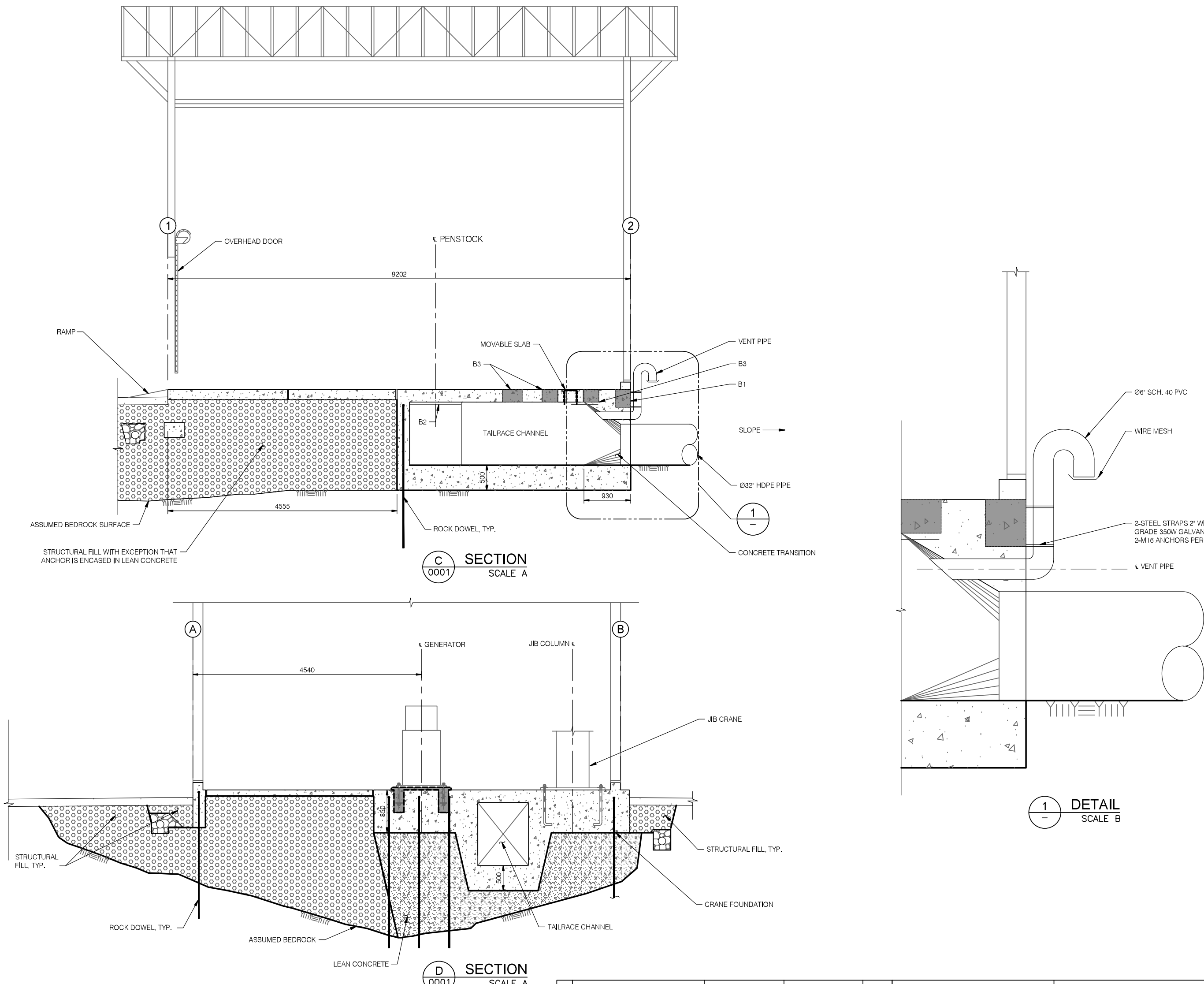
TITLE: POWERHOUSE GENERAL ARRANGEMENT SECTION SHEET 2 OF 3

DESIGNED BY: S. PARK	DRAFTED BY: S. PARK
VERIFIED BY: M. SHAHRAKI	APPROVED BY: M. SHAHRAKI
SCALE: AS SHOWN	DATE: 2023-03-14
DRAWING No.: 7035002-000000-41-D20-0003	SHEET: 01 SIZE: A1 REV.: AA

7035002-000000-41-D20-0003

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRE AND ELEVATION IN METERS UNLESS NOTED OTHERWISE.
2. THE DESIGN IS CONCEPTUAL ONLY. THE PRELIMINARY/DETAILED DESIGN OF THE POWERHOUSE WILL DEPEND ON RESULTS OF FURTHER GEOTECHNICAL INVESTIGATION AND TURBINE/GENERATOR/ELECTRICAL EQUIPMENT SIZING AND ARRANGEMENT.



PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

SCALE B 1:15 — 250, 0, 500, 1000, 1500 mm
SCALE A 1:40 — 0.5, 0, 1, 2, 3, 4 m

REV	DESCRIPTION	VERIFIED BY	APPROVED BY	DATE
AA	PRELIMINARY	M.SHAHRAKI	M.SHAHRAKI	2023-03-14

REVISIONS

DRAWING No.	DESCRIPTION

REFERENCE DRAWINGS

SEAL:

CLIENT: ATCO Electric YUKON

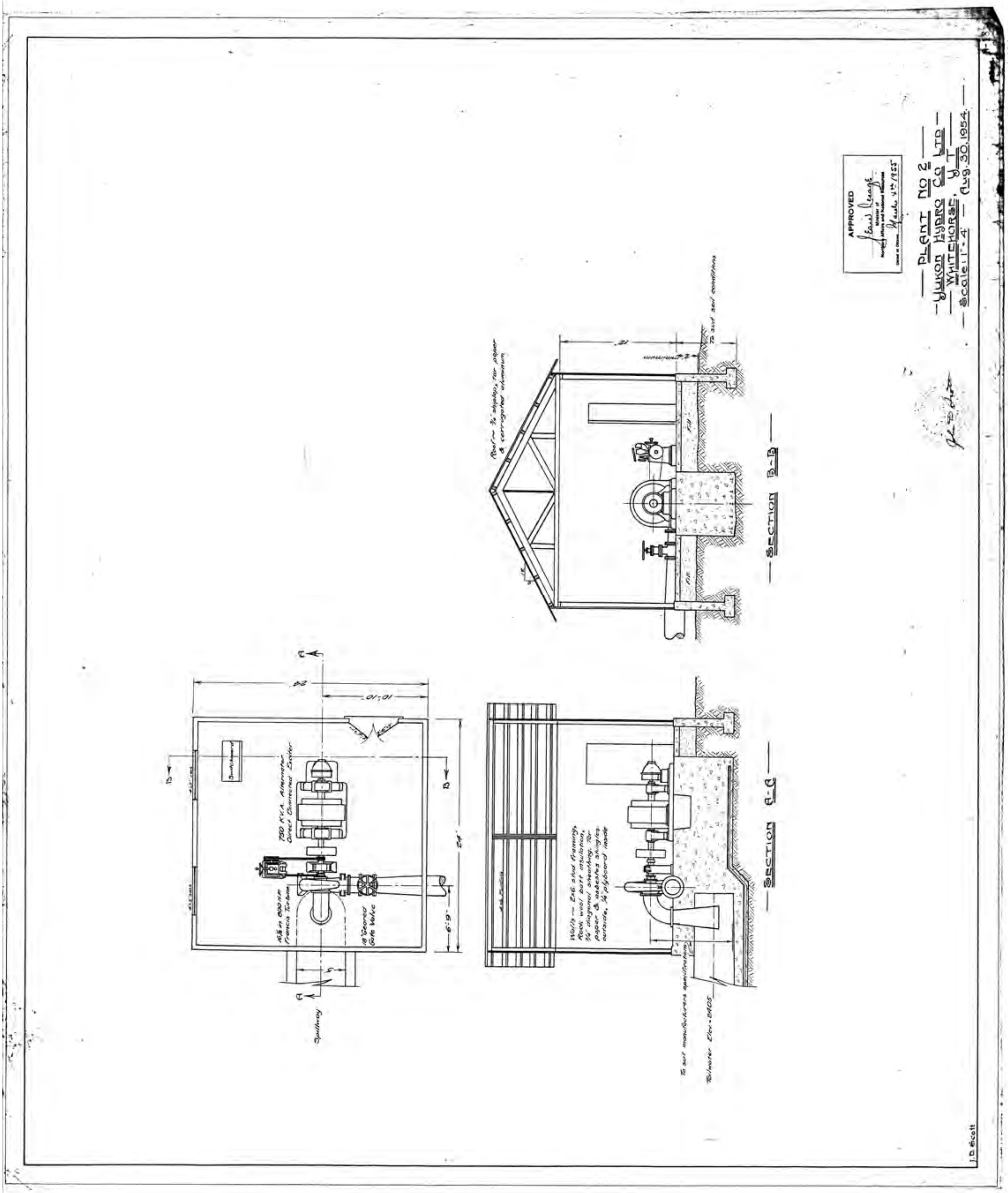
PROJECT: FISH LAKE 2

TITLE: POWERHOUSE GENERAL ARRANGEMENT SECTION SHEET 3 OF 3

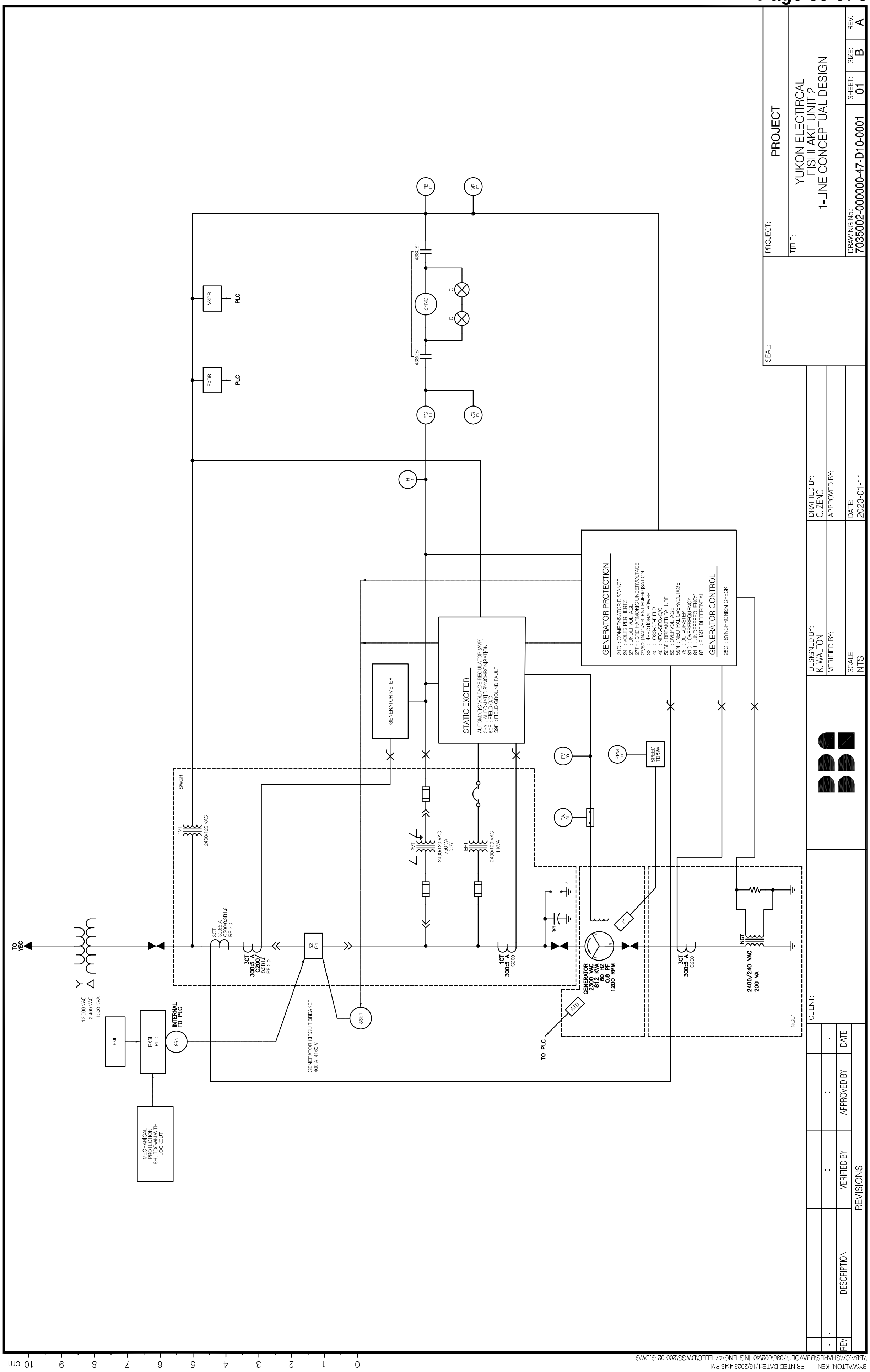
DESIGNED BY: S. PARK	DRAFTED BY: S. PARK
VERIFIED BY: M. SHAHRAKI	APPROVED BY: M. SHAHRAKI
SCALE: AS SHOWN	DATE: 2023-03-14

DRAWING No.: 7035002-000000-41-D20-0004 | SHEET: 01 | SIZE: A1 | REV.: AA

Appendix B: Mechanical Scope Boundary


APPROVED
PLANT NO 2
YUKON HYDRO CO LTD
WHITEHORSE, Y.T.
Scale: 1"=4' — Aug. 30, 1954.
SECTION B-B
SECTION A-A
750 K.V.A. Alternator Direct Connected Exciter
18" Geared Gate Valve
Spillway
Tailwater Elev.-2405
24'

Appendix C: Electrical Conceptual Single Line Diagram


TO YEC
12,000 VAC
2,400 VAC
1500 KVA
SWGR
GENERATOR CIRCUIT BREAKER
400 A, 4160 V
INTERNAL TO PLC
MECHANICAL PROTECTION SHUTDOWN WITH LOCKOUT
GENERATOR METER
STATIC EXCITER
AUTOMATIC VOLTAGE REGULATOR (AVR)
25A : AUTOMATIC SYNCHRONISATION
GENERATOR PROTECTION
GENERATOR CONTROL
25G : SYNCHRONISM CHECK
GENERATOR
2300 VAC
812 KVA
60 HZ
0.8 PF
1200 RPM
2400/240 VAC
200 VA
SYNC
PLC
TO PLC
PROJECT:
PROJECT
TITLE:
YUKON ELECTIRCAL
FISHLAKE UNIT 2
1-LINE CONCEPTUAL DESIGN
DRAWING No.:
7035002-000000-47-D10-0001
SHEET:
01
SIZE:
B
REV.
A
SEAL:
DRAFTED BY:
C. ZENG
APPROVED BY:
DATE:
2023-01-11
DESIGNED BY:
K. WALTON
VERIFIED BY:
SCALE:
NTS
CLIENT:
REV
DESCRIPTION
VERIFIED BY
APPROVED BY
DATE
REVISIONS
BY:WALTON, KEN
10 cm

Appendix D: Fish Lake 2 Life Cycle Costs

Fish Lake 2 Condition Assessment and Options Analysis
Life Cycle Plan
Appendix D

Targeted Safety Replacement	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043+**
Capital Cost ($)	$6.50mil			$210k				$135k				$70k						$50k			$200k
Maintenance ($)	$268k	$268k	$268k	$268k	$268k	$282k	$274k	$268k	$311k	$268k	$282k	$268k	$274k	$268k	$268k	$282k	$311k	$268k	$274k	$268k	$285k
Energy Production (GWh/yr)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

Full Replacement	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043+**
Capital Cost ($)	$6.54mil																				
Maintenance ($)	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k
Energy Production (GWh/yr)	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843	3.843

Optimized Replacement	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043+**
Capital Cost ($)	$7.06mil																				
Maintenance ($)	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k	$223k
Energy Production (GWh/yr)	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847	3.847

** It should be noted that the unit rated capacities, costs, and annual energy production values noted above are preliminary. These values must be reviewed in more detail during the feasibility design stage.*

*** Estimated costs are as of 2023 and are not inflated.*

2023-2024 General Rate Application (GRA)

Condition Assessment and Options Program for Beaver Creek, Destruction Bay, and Stewart Crossing Generating Plants

2023-2024 Business Case #40

Executive Summary

1. Stewart Crossing (SC), Beaver Creek (BC), and Destruction Bay (DB) generating plants are known to be in poor condition and are approaching end of life based on prior assessments and current operating experience. Maintenance improvements and minor investments over the past 10 years have extended their lifespan but these legacy facilities are old and expected to require significant investment in the near term.

2. To evaluate rehabilitation, replacement, or other alternatives to provide utility power at these sites, a comprehensive and thorough inspection, condition evaluation, and options analysis is necessary. The necessary function and specification for generating plants at these sites will be considered in the context of current policy and potential future changes with respect to local renewable power projects, load growth, and reliability expectations. Preliminary designs will be advanced for recommended solutions to end of life, safety, reliability, and modernization issues.

Background

3. AEY contracted ATCO Electric to conduct site inspections and condition reports in 2012, using the corporate asset management health indices in place at the time. Priority work was undertaken based on recommendations such as foundation crack repair, but end of lifespan was not addressed. A summary of findings for each site is as follows:

- SC: end-of-life; significant investment or replacement (with mobile skid-genset) should be investigated.
- BC: corrective actions are required to extend life 10 years (i.e., 2022).
- DB: significant settlement on site, mid-life with major rehab improvements.

4. Furthermore, AEY contracted independent structural assessments due to site specific observations. A summary of these findings is as follows:

(1) SC – 2019; end-of-life.

(2) DB – 2012; unstable foundation – consider rebuild if any modifications are being undertaken.

Project Description

5. An engineering consultant with proficiency in electrical, mechanical, controls/automation, architectural, civil, structural disciplines will be engaged to evaluate each site. Expertise is required to inventory condition and prioritize rehabilitation options, and to articulate best practices for replacements or improvements to equipment and infrastructure.

6. The scope will consist of detailed site inspections and drawing reviews, evaluation of equipment lifespan and maintenance standards, consideration of demand and operational contingencies/risks, review of regulatory and industry practices, and cost estimating of technical alternatives. Reports will be created for each site for AEY to develop economic and Business Cases for future investments.

7. Once the recommended improvements are identified, the site of highest priority will begin preliminary design to advance a solution to investment quality accuracy. AEY forecast that sites will need to have their work allocated in a sequenced manner based on urgency, due to resource constrains and capital availability.

Project Schedule and Costs

Table 1: Project Schedule and Costs
($000)

	2023	2024	Total
Site Evaluation and Options			
Beaver Creek	106	-	106
Destruction Bay	106	-	106
Stewart Crossing	106	-	106
Preliminary Design for priority site	-	309	309
Total	**318**	**309**	**627**

Business Drivers and Benefits

8. The identification of issues, improvements, and maintenance repairs is ad hoc at these sites. These are known to be near end-of-life. Therefore, ongoing reliability and functional performance is unclear and potentially at risk. This is not an ideal operating context for a utility generating asset, and not sustainable going forward.

9. The project will result in 1) understanding of current condition of each asset 2) recommended rehabilitation or maintenance priorities to continue operations; and 3) identified long-term solution for investment.

Evaluation of Viable Alternatives

10. The alternative is to await the development of an asset management program to a stage where health indices and capital investment priorities are fully built out and can provide the same output as suggested to be outsourced to the consultant. However, this may take several years and will still require external resources for discipline expertise and Business Case development that are not available internally. In the meantime, these sites are known to be near end-of-life and ongoing reliability concerns need to be defined and mitigated without delay.

Recommendation

11. Proceed with condition assessment.

ATCO Electric
YUKON

2023-2024 General Rate Application (GRA)

Old Crow Plant Design

Business Case #41

Executive Summary

1. AEY is preparing to complete a design for a new generation facility to replace the existing diesel generating facility that was constructed in 1982 in Old Crow. In 2014, a new facility was constructed in the community with the intent that, once completed, it would provide the contingency required to upgrade the 1982 facility. Due to the remoteness of the community of Old Crow, AEY operates two separate facilities to ensure security of supply against loss of power to a facility or critical equipment. To determine the scope of required renovations to the existing facility, a multidisciplinary review was conducted in 2015. Based on the outcome of this review and factoring in the continual load growth seen in the community, the recommendation is to construct a new facility.

Background

2. The two diesel facilities are currently the only source of dispatchable power for the fly-in community of Old Crow (YK). AEY provides service to approximately 211 customers in Old Crow. Currently, each of the diesel generating facilities house two generating units. To allow for basic contingencies and facility maintenance, these two facilities must be able to fully supply the peak load and meet firm capacity requirements while operating efficiently.

Project Description

3. The scope of the project is to complete comprehensive design for the new generating facility. Refined estimates will be provided as part of the completed design which will be utilized to support the Business Case for the construction of the new facility. With a completed design.

Project Schedule and Cost

4. Table 1 below provides an estimated milestone schedule for the project:

Table 1: Project Timetable

Milestone	Completion Dates
Design Tender	Q4, 2020
Design Award	Q1, 2021
Completed Design	Q3, 2022
Facility Construction Tender	Q4, 2024
Facility Construction	Q2, 2025 – Q4, 2026

5. Table 2 below details the costs of the new facility design. Table 3 shows the current estimated costs for new facility construction.

Table 2: New Facility Design Costs ($000)

Year	Total Cost
2018-22	294
2023	150
Total	**444**

Table 3: New Facility Construction Costs ($000)

Year	Total Cost
2024	515
2025	5,000
2026	5,000
Total	**10,515**

Business Drivers and Benefits

<u>Condition of Existing Facility</u>

6. Based on the review completed in 2015, numerous deficiencies were identified within the existing facility. These ranged from foundation, structural, and flooding concerns due to current elevation, as well as concerns with the current condition of electrical and mechanical systems. Solutions to address these concerns ranged from complete replacement (electrical and mechanical systems), significant renovations (structure), and acceptance or mitigation (foundation and elevation). Overall, this

represented significant work with limited return. As a result, the review recommended replacement. Refer to Appendix A for further information on the review completed and recommendations for facility replacement.

Generation Capacity Required to Meet Electrical Load

7. The load within the community is steadily growing. From 2016 to 2022 the annual generation increased by 25 percent and reported peak loading has increased by 23 percent with peak in loads in 2023 to date being reported at over 700kW. The community owned Photovoltaic (PV) project (solar panels) has been beneficial in diesel fuel use reduction for the community on an annual average basis but its ability to supply electrical power during the peak load periods is negligible as the peak loads occur in the winter when sunlight is in very short supply at that latitude. Consequently, the PV project is not able to support diesel infrastructure capacity reductions.

Table 4: Generation and Peak Load

Year	Annual Generation (MWh)	Peak Load (kW)
2016	2,389	549
2022*	2,993	677
Change (%)	25	23
* Reflects Combination of Total PV and Diesel Generation		

8. With this rapid increase in load, multiple units are now required to supply the community's needs as loads have exceeded the prime rating of the largest unit installed. Use of multiple units reduces AEY's available contingency, requiring either the replacement of an existing unit with a larger capacity one or the addition of a new unit. AEY's current facilities are unable to accommodate either of these options. Larger capacity units will exceed the design maximum of both facilities' foundations and the lifting capacity of locally available equipment. Neither facility has the available space to house an additional generator. Thus, a new facility is required to allow AEY to meet the current and future energy needs of the community.

Evaluation of Viable Alternatives

9. A comprehensive multi-discipline assessment was completed on the 1982 facility in 2015. From that study came three viable alternatives, as shown below.

10. These alternatives were the basis for the design work completed in the 2018-2022 (costs in Table 2). The cost estimates below were based on the information at the time and was one of the factors that led to the decision to proceed with the design work for Alternative 3. The cost estimates in the alternatives were not updated in this business case as the decision to proceed with the design work has already commenced and the costs provided in Table 3 above represents a high-level estimate of this rebuild project to inform the Board of the upcoming capital expenditures for this much needed project.

11. Note: Option costs below are in 2015 dollars and Class D estimates with no supporting design.

Alternative 1: Repair Existing Facility; Cost N/A

12. Repair facility to address deficiencies from the report. A sub floor would be installed to ensure equipment is above flood level. Pricing for this option was not considered as the use of a sub floor would not actually correct the floor subsidence issue and the final product would provide less floor space than that of the existing facility.

Alternative 2: Rebuild on Existing Foundation

13. Construction cost estimated at $3.6 million**.** Demolish existing facility, reuse and extend existing slab and fabricate new building. This option introduces the highest system risk and tightest timeline to ensure construction is completed. Although this alternative is the lowest cost from a construction standpoint, overall cost would be significantly higher after factoring in the cost for transportation of backup generation for contingency during construction. The transportation in and out, and interconnection materials and labour are estimated at $0.4 million, and if the generators need to be rented that is estimated at $0.4 million for an 18 month build.

Alternative 3: New Building/New Location

14. Construction cost estimated at $3.9 million. Select a suitable location within yard and construct new building. Staged relocation of generating units once building is completed. This was the preferred option from the study as it poses the lowest system and construction risk and should not require backup generation for construction.

Alternative 4: Extend New Facility

15. Construction cost estimated at $4.4 million. Remove entrance ramp and build onto new (2014) facility. This is the most expensive option and removes the contingency of having two separate structures, which was the intent of the new (2014) facility.

Recommendation

16. Start new facility design in 2021 with construction to follow in 2024, utilizing alternative 3.

Appendices

Appendix A Site Evaluation: Old Crow

Appendix A – Site Evaluation: Old Crow

17. Based on the 2015 assessment and current operational needs.

Table 5: Assessment of Needs

System	Status
Foundation	Approaching End of Life
Structure	End of Life
Electrical	Approaching End of Life
Mechanical	Approaching End of Life
Generation Units	Mid Life
Available Space	Low
Load Growth	High
External Drivers for Replacement	High

Foundation (Approaching End-of-Life)

18. From the ONEC report it was identified that the foundation is starting to sink. The potential cause for this has been the disabling of the passive ventilation system under the slab. This system was disabled to accommodate the waste heat piping addition on the west side of the facility.

Structure (End-of-Life)

19. Modifications over the years have significantly weakened the structure. Repairs would be significant as they would need to address the deficiency and bring the aging structure up to the current code requirements. The facility is also constructed below 100-year flood levels.

Electrical (Approaching End-of-Life)

20. The complete electric system (power distribution and control) is in poor shape. The electrical system is currently comprised of poorly installed conductors, poor documentation and labelling, and obsolete equipment. The current system functions for the facility but does not allow for easy repairs or modifications. Complete replacement like that carried out at Destruction Bay and Beaver Creek are required.

Mechanical (Approaching End-of-Life)

21. Current piping systems are functional, but the quality of installation, location and sizing pose challenges which will need to be addressed. Currently the radiators are installed in an inaccessible location on the north side of the facility. This location adds unneeded piping length and makes servicing these radiators extremely challenging. Heat exchangers are not sized for full flow from units which limits their ability to provide heat to the waste heat system. The silencer and radiator for Unit 2 was originally sized for a 1200 rpm 3412 and cannot handle full capacity from the 1800 rpm 3412 replacement. Finally, to get the pad passive ventilation system functional a significant portion of waste heat piping in the extension would need to be relocated.

Generation Units (Mid-Life)

22. Unit 1 is approaching its first major overhaul and Unit 2 just recently received a new long block (a short block with head and valve train).

Available Space (Low)

23. The facility currently has very little floor and wall space for installation of new equipment and working within the facility is challenging. Removal of the unused old Unit 3 could free up some working floor space. Regardless, the existing footprint does not provide sufficient space for an additional unit which will be required to meet ongoing load growth.

Load Growth (High)

24. Old Crow is seeing the highest load growth of AEY’s isolated systems. Current construction projects are placing significant load growth on the system. Unfortunately, peak loading does not coincide with generation from the solar IPP within this community, thus requiring AEY to continue to increase its generation capacity to meet the community load requirements.

External Drivers for Replacement (High)

25. Funded, renewable and waste heat initiatives in the community favor a new facility. It will be easier, and in the long term more cost efficient, to integrate these initiatives into a new facility rather than the existing facility.

Recommendation:

26. Complete Business Case and start new facility design in 2021 with construction to follow in 2024 Compared to repair, this approach provides few sunk costs.