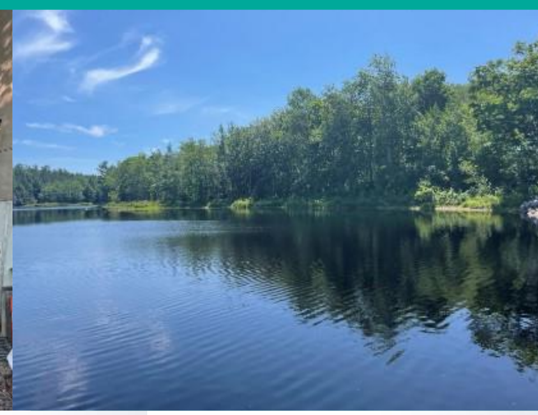
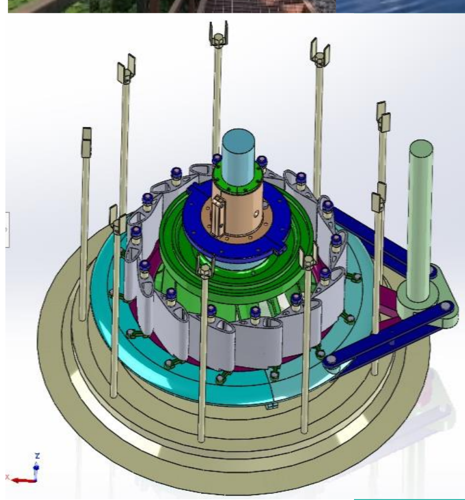
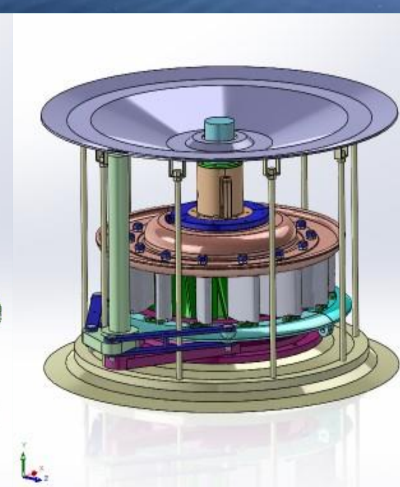
2024

CONDITION ASSESSMENT and COSTED OPTION ANALYSIS:

Factorydale Turbine Project – Berwick Electric Commission

Prepared for

TOWN OF berwick ELECTRIC COMMISSION

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EXECUTIVE SUMMARY

This report presents a comprehensive condition assessment and costed option analysis for the Factorydale Hydropower Plant, under the management of Berwick Electric Commission. The evaluation focuses on critical components of the plant, including the turbine, generator, governor, circuit breakers, and the civil structure, following the HydroAMP (Hydropower Asset Management Project) methodology. This framework provides a systematic approach to assessing mechanical and electrical equipment within the plant, ensuring consistent and reliable results.

The turbine, an original 1968 Francis-type runner, has sustained significant damage, rendering it inoperable. The runner and wicket gates display severe physical deterioration due to a combination of aging, corrosion, and impact damage. A root cause analysis identified that these damages are beyond repair, necessitating a full replacement of the unit.

The generator, despite being over 50 years old, underwent a stator and rotor rewind in 2023, resulting in improved operational status. However, further monitoring and testing are recommended to ensure long-term reliability. Other major components, such as the circuit breakers and the governor, are functional but aging, requiring ongoing maintenance and potential upgrades to maintain operational efficiency. The plant's emergency closure systems, including intake gates and valves, are in generally good condition but would benefit from periodic testing and minor repairs.

This assessment identifies critical short-term actions, such as turbine replacement and repairs, and provides recommendations for long-term maintenance strategies to ensure the sustainable operation of the plant. Three costed options—like-for-like replacement, installation of a new unit, and full decommissioning—are presented to guide investment decisions.

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SECTION 1 - PLANT OVERVIEW

1.1 General Description

The Factorydale hydropower plant is a Reservoir-Based plant, with a Francis runner and a synchronous generator.

1.1.1 Main components:

- Turbine: Francis type, 12 blades, 692 hp, 614 rpm, Manufactured by Barber Turbine & Foundries, 1968.
- Generator: 520 kVa,, 2300 V, 131 A, 14 poles, Synchronous, Canadian General Electric, No 140147.

Figure 1: Generator Name Plate

- Governor: Hydraulic, Woodward, type HR, torque: 6700 ft.lb.

Figure 2: Woodward Governor

- Bearing cooling system: not existent
- Transformer: not available during the inspection, on a separate location

1.1.2 Operational History

The community has operated a hydroelectric generating system on the South Branch Annapolis River since 1921, prior to its incorporation as the Town of Berwick in 1923. Previously, dams upstream from the present day head-pond in Factorydale had been constructed and used for log driving. There was a sawmill at the Factorydale site until 1919 or so, operated by the Easson family. In the period 1919-1921, the Town acquired this property from the Eassons and converted the millpond to a hydro head-pond. The upstream dams were used to impound water for later generation, as well as using run of river. The first generator was a 125 kW machine.

Berwick continued to operate the Factorydale plant, and in the 1930s replaced the original generator with a 250 kW machine.

In the period 1964 to 1968, design work and improvements were carried out on the head-pond and generating plant in Factorydale, including building a new penstock and surge tank, and constructing a new powerhouse. A larger generator of 520kVa was installed. That's the current generator, and the turbine that is installed currently.

During our condition assessment, several interviews were conducted to the personnel of the Berwick Electric Commission, and some details of the story of the plant came to light.

In 1968 when the improvements were carried out to build a new powerhouse with a capacity of 520 kVa, the new Draft tube was installed out of specifications.

- The riverbed was left 10" too high so it (*the draft tube*) was pushed in place and the circular shape was compromised.
- The contractor stopped excavating to reach the proper depth.
- The elbow was adjusted to fit and is not a true elbow.
- The elbow deflector plate was never installed.
- The draft tube detached during operation several times.
- An angle ring was installed but it failed a few years later.
- A concrete ring was made to support it, but it also failed
- Then a 12" channel frame was anchored into the concrete structure. The concrete thickness was about 16 to 18".
- These events occurred through the 1980's and 1990's and are considered complete.
- The access ladder and steel platform the bottom is rotten.
- Cavitation occurred years ago so an air injection nozzle was installed and that helped
- Corrosion and cavitation on the runner blades were observed during this period and the runner was coated with Belzona 30 years ago in the 1990's.
- In 2006 there was an **axe head that passed through the turbine** and broke a couple of wicket gates. These replacement gates were manufactured by a local artisan. A sample was taken by Hysovent for 3D scanning.
- There is a 1 to 1 1/2" degree misalignment vertical between the generator and turbine and this has not been remedied.

1.1.3 Recollections of the incident in December 2023

One of the PLT during our site assessment explained the incident. He reported that he was called to investigate why the power was decreasing. He saw that the wicket gate controls were trying to open the gates to increase power**, the rpm was held steady**, but the controls wouldn't respond. He arrived at the site and heard loud grinding noises that did not sound like air bubbles or rocks in the system. He immediately shut down the turbine and when they finished dewatering the turbine it was opened, and in the same condition as we see here today. Don confirmed these observations.

1.1.4 Environmental and Regulatory Context

The plant has been operating without environmental concerns for many years. The dams of the system as well has not been a reason for environmental concerns. The plant currently operates in concordance with local environmental regulations.

Regarding the regulatory aspects of the power generation, the plant, as any other plant and utility in the province, is under the oversight of the Nova Scotia Utility and Review Board. Any capital investment on the plant, as well any expenditure that the plant may require and that may affect the rate payers, will require approval of the board.

SECTION 2 - CONDITION ASSESSMENT METHODOLOGY

2.1 Assessment Criteria

In this assessment, we will be utilizing the HydroAMP (Hydropower Asset Management Project) framework to systematically evaluate the condition of various components within the hydroelectric plant. HydroAMP provides a standardized methodology for assessing the condition and performance of hydropower assets, ensuring a comprehensive and consistent evaluation process.

We will apply HydroAMP by first defining the key components of the plant, especifically mechanical and electrical equipment, control systems, and auxiliary systems. Each component will be assessed based on criteria such as physical condition, operational performance, and maintenance history. HydroAMP's scoring system will be used to rate the condition of each component, allowing us to identify areas of potential risk or necessary maintenance.

HydroAMP does not include a guideline specifically for civil structures. HydroAMP primarily focuses on the condition assessment of mechanical and electrical equipment in hydroelectric plants, such as turbines, generators, and transformers. Civil structures like dams, penstocks, and powerhouses typically require separate assessment methodologies, often involving structural engineering evaluations, to complement the overall condition assessment process in a hydro plant. For this reason, a separate structural assessment for the powerhouse, and a dam safety assessment are being conducted.

Furthermore, HydroAMP will guide our analysis in determining the overall health of the plant by aggregating component scores to provide a holistic view of the plant's condition. This approach will help prioritize maintenance activities and investment decisions, ensuring the long-term reliability and efficiency of the hydroelectric plant. The use of HydroAMP also facilitates benchmarking against industry standards, allowing us to compare the plant's condition with similar facilities.

The advantages of using HydroAMP is that it has a different scoring per system analyzed, and it is based on statistics. So each system will have different aspects to be looked at, and different scoring. We will present them for each system individually.

In 2001, the Bureau of Reclamation (BOR), Hydro-Québec (HQ), the Army Corps of Engineers' Hydroelectric Design Center (HDC), and Bonneville Power Administration (BPA) began collaborating on a technique for assessing the condition of hydroelectric equipment, later named "hydroAMP" or Hydro Asset Management Partnership.

The hydroAMP partners worked on the program for five years, and in 2006, with the publication of a report detailing the condition assessment technique, its development, and potential applications, hydroAMP was officially launched at HydroVision.

The HydroAMP assessment process for hydroelectric plant equipment is straightforward and based on two levels of evaluation, Tier 1 and Tier 2. The Tier 1 evaluation is more "superficial" and gathers information from routine operation and maintenance tasks as well as dedicated assessment activities. The Tier 2 evaluation is more in-depth and includes field tests and non-destructive testing, among other methods. HydroAMP consists of 11 guides for different plant equipment, which are:

- Turbines
- Generators
- Circuit Breakers
- Governors
- Excitation Systems
- Transformers
- Batteries
- Compressed Air Systems
- Cranes
- Surge Arresters
- Emergency Closure Gates and Valves

For this specific evaluation, we will go and perform a Tier 1 analysis of the following systems on Factorydale,:

- Turbines
- Generators
- Circuit Breakers
- Governors
- Batteries
- Cranes
- Emergency Closure Gates and Valves

2.2 Data Collection

In our data collection phase, we conducted three site visits to thoroughly assess the plant's condition. The first visit on July 19 focused on evaluating the civil structures of the plant, where we inspected the dam, penstock, and powerhouse foundation. The second visit, on July 25, centered on the electromechanical components, including a detailed 3D scan of the turbine. The final visit, on August 8, involved further inspection of the electromechanical systems, additional 3D scanning of the turbine, and an in-depth examination of the penstock intake and draft tube.

To ensure transparency and provide detailed insights, the site visit reports from each of these inspections will be attached as appendices to this report. These reports include observations, measurements, and photographic evidence collected during each visit, forming a crucial part of our overall condition assessment.

2.3 Scoring and Ranking

The advantages of using HydroAMP is that it has a different scoring per system analyzed, and it is based on statistics. So each system will have different aspects to be looked at, and different scoring. We will present them for each system individually.

To reduce the size of this report, we will upload to the SharePoint shared folder the HydroAMP guide for future reference. We will only show the different scores and the logic behind the scoring, on each system.

SECTION 3 - COMPONENT CONDITION ASSESSMENTS

3.1 Turbine

3.1.1 Turbine Condition Indicator 1 – Age

Table 1: HydroAMP - Turbine Age Scoring

Turbine Age Scoring		
Age (New/Full Rehabilitation)	**Age (Partial Rehabilitation)**	**Condition Indicator Score**
< 25 years	< 15 years	3
≥ 25 and < 35 years	≥ 15 and < 25 years	2
≥ 35 and < 45 years	≥ 25 and < 35 years	1
≥ 45 years	≥ 35 years	0

In this case, the indicator is 0, the turbine and all its mechanical components are older than 45 years.

3.1.2 Turbine Condition Indicator 2 – Physical Condition

Table 2: HydroAMP - Turbine Condition Scoring

Physical Condition Scoring	
Cracks	
Results*	Condition Indicator Score
No Cracking	2
Inactive Cracks	1
Active Cracks	0
Cavitation and Surface Damage	

Results*	Condition Indicator Score
Good Surface/Minimal Cavitation Damage	2
Fair Surface/ Moderate Cavitation Damage	1
Poor Surface/Severe Cavitation Damage	0
Total	
	Physical Condition Score
Sum of Cracks plus Cavitation and Surface Damage Condition Indicator Scores	0

In this case, the indicator is 0, the turbine and all its mechanical components are almost completely destroyed or in very bad condition.

Runner

In short, the runner is destroyed beyond repair.

Figure 3: Runner Damage

On the Root Cause Analysis of the failure of the machine we will elaborate a little bit more about the runner destruction.

But there are a few aspects to keep in mind:

- Runner was the original one since 1968

- In the 1990s, the runner was coated with Belzona, during an overhaul, to compensate for cavitation issues, and protect against corrosion.
- No other repairs were done to the runner in the following years until its failure.
- We noticed that there was already corrosion on the blades, regardless of the Belzona coating, and that's because of the number of years since the application of the coating.
- Corrosion could have led to weakening of the runner blades itself, even though that this level of destruction, caused by impacts at high speed with pieces of casting from the wicket gates, could not have been withstood by a new replacement runner either.

Scroll Case

This machine has a cylindrical scroll case, fixed dimensions, which is very inefficient in terms of helping the runner to get the maximum amount of energy from the water. More details can be found on drawing HSV-2024-043-02 on the appendix and the SharePoint shared folder.

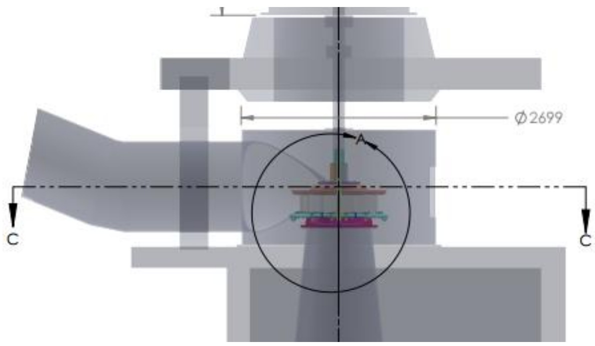


Figure 4: Turbine Scroll Case - Section View

Figure 5: Scroll Case from the outside

Figure 6: More details about the scroll case

The presence of corrosion is evident, inside and outside. The steel doesn't seem to be fractured though, and no leaks through it had been reported. But the headcover unions are where the leaks are present. There is no good seal between the headcover and the structure of the case, and water is always present during normal operations. The headcover is heavily corroded as well. No coating is left outside, and no epoxy coating was noticed inside either.

Wicket Gate mechanism

The mechanism is operated by a hydraulic governor, which operates a rotating shaft and moves two pairs of levers, a common arrangement on units of this age.

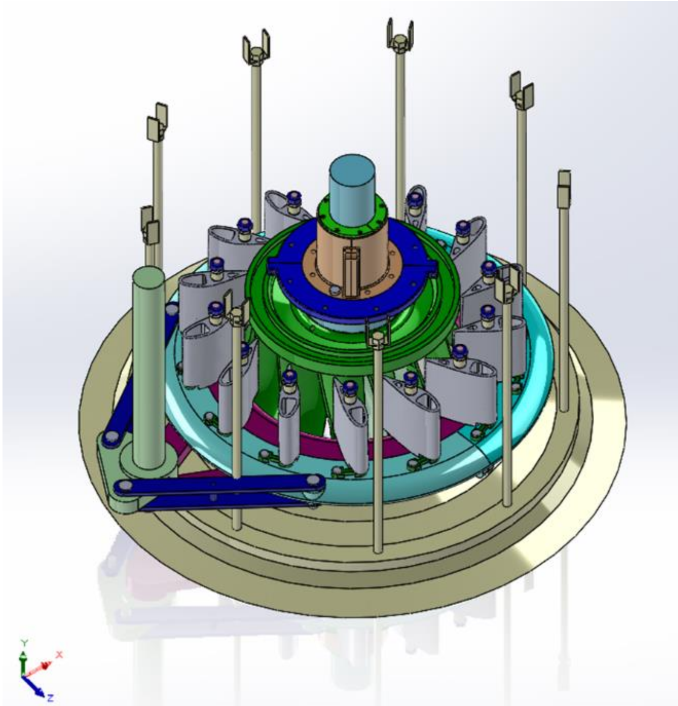


Figure 7: Wicket gate mechanism in 3D

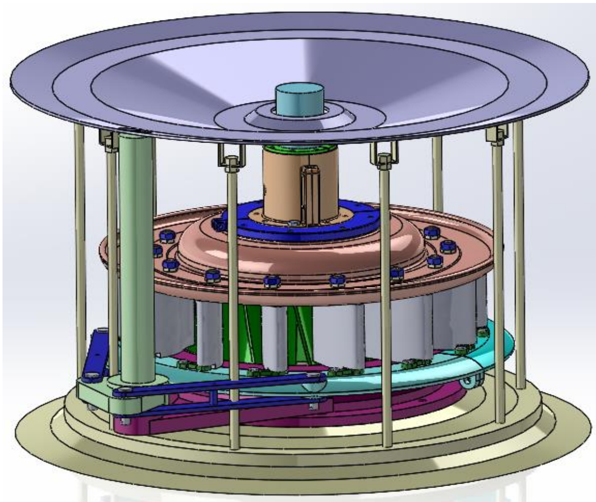


Figure 8: Unit fully assembled in 3D

Now, a wooden branch approximately 2 ½" in Diameter and 14" long was found inside the scroll case.

While this is not likely the initiator of the destruction of the wicket gates and the runner, it indicates that large objects can get into the scroll case.

Figure 9: Wicket Gate Mechanism Arms - left and right arms. Notice the wood log on the right picture.

Same comment than the rest of the turbine components. The corrosion is evident. In this case, interesting though, the pins that connect the operating arms with the operating ring, and the pivot, are in fact in good condition. But they have been changed in the past, after failures, as there was the presence of damaged pins on the shop table. No signs of bending, or deformation on the arms, pivot, or shaft.

Figure 10: Wicket Gate Mechanism Arms, details

Wicket gates

There are 13 wicket gates still in place, of 14. One was completely destroyed, two are cut in half, and the rest have several degrees of damage. Only a few are still in good condition.

Wicket gates metallurgical tests

On the appendix 1, the metallurgical report for the wicket gates is included. The report shows several aspects to be noted:

- The sample consisted in two different wicket gates, both damaged, which were removed from the unit at one point in time.
- Both castings are different, showing that there was no proper quality control or standard followed during their manufacturing.
- The strength of the materials in both wicket gates was substantially lower than the lowest class of gray cast iron in ASTM A48.

In summary, the wicket gates were more fragile and weaker than they should be.

Wicket gate 01

Figure 11: Wicket gate 01

The wicket gate 01 appears to be “intact”, even though it is just right next to the wicket gate 14, which was completely destroyed. The bronze link is not present; totally destroyed. The link pin is still present in place.

Wicket gate 02

Figure 12: Wicket Gate 02

Both ends of the wicket gate are damaged, missing over 10% of its mass. The control pin and the control link are missing.

Wicket gate 03

Figure 13: Wicket Gate 03

The control link of Wicket Gate 03 was found broken, and the wicket gate rotated 180 degrees. This was the position it was found, which proves that the wicket gate could have been rotating freely during the failure event. No major damage, other than small amount (1% or less) of missing material on the lower tip of the gate.

Wicket gate 04

Figure 14: Wicket Gate 04

Missing control link and 180 degrees rotated was how we found Wicket Gate 04. No major damage, other than small amount (1% or less) of missing material on the lower tip of the gate. The link pin on the gate is missed as well.

Wicket gate 05

Figure 15: Wicket Gate 05

The top and bottom sections of the gate edge have damage, indication of impacts with a solid object. The control link is missed, but the control pin is there. Same as other wicket gates, it was found fully rotated 180 degrees.

Wicket gate 06

Figure 16: Wicket Gate 06

This is one of the most damaged ones. Only around 20% of the entire mass of the wicket gate remains. No signs of the rest.

Wicket gate 07

Figure 17: Wicket gate 07

This wicket gate only suffered damage on the lower tip of the edge. Most definitively caused by impact. Was found rotated over 180 degrees of its expected position. Control link completely destroyed.

Wicket gate 08

Figure 18: Wicket gate 08, half attached to the pivot shaft

Figure 19: Wicket gate 8, half attached to the control link

Of all the Wicket Gates, this one, and the missed number 14, are key to understanding one of the causes of the incident. The wicket gate was broken in two pieces, and the control link remained intact, and stuck in place, impossible to move. Let’s remember that the link is made of bronze, way less resistant than the casting of the wicket gate, and it is designed to fail, as a “mechanical fuse”.

Now, this wicket gate is broken in two pieces. The pieces match quite closely after comparing them with the 3D scanner, which means that an impact caused the wicket gate to break first, and impact on the body of the wicket gate. This would explain why the link is still intact, there is no resistance to movement now that it is the only point connecting that half of the wicket gate with the operating ring.

The other thing that came to light with this, is the quality of the casting, which we already discussed during the analysis of the metallurgical tests to the wicket gates available.

Wicket gate 09

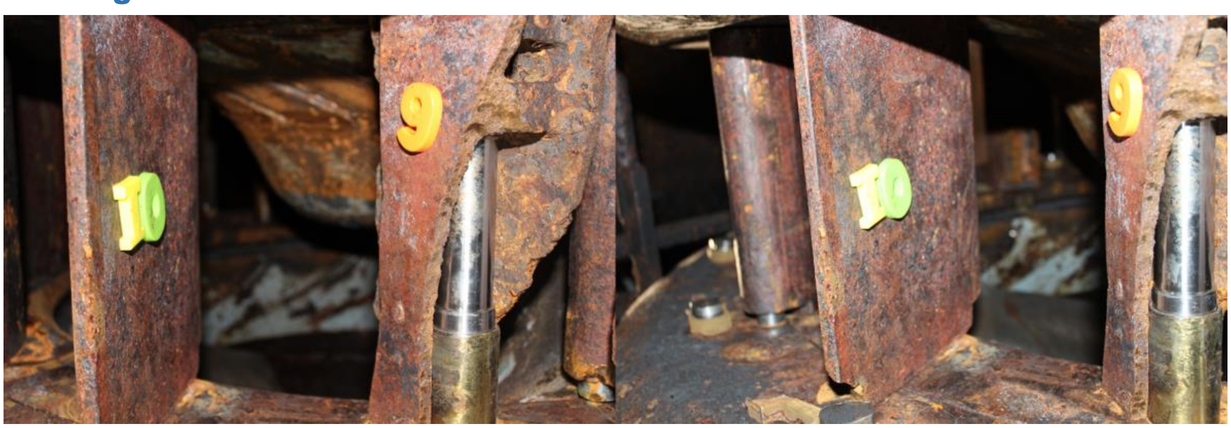


Figure 20: Wicket gate 09 - In the picture is marked as Wicket gate 10

We marked Wicket Gate 09 as 10 by confusion during our inspection. This wicket gate only suffered damage on the lower tip of the edge. Most definitively caused by impact. Was found rotated over 180 degrees of its expected position. Control link completely destroyed. Apparently, the damage on the tip happened during the uncontrolled rotation of the wicket gate, impacting the control link pin.

Wicket gate 10

Figure 21: Wicket Gate 10

Apart from a control link destroyed, there were no signs of damage on this wicket gate. Was found in the correct position as well.

Wicket gate 11

Figure 22: Wicket gate 11

Similar to Wicket Gate 10, apart from a control link destroyed, no signs of damage on this wicket gate. Was found in the correct position as well.

Wicket gate 12

Figure 23: Wicket gate 12

This wicket gate only suffered damage on the lower tip of the edge. Most definitively caused by impact. Was found rotated over 180 degrees to its expected position. Control link completely destroyed.

Wicket gate 13

Figure 24: Wicket gate 13

This wicket gate only suffered damage on the lower tip of the edge. Most definitively caused by impact. Was found rotated over 180 degrees to its expected position. Control link completely destroyed.

Wicket Gate 14

Figure 25: Wicket Gate 14 shaft, the only remain

The Wicket Gate 14 was totally destroyed, nothing left from it. Due to its position on the wicket gate arrangement, it is possible that this was the one that received the impact of the object (our most plausible cause so far) and started the damage chain reaction.

Turbine Shaft, Guide bearing and generator bearing:

We didn't have access to the bearings because that would require a disassembly of the unit, but we saw the condition of the shaft on the area closer to the guide bearing.

Figure 26: Runner shaft scoring

We noticed, though, something very interesting. The shaft had scoring and friction lines above the guide bearing. That area should be clean from scoring, because is not in contact with anything. There are two possibilities: damage due to sediments in the water, or the shaft moved on the Y axis and caused the damage at some point.

We couldn't evaluate the trueness of the shaft, for that to be done properly the runner must be able to freely rotate, or the shaft to be put on a lathe. For a repair scenario, that must be done, to properly assess if a new shaft is required.

With the runner being destroyed as it is

Draft tube

Figure 27: Draft tube exterior, corrosion present, but expected, no damage noticed

There are signs of corrosion outside the draft tube, we may assume that the inside, if it is not coated, is in similar condition. Proper NDE is recommended in this case to evaluate the structure of the draft tube. Replacement of the adjustment rods is required as well (the 8 rods, 4 at the top, 4 at the bottom, that adjust the vertical position of the draft tube).

Figure 28: Areas with concrete and rebar exposed

We noticed that around the draft tube there are areas with rebar and concrete exposed, like if they had fallen at some point on time. But no rest was found in the ground. We think that this was removed during construction, to ease the installation of the draft tube. Because is not attached to the draft tube and there are no loads over that specific area this does not represent a risk.

From the inside, we were able to put the GoPro and reach the bottom of the draft tube, but poor light and the darkness of the water didn't allow us to see if debris from the turbine were present at the bottom.

The platform to access the draft tube as well is in very poor condition, it should be replaced immediately.

3.1.3 Turbine Condition Indicator 3 – Operations

Table 3: HydroAMP - Operational Limitations Scoring

Operational Limitations Scoring	
Form of Operation	**Condition Indicator Score**
No operating restraints	1.5
Minimal operating restraints	1.0
Moderate operating restraints	0.5
Severe limitations, inoperable	0

The unit is inoperable, the score is 0.

3.1.4 Turbine Condition Indicator 4 – Maintenance

Table 4: HydroAMP - Operational Limitations Scoring

Maintenance Scoring	
Corrective Maintenance	**Condition Indicator Score**
No corrective maintenance	1.5
Small amounts of corrective maintenance (e.g., less than 3 staff days per unit per year)	1.0
Moderate corrective maintenance that causes extensions of unit preventative maintenance outages	0.5
Severe corrective maintenance or forced outages	0

The unit is currently under a forced outage. The score is 0.

3.1.5 Turbine Condition Summary

Table 5: HydroAMP – Turbine Condition Summary

Tier 1 Turbine Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score x**	**Weighting Factor =**	**Total Score**
1	Age *(Score must be 0, 1, 2, or 3)*	0	0.667	0

2	Physical Condition *(Score must be 0, 1, 2, 3, or 4)*	0	1.250	0
3	Operations *(Score must be 0, 0.5, 1, or 1.5)*	0	1.000	0
4	Maintenance *(Score must be 0, 0.5, 1, or 1.5)*	0	1.000	0
	Tier 1 Turbine Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*			0

This is basically a formality. The unit requires a full refurbishment or be replaced by a completely new unit.

3.1.6 Turbine Data Quality Scoring

Table 6: HydroAMP - Turbine Data Quality Scoring

Turbine Data Quality Scoring	
Results	**Data Quality Indicator Score**
All Tier 1 inspections, tests and measurements were completed within the normal frequency.	10
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 6 and < 24 months past the normal frequency.	7
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 24 and < 36 months past the normal frequency, or some of the results are not available.	4
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 36 months past the normal frequency, or no results are available.	0

One Tier 1 inspections completed in the last 36 months, which was done by BI&I, focused on the generator and electrical systems of the plant. The Score is 4.

3.2 Generator

Generator: 520 kVA, 2300 V, 131 A, 14 poles, Synchronous, Canadian General Electric, No 140147

Figure 29: Generator at Factordydale Powerplant

The condition assessment methodology described by HydroAMP guideline: Generator Condition Assessment, which is part of the Hydropower Power Plant Risk Assessment Guide; applies to hydroelectric generators, motors/generators, and motors rated at 2 MW (megawatts) or more. However, we can take it as a reference guide for the present research, considering that the Generator under study is much lower than that value (0.416 MW).

For the study of this generator, an inspection was carried out looking for causes of failure and extent of damage in this part. The preliminary results, no evidence of mechanical damage could be seen visually in this generator. A project to rewind the generator (Stator / Rotor Conjunction) was conducted in 2023. We are waiting for more details about that project to understand the actual conditions of the generator.

3.2.1 Generator Stator / Rotor Condition Indicator 1 – Operation & Maintenance History

Table 7: HydroAMP - Stator / Rotor Winding Operation & Maintenance History Scoring

Stator / Rotor Winding Operation & Maintenance History Scoring	
Results	**Stator / Rotor Condition Indicator Score**
Operation and maintenance normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal occurring.	2
Significant operation outside normal and/or significant additional maintenance is required; forced outage occurs; outages are regularly extended due to maintenance problems; similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; major electrical or mechanical failures; similar units have reached end-of-life.	0

Since there is no known consistent data and history of the generator up to the time of the operational failure, this with respect to Generator Electrical Maintenance data, then the Reference Guide recommends that when data is not available to correctly score a condition indicator, it can be assumed that the score is "Good" or numerically equal to some mid-range number such as 2. This strategy should be used judiciously to avoid erroneous results and conclusions.

3.2.2 Generator Stator / Rotor Condition Indicator 2 – Physical Inspection

Table 8: HydroAMP - Stator / Rotor Winding Physical Inspection Scoring

Stator / Rotor Winding Physical Inspection Scoring	
Results	**Stator / Rotor Condition Indicator Score**
Inspection results are normal.	3
Inspection shows some deterioration.	2
Inspection shows significant deterioration.	1
Inspection shows complete or imminent failure of stator winding components.	0

The imminent presence of humidity in the area and with the passage of time without operations or electrical energization of the generator, the windings should show some presence of some deterioration due to this effect. Previous tests carried out by L&B in its PdMA Testing Report (February 17, 2023) commented on this, the operations and energization would cause to improve some parameters related to this issue.

3.2.3 Generator Stator / Rotor Condition Indicator 3 – Insulation Resistance and Polarization Index

Table 9: - HydroAMP - Stator / Rotor Winding Insulation Resistance and Polarization Index Scoring

Stator / Rotor Winding Insulation Resistance and Polarization Index Scoring	
Results	**Stator / Rotor Condition Indicator Score**
Results are normal and similar to previous tests.	3
Results indicate a minor decrease in insulation resistance or polarization index (e.g., factor of 2 decrease).	2
Results indicate significant decrease in insulation resistance or polarization index (e.g., factor of 10 decrease).	1
Insulation resistance or polarization index is below minimum acceptable values.	0

This scoring is based on the results shown in the testing report by L&B, on February 17, 2023.

3.2.4 Generator Stator / Rotor Condition Indicator 4 – Winding Age

Table 10: HydroAMP - Stator / Rotor Winding Age Scoring

Stator / Rotor Winding Age Scoring	
Age	**Stator / Rotor Condition Indicator Score**
< 20 years	3
≥ 20 and < 30 years	2
≥ 30 and < 40 years	1
≥ 40 years	0

A project to rewind the generator was conducted in 2023. Even though the generator itself is way older than that, the rewinding makes it score high in the scale.

3.2.5 Generator Stator / Rotor Condition Summary

Table 11: - HydroAMP - Generator Stator / Rotor Condition Summary

Tier 1 Generator Stator / Rotor Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score ×**	**Weighting Factor =**	**Total Score**
1	O & M History *(Score must be 0, 1, 2, or 3)*	**2**	1.18	**2.36**
2	Physical Inspection *(Score must be 0, 1, 2, or 3)*	**2**	1.18	**2.36**
3	Insulation Resistance and Polarization Index *(Score must be 0, 1, 2, or 3)*	**2**	0.58	**1.16**
4	Winding Age *(Score must be 0, 1, 2, or 3)*	**3**	0.39	**1.17**
	Tier 1 Generator Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*			**7.05**

The recommendation from the HydroAMP guideline for a 7.05 condition index is: Continue O&M without restriction. Repeat condition assessment as needed.

3.2.6 Generator Stator / Rotor Data Quality Indicator – Quality of Inspections, Tests, and Measurements

Table 12: HydroAMP - Stator / Rotor Data Quality Scoring

Stator / Rotor Data Quality Scoring	
Results	**Stator / Rotor Data Quality Indicator Score**

All Tier 1 inspections, tests and measurements were completed within the normal testing frequency and the results are reliable.	10
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 6 and < 24 months past the normal testing frequency.	7
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 24 and < 36 months past the normal testing frequency, or some of the results are not available.	4
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 36 months past the normal frequency, or no results are available.	0

The verifications and tests were carried out by the contractor L&B during 2023 (February and September), for which an indicator score of 7 in this reference table, corresponding to the measures taken in the range de 6 to 24 months ago.

3.3 Circuit Breakers

There is no exact and specific data of the electrical power installation, corresponding to Main Switch; therefore, to follow the protocol described in Appendix E2: Circuit Breaker Condition Assessment, It will be completed with general data of an adequate operation, however It's a facility with no any intervention reference for measurement, testing or maintenance activities.

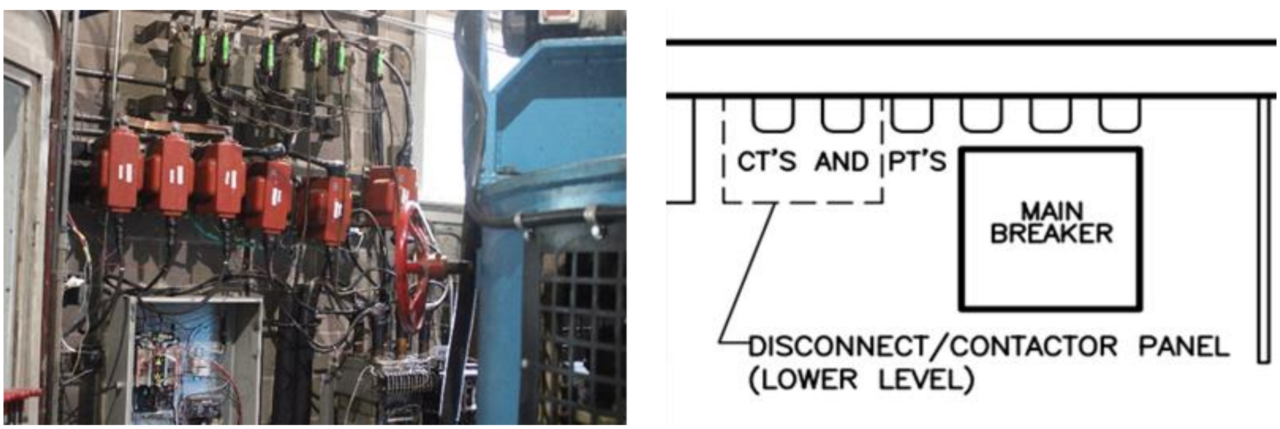


Figure 30: Description Unit Circuit Breaker.

A proper switchgear cabinet is not present in the plant. The breakers are exposed, even though they are individually guarded and insulated. As per the interviews with the personnel, there are not know electrical issues.

The evaluation performed by L&B Electric in September 2023 it is still valid, and its recommendations should be followed. There are four condition indicators generally regarded as a sound basis for assessing circuit breaker condition:

- Dielectric Condition
- Operation and Maintenance History
- Contact Resistance
- Number of Operations.

These condition indicators are initially evaluated using Tier 1 inspections, tests, and measurements, which are conducted by utility staff or contractors over the course of time and as a part of routine maintenance activities. Numerical scores are assigned to each condition indicator, which are then weighted and summed to determine the Circuit Breaker Condition Index.

Let's also keep in mind that for the study of this generator, an inspection was carried out looking for causes of failure and extent of damage in this part. The preliminary results, no evidence of electrical damage could be seen visually in the entire installation.

3.3.1 General Circuit Breaker Condition Indicator 1 – Dielectric Tests

Table 12: HydroAMP – General Dielectric Test Scoring

General Dielectric Test Scoring	
Results	**Condition Indicator Score**
Test results are normal. (Good - G)*	3
Test results show minor deterioration. (Deteriorated - D)*	2
Test results show significant deterioration. (Investigate - I)*	1
Test results show severe deterioration. (Bad - B)* (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)	0

* Doble insulation rating shown in parentheses.

Since there is no known consistent data and history in this equipment up to the time of the operational failure, this with respect to Electrical Maintenance data, then the Reference Guide recommends that when data is not available to correctly score a condition indicator, it can be assumed that the score is "Good" or numerically equal to some mid-range number such as 2. This strategy should be used judiciously to avoid erroneous results and conclusions in this case and subsequent.

3.3.2 General Circuit Breaker Condition Indicator 2 – Operation and Maintenance History

Table 13: HydroAMP – General Circuit Breaker O & M History Scoring

General Circuit Breaker O & M History Scoring	
Results	**Condition Indicator Score**
Operation and Maintenance are normal.	3
Some abnormal operating conditions experienced and/or additional maintenance above normal occurring.	2

Significant operation outside normal and/or significant additional maintenance is required; or forced outage occurs; or outages are regularly extended due to maintenance problems; or similar units are problematic.	1
Repeated forced outages; maintenance not cost effective; or severe mechanical problems; or similar units have failed.	0

3.3.3 General Circuit Breaker Condition Indicator 3 – Contact Resistance Tests

Table 14: HydroAMP – General Contact Resistance Test Scoring

General Contact Resistance Test Scoring	
Results	**Condition Indicator Score**
< 25 percent increase since last test AND below manufacturer recommended maximum resistance.	3
≥ 25 and < 75 percent increase since last test AND below manufacturer recommended maximum resistance.	2
≥ 75 percent increase since last test OR above manufacturer recommended maximum resistance. (May indicate serious problem requiring immediate evaluation, additional testing, consultation with experts, and remediation prior to re-energization.)	1

3.3.4 General Circuit Breaker Condition Indicator 4 – Number of Operations

Table 15: HydroAMP – General Operations Scoring

General Operations Scoring	
Results	**Condition Indicator Score**
< 1,000 normal operations < 250 normal operations (Oil Tank) < 2,000 normal operations (SF6)	3
≥ 1,000 and < 3,000 normal operations ≥ 250 and < 750 normal operations (Oil Tank) ≥ 2,000 and < 5,000 normal operations (SF6)	2
≥ 3,000 and < 5,000 normal operations ≥ 750 and < 1,500 normal operations (Oil Tank) ≥ 5,000 and < 8,000 normal operations (SF6)	1
≥ 5,000 normal operations ≥ 1,500 normal operations (Oil Tank) ≥ 8,000 normal operations (SF6)	0

3.3.5 General Circuit Breaker Data Quality Scoring – Quality of Inspections, Tests, and Measurements

Table 16: HydroAMP – Circuit Breaker Data Quality Scoring

Circuit Breaker Data Quality Scoring	
Results	**Data Quality Indicator Score**
Al Tier 1 inspections, tests and measurements were completed within the normal testing frequency and the results are reliable AND comparison of breaker interrupting rating with short circuit study results was performed within the last < 5 years.	10
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 6 and < 24 months past the normal testing frequency and results are reliable OR comparison of breaker interrupting rating with short circuit study results was performed ≥ 5 and < 10 years ago.	7
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 24 and < 36 months past the normal testing frequency, or some of the results are not available or are of questionable integrity OR comparison of breaker interrupting rating with short circuit study results was performed ≥ 10 and < 15 years ago.	4
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 36 months past the normal frequency, or no results are available or many are of questionable integrity OR comparison of breaker interrupting rating with short circuit study results was performed ≥ 15 years ago.	0

Since there are no references available, our diagnosis about Data Quality Scoring is the lowest, given the importance of inspection, maintenance, and in-depth evaluation of the condition state.

3.3.6 General Circuit Breaker TIER 1 Condition Assessment Summary

Table 17: HydroAMP – Circuit Breaker Condition Summary

Tier 1 Circuit Breaker Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score**	**X Weighting Factor**	**= Total Score**
1	Dielectric Condition of Breaker *(Score must be 0, 1, 2, or 3)*	2	0.877	1.754

2	Operation and Maintenance History *(Score must be 0, 1, 2, or 3)*	2	1.315 6	2.6312
3	Contact Resistance *(Score must be 1, 2, or 3)*	2	0.702	1.404
4	Number of Operations *(Score must be 0, 1, 2, or 3)*	2	0.439	0.878
Tier 1 Circuit Breaker Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*				**6.6672**

3.3.7 General Circuit Breaker Condition-Based Alternatives

Table 18: HydroAMP – Circuit Breaker Condition-Based Alternatives

Circuit Breaker Condition-Based Alternatives	
Generator Condition Index	**Suggested Course of Action**
≥ 7.0 and ≤ 10 (Good)	Continue O & M without restriction. Repeat condition assessment as needed.
≥ 3.0 and < 7 (Fair)	Continue operation but reevaluate O & M practices. Consider using appropriate Tier 2 tests. Repeat condition assessment process as needed.
≥ 0 and < 3.0 (Poor)	Immediate evaluation including additional Tier 2 testing. Consultation with experts. Adjust O & M as prudent. Begin replacement/rehabilitation process.

The value provided by the analysis gives us a limit of condition Fair. This equipment requires a O&M plan.

3.4 Governor

The hydraulic governor is the original from 1968, when the plant was commissioned to its current state.

Figure 31: Woodward Governor

Figure 32: Woodward Governor, additional views

We couldn't find technical specs of this governor until the moment of issuing this report. But the company Emerson still manufactures and services these governors. We have been contacting them to see what additional information we can collect about the governor. Regardless, that does not affect the condition assessment on it.

The governor had been through several modifications and repairs for the last 60 years, that is evident, but not all of them have been properly documented. It is not clean outside, and there are signs of oil leaks, something that as well was visible on the oil tank located on the turbine level.

Figure 33: Governor Oil tank, turbine level

This is not an uncommon arrangement. The oil tank presents leaks on its pipes as well, and it is not clean in its surroundings, with buckets ready to catch oil. This presents a safety and an environmental risk.

We understand that the governor was working properly before the failure in December 2023. A proper register of modifications / repairs was not available at the moment of this condition assessment.

3.4.1 Governor Condition Indicator 1 – Age

Table 19: HydroAMP - Age Scoring - Mechanical Control System

Age Scoring Mechanical Control System	
Age	**Condition Indicator Score**
< 25 years	3
≥ 25 and < 40 years	2
≥ 40 years	1

In this case, the score is 1, the governor is older than 40 years.

3.4.2 Condition Indicator 2 – Operation & Maintenance History

Table 20: HydroAMP - Operation & Maintenance History Scoring

Operation & Maintenance History Scoring	
Historical Results	**Condition Indicator Score**
Normal preventive and corrective maintenance (< 50 hours/year/unit) or no significant increase in preventive and corrective maintenance (less than 1.5 x baseline, as established by maintenance records).	3
Significant increase (over 1.5 x baseline) in preventive maintenance, but no significant increase in corrective maintenance, or operational constraints occurring rarely.	2
Significant increase (over 1.5 x baseline) in corrective maintenance or operational constraints occurring occasionally.	1
Repeated corrective maintenance or operational constraints.	0

From interviews, the governor, even though had gone through modifications over the years, can be considered to be under “normal” maintenance. The main limitation is the maintenance record keeping, which is very limited, so a statistical analysis cannot be performed. We will score 2 for that reason.

3.4.3 Condition Indicator 3 – Availability of Spare Parts

Table 21: HydroAMP - Availability of Spare Parts

Availability of Spare Parts Scoring	
Availability	**Condition Indicator Score**
All necessary mechanical and electronic parts are available from original supplier.	3
Necessary mechanical and electronic parts are no longer available from original supplier and must be obtained from alternate suppliers.	2
Some electronic and mechanical parts are not available at all and/or some mechanical parts must be reverse-engineered and manufactured by alternate suppliers.	1
Most mechanical and electronic parts are not available at all and/or there are significant obstacles to successful reverse-engineering of mechanical parts.	0

Interesting fact: even though the governor is not in production anymore, Emerson, a company in the US specialized in controls, bought the brand many years ago, and offer spares and service. These governors are very common in North America, and through this company, spares and service can be obtained. The score is 3.

3.4.4 Condition Indicator 4 – Performance

Table 22: HydroAMP - Performance Scoring

Performance Scoring	
Observations (Criteria)	**Condition Indicator Score**
Off-line and on-line response and stability normal, governor free from hunting, accuracy of frequency within < 0.2 Hz, synchronization time within the norm, and able to remote start.	3
Off-line and on-line response and stability are fair, occasional hunting problems, synchronization time and accuracy of frequency outside the norm, or remote start is difficult.	2
Poor off-line and on-line response and stability, re-occurring hunting problems, difficulty in synchronization, or unable to remote start.	1

This governor is not designed or modified for remote start. Having said that, based on the interviews, its response to local commands is good. We will score 2.

3.4.5 Governor Condition Summary

Table 23: Governor Condition Summary

Tier 1 Governor Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score ×**	**Weighting Factor =**	**Total Score**
1	Age *(Score must be 1, 2, or 3)*	1	0.17	0.17
2	Operation & Maintenance History *(Score must be 0, 1, 2, or 3)*	2	1.17	2.34
3	Availability of Spare Parts *(Score must be 0, 1, 2, or 3)*	3	0.83	2.49
4	Performance *(Score must be 1, 2, or 3)*	2	1.17	2.34

Tier 1 Governor Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*	7.34

This score of 7.34 recommends: Continue O & M without restriction. Repeat condition assessment as needed.

3.4.6 Governor Data Quality Indicator

Table 24: HydroAMP - Governor Data Quality Scoring

Governor Data Quality Scoring	
Results	**Data Quality Indicator Score**
All Tier 1 inspections, tests and measurements were completed within the normal frequency.	10
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 6 and < 24 months past the normal frequency.	7
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 24 and < 36 months past the normal frequency, or some of the results are not available.	4
One or more of the Tier 1 inspections, tests and measurements were completed ≥ 36 months past the normal frequency, or no results are available.	0

The Score selected in this case is 0, there are no records of inspections or maintenance performed in the last 3 years, other than the testimony of personnel.

3.5 Batteries

Figure 34: Battery bank and charger

Battery bank looks quite dirty, but it is functional. The charging system is working properly.

3.5.1 Battery Condition Indicator 1 – Visual Inspection

Table 25: HydroAMP - Visual Inspection

Visual Inspection Scoring	
Results	**Condition Indicator Score**
Inspection normal.	3
Minor degradation – no cracks or leaks, minimal corrosion; minimal sedimentation; normal electrolyte level.	2
Significant degradation – no cracks; few if any unrepairable leaks; moderate corrosion; moderate sedimentation; normal electrolyte level or needing minimal replacement.	1
Extreme degradation – cracks, leaks, or corrosion leaching into cell or cable; heavy sedimentation (quantity or size), consistently low electrolyte.	0

In this case, the score is 3, the batteries are dirty but in general good condition, no cracks or leaks.

3.5.2 Battery Condition Indicator 2 – Age

Table 26: HydroAMP - Age Scoring – Vented Lead-Acid

Age Scoring – Vented Lead-Acid	
Results	**Condition Indicator Score**
< 12 years (< 60% of expected life)	3
≥ 12 and < 16 years (≥ 60 and < 80% of expected life)	2
≥ 16 and < 20 years (≥ 80 and < 100% of expected life)	1
≥ 20 years (≥ 100% of expected life)	0

Batteries are less than 12 years old, the score is 3.

3.5.3 Battery Condition Indicator 3 – Routine Testing

Table 27: HydroAMP - Routine Testing Scoring

Routine Testing Scoring	
Results	**Condition Indicator Score**
Results Normal: {Impedance/Internal Resistance: Less than 105% of baseline for multi-cell VRLA jars OR Impedance/Internal Resistance: Less than 115% of baseline for single-cell VLA or VRLA jars} AND Float Voltages: Less than +/- 0.5% difference from manufacturer's data AND Specific Gravity: Less than - 0.005 difference from manufacturer's data AND Temperature: Cell variance less than +/- 2 °F AND Connection Resistance: Less than 110% of baseline (VLA or VRLA) excluding long jumpers. *	3
Minimal Deviation from Normal: {Impedance/Internal Resistance: Less than 115% of baseline for multi-cell VRLA jars OR Impedance/Internal Resistance: Less than 125% of baseline for single-cell VLA or VRLA jars} AND Float Voltages: Less than +/- 1% difference from manufacturer's data AND	2

Specific Gravity: Less than - 0.010 difference from manufacturer's data AND Temperature: Cell variance less than +/- 4 °F AND Connection Resistance: Less than 120% of baseline (VLA or VRLA) excluding long jumpers. *	
Significant Deviation from Normal: {Impedance/Internal Resistance: Less than 125% of baseline for multi-cell VRLA jars OR Impedance/Internal Resistance: Less than 135% of baseline for single-cell VLA or VRLA jars} AND Float Voltages: Less than +/- 2% difference from manufacturer's data AND Specific Gravity: Less than - 0.015 difference from manufacturer's data AND Temperature: Cell variance less than +/- 5 °F AND Connection Resistance: Less than 150% of baseline (VLA or VRLA) excluding long jumpers. *	1
Extreme Deviation from Normal: {Impedance/Internal Resistance: Greater than or equal to 125% of baseline for multi-cell VRLA jars OR Impedance/Internal Resistance: Greater than or equal to 135% of baseline for single-cell VLA or VRLA jars} OR Float Voltages: Greater than or equal to +/- 2% difference from manufacturer's data OR Specific Gravity: Greater than or equal to - 0.015 difference from manufacturer's data OR Temperature: Cell variance greater than or equal to +/- 5 °F OR Connection Resistance: Greater than or equal to 150% of baseline (VLA or VRLA) excluding long jumpers. *	0

From interviews with personnel, there have been no issues with the batteries. As well, the charger indicates that they are in good condition overall. The score for this indicator is 3.

3.5.4 Plant Battery Condition Summary

Table 28: HydroAMP - Plant Battery Condition Summary

Tier 1 Plant Battery Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score** ×	**Weighting Factor** =	**Total Score**
1	Visual Inspection *(Score must be 0, 1, 2, or 3)*	3	0.833	2.499
2	Age *(Score must be 0, 1, 2, or 3)*	3	0.833	2.499
3	Routine Testing *(Score must be 0, 1, 2, or 3)*	3	1.667	5.001
	Tier 1 Plant Battery Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*			10

The score in this case is 10. The battery bank is in good condition.

3.5.5 Plant Battery Data Quality Indicator

Table 29: HydroAMP – Plant Battery Data Quality Scoring

Plant Battery Data Quality Scoring	
Results	**Data Quality Indicator Score**
All Tier 1 inspections, tests and measurements were completed within the normal testing time interval and the results are reliable.	10
Tier 1 inspections, tests and measurements were completed < 150 percent of the normal testing time interval and the results are reliable.	7
Tier 1 inspections, tests and measurements were completed ≥ 150 and < 200 percent of the normal testing time interval, or some of the results are not available or are of questionable integrity.	4
Tier 1 inspections, tests and measurements were completed ≥ 200 percent of the normal testing time interval, or no results are available, or many are of questionable integrity.	0

The Score selected in this case is 0, there are no records of inspections or maintenance performed in the last 3 years, other than the testimony of personnel.

3.6 Cranes

There is one single crane in the plant, located on the first floor. It is a manual chain hoist. Has been certified recently as shown in documentation available.

Figure 35: Chain hoist manual crane

Crane Capacity: 9,991 kg.

Crane is certified and has been inspected recently. We didn't have access to the certificate (apparently was lost) but there is a plaque on the first level of the powerhouse indicating the capacity of the crane. As per the technicians on site, that plaque was put by the certifier of the crane.

3.6.1 Crane Condition Indicator 1 – Crane Physical Condition

Table 30: HydroAMP - Crane Physical Condition

Crane Physical Condition Scoring	
Results	**Condition Indicator Score**
Excellent Condition:	3

• Crane surfaces and coatings are free of corrosion; • No structural damage or cracks; no loose bolts or rivets found; • Couplings are tight and properly aligned; • Moving parts are lubricated; • Gearbox oil is free from contaminants and moisture; • No groove wear on drums or sheaves; • Bearings have no wear and are well lubricated; • Oil seals do not leak; • Gears are properly aligned and have no wear; • Hoist ropes have no broken strands or deformation; • The rope is laying properly on the drum; • Limit switches are properly set and functioning properly; • Brakes have no wear and operate properly; there is no record of loads slipping with the brakes applied; • No unusual noises or binding of any mechanism during operation; • Electrical components are clean and function properly; • Controls function properly; • Motors are clean and current draw is within limits; motor brushes and rings show minimal wear; • Hooks or grapples are free of nicks, gouges and cracks and swivel freely; hook latches function properly; • All wheels contact the rails, run smoothly and show no signs of wear; • Below-the-block lifting devices are in good condition; • Spare parts are readily available.	
Good Condition: • Crane surfaces and coatings have minor defects or corrosion; • No structural damage or cracks; no loose bolts or rivets found; • Couplings are tight and properly aligned; • Moving parts are lubricated; • Gearbox oil has minor contaminants noted; • No groove wear on drums or sheaves; • Oil seals do not leak; • Gears are properly aligned and have no wear; • Hoist ropes have no broken strands or deformation; • The rope is laying properly on the drum; • Limit switches are properly set and functioning properly; • Brake pads have ≥ 50% of the lining left and operate properly; • No unusual noises or binding of the mechanism during operation; • Electrical components are clean and functional; • Controls function properly; • Motors are clean and current draw is within limits; motor brushes and rings show minimal wear; • Hooks or grapples are free of nicks, gouges and cracks and swivel freely; hook latches function properly; • All wheels contact the rails, run smoothly and have minimal wear; • Below-the-block lifting devices are in good condition; • Spare parts are somewhat available.	2
Fair Condition: • Crane surfaces and coatings have minor defects or corrosion; • Minimal structural damage with no cracks;	1

• Couplings are tight and properly aligned; • Gearbox oil has minor contaminants or water is noted; • Some groove wear on drums or sheaves; • Oil seals have minor leaks; • Gears are misaligned but no major wear or damage to the gears; • Hoist ropes have broken strands within the allowable limit of ASME B30.2; • Limit switches are properly set and functioning properly; • Brakes pads have ≥ 20% of the lining left and operate properly; • Some unusual noises are noted during operation; • Electrical components are dirty; • Controls have minor problems; • Motor current draw is excessive; • Hooks have minor defects and some wear; • All wheels contact the rails but have some wear noted; • There are multiple trouble reports on record such as repairs to the electrical controls; • Spare parts are somewhat difficult to obtain.	
Poor Condition: • There are serious concerns with the crane's condition such as: • Operational restrictions or limits have been placed on the crane; • Major corrosion on the critical components; • Indication of frame skewing or ≥ 10% loose fasteners; • Wire rope corrosion, broken strands or deformation; • Brake pads have < 20% of the lining left; • Significant lubricating oil contamination; • Unusual noises or vibrations during operation; • Control problems; • Motors often trip out, vibrate or run hot; brittle or asbestos containing wiring insulation; • Hooks and grapples have increased throat opening or are bent; have cracks, nicks or gouges or abnormal wear; • Wheels do not contact rail or racking and binding of wheels occur during travel; wheels are worn extensively; • Frequent trouble reports; • Spare parts are very difficult to obtain.	0

From the visual inspection, understanding the simplicity of the chain hoist crane, and that its condition is very good, we will score 2. It is not excellent due to some minor corrosion visible, as well as the incomplete coating of the rail.

3.6.2 Condition Indicator 2 – Design Criteria

Table 31: HydroAMP – Design Criteria Scoring

Design Criteria Scoring	
Results	**Condition Indicator Score**

• Heaviest lift < 100% of rated capacity. • Crane usage is appropriate for its duty classification. • Crane configuration is adequate for handling intended loads. • Crane has no regulation and code violations.	3
• Heaviest lift < 100% of rated capacity. • Crane usage is slightly higher than appropriate for its duty classification. • Crane configuration is adequate for handling intended loads. • Crane has no regulation and code violations; however may not have features required in new regulations and codes that are not required for older cranes.	2
• Heaviest lift is ≥ 100 and < 110% of rated capacity. • Crane usage is moderately higher than appropriate for its duty classification. • Crane has minor handling deficiencies, may need modifications to handle loads properly. • Crane has minor regulation and code violations. Also, may not have features required in new regulations and codes that are not required for older cranes.	1
• Heaviest lift ≥ 110% of rated capacity. • Crane usage is considerably higher than appropriate for its duty classification. • Crane has serious handling deficiencies, needs modifications to handle loads properly. • Crane has major regulation and code violations.	0

The crane was recently inspected and passed as a Lifting Device under Nova Scotia regulations. The score is 3.

3.6.3 Condition Indicator 3 – Maintenance Requirements

Table 32: HydroAMP – Cranes- Maintenance Requirements Scoring

Maintenance Requirements Scoring	
Results	**Condition Indicator Score**
Small	3
Moderate	2
Excessive	1

As per HydroAMP guide: Small: A small amount of routine annual preventative maintenance is required for the crane. We will give a score of 3.

3.6.4 Condition Indicator 4 – Age of Crane

Table 33: HydroAMP – Cranes- Age of Crane

Age of Crane	
Results	**Condition Indicator Score**
< 20 years	3
≥ 20 and < 35 years	2
≥ 35 years	1

In this case, we give a score of 1, the crane is older than 35 years.

3.6.5 Crane Condition Summary

Table 34: Crane Condition Summary

Tier 1 Crane Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score x**	**Weighting Factor =**	**Total Score**
1	Physical Condition *(Score must be 0, 1, 2, or 3)*	2	1.2	2.4
2	Design Criteria *(Score must be 0, 1, 2, or 3)*	3	1.0	3
3	Maintenance Requirements *(Score must be 1, 2, or 3)*	3	0.8	2.4
4	Age *(Score must be 1, 2, or 3)*	1	0.333	0.333
Tier 1 Crane Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*				8.133

Following HydroAMP recommendations for a condition index of 8.1333: continue O & M without restriction. Repeat condition assessment as needed.

3.6.6 Crane Data Quality Indicator

Table 35: HydroAMP - Crane Data Quality Scoring

Governor Data Quality Scoring	
Results	**Data Quality Indicator Score**
The last crane periodic inspection was performed within the normal inspection frequency and results are reliable.	10

The last crane periodic inspection was performed < 36 months past the normal inspection frequency and results are reliable.	7
The last crane periodic inspection was performed ≥ 36 and < 60 months past the normal inspection frequency OR some of the results are not available or are of questionable integrity.	4
The last crane periodic inspection was performed ≥ 60 months past the normal inspection frequency OR many results are of questionable integrity or no results are available.	0

The Score selected in this case is 7, even though the inspection was performed recently, there is no established frequency of inspections.

3.7 Emergency Closure Gates and Valves

It is important to understand that the emergency closure itself is not as fast as it may sounds. The only emergency closure mode existent now, is the closure of the wicket gates. The intake butterfly valve is manually operated, and the intake gate in the penstock is as well manually operated, no motors, no controls, pure manual operation.

Intake gate valve

The intake gate valve is a typical 48 inch diameter butterfly valve, manually operated with a torque multiplier, and ith a bypass valve.

Figure 36: Intake valve

The valve is in very good condition, operates like it should be, and does not have any noticeable problems. From our inspection inside the scroll case there are no signs of leaks. The water in the case was leftover of the drainage. There are no concerns on the valve.

Pressure relief valve

Figure 37: Pressure relief valve

The plant, instead of having a surge tank, has a pressure relief valve installed, with surge anticipation. This is a common system that it is used in small hydro plants to avoid the construction of a surge tank. This protects the penstock and the powerhouse of the water-ram effect in the event of a sudden closure of the intake valve, or the wicket gates in this case.

The valve is in good condition and was commissioned and tested properly in previous years. Maintenance had been kept up, but no formal registration of it was available at the moment of inspection. There are no concerns on the valve.

Intake Gate

Wooden intake gate, manually operated, in good condition in general.

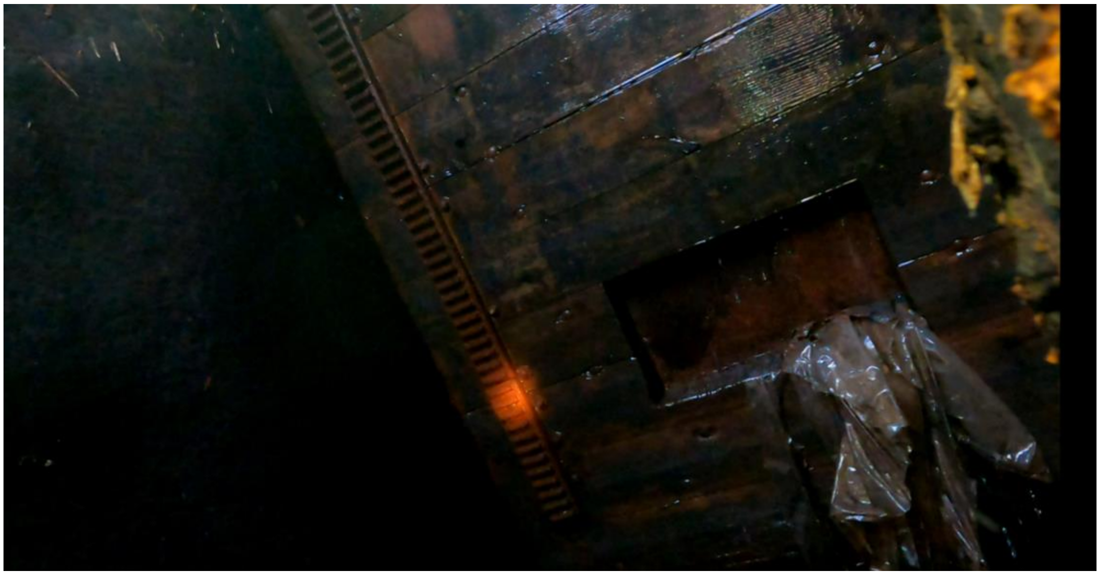


Figure 38: Intake Gate

The seal is not perfect as is expected on a wooden gate, but it is very good. There are no massive leaks or signs of damage to it.

3.7.1 Condition Indicator 1 – Age of Gates, Valves, and Operators

Table 36: HydroAMP – Age of Gates, Valves, and Operators

Age of Gate, Valve, and Operator	
Age of the Equipment	**Emergency Closure System Age Indicator Score**
< 20 years	3
≥ 20 and < 35 years	2
≥ 35 and < 60 years	1
≥ 60 years	0

In this case, the equipment is a mix of original equipment from 1968 and relatively new equipment, the pressure relief valve. We assign a score of 1, to be in line with the oldest equipment on the plant.

3.7.2 Condition Indicator 2 – Physical Condition of Gates/Valves

Gates and valves are evaluated separately.

Table 37: HydroAMP – Gate Physical Condition

Gate Physical Condition	
Results	**Gate condition indicator score**
Limited corrosion on gates, wheels, or rollers; wheels/rollers turn; coating is in good condition; anodes are in good condition; no cracked welds in structure or loose bolts/rivets; gate guides are in good condition; sill is in good condition; leakage past seals is minimal (< 25 gpm or < 1.6 liters/s).	3
Moderate corrosion on the gates, wheels, or rollers; most of the wheels/rollers turn; three-quarters of the anodes are left; no cracked welds in the structure or loose bolts/rivets; gate guides are in good condition; sill is in good condition; leakage past seals is minimal (< 25 gpm or < 1.6 liters/s).	2
Large areas of corrosion on the gates, wheels, or rollers; most of the wheels/rollers turn; one-half of the anodes are left; no cracked welds in the structure or loose bolts/rivets; gate guides are in good condition; sill is in good condition; leakage past seals is moderate (≥ 25 and < 50 gpm or ≥ 1.6 and < 3.2 liters/s).	1
Severe corrosion on the gates, wheels, or rollers; few of the wheels/rollers turn; coating is poor; one-quarter or less of the anodes are left; some cracked welds in the structure or loose or missing bolts/rivets; gate guides are in poor condition; sill is in poor condition; excessive leakage past the seals (≥ 50 gpm or ≥ 3.2 liters/s).	0

For the intake gate, we will assign a score of 2. The gate is in general good condition, but there is corrosion present on the guides, and there is leakage through the wood and the seals.

Table 38: HydroAMP – Valve Physical Condition

Valve Physical Condition	
Results	**Gate condition indicator score**
Limited corrosion on leaf/plug and water passage; coating is in good condition; seals and seats are in good condition and properly adjusted with no or minimal leakage, bearing/pivot point lubrication is in good condition; the bypass is in good condition; valve is regularly exercised.	3
Moderate corrosion on leaf/plug and water passage; coating is in adequate condition; seals and seats are in adequate condition with minimal leakage; bearing/pivot point lubrication is in good condition; the bypass is in good condition; valve is regularly exercised.	2

Large areas of corrosion on leaf/plug and water passage; coating is less than adequate; seals and seats have some damage with minor leakage; bearing/pivot point lubrication is in adequate condition; the bypass has moderate corrosion; valve is regularly exercised.	1
Severe corrosion on leaf/plug and water passage; coating is poor; seals and seats are damaged allowing excessive leakage; bearing/pivot point lubrication is not functioning properly; the bypass has excessive corrosion; there is severe chattering, vibration, or binding during operation; the valve is either rarely exercised or is excessively exercised (i.e., ≥ 50 cycles per year).	0

For the intake gate, the conditions are good enough to have a score of 2, as per the guidelines. For the pressure relief valve, the score would be 3, with the caveat that the valve is not "exercised" frequently. We think then, that 2 is a more realistic score for the valves as an equipment group.

3.7.3 Condition Indicator 3 – Physical Condition of Operators

Valves and gates are evaluated separately. HydroAMP uses Hydraulic and Electric operators only. The plant at Factorydale uses Manual mechanical operators, the closest evaluation matrix then is electrical operators.

Table 39: HydroAMP – Gate Operator (Electric Hoist) Physical Condition, evaluating a mechanical operator

Gate Operator (Electric Hoist) Physical Condition	
Results	**Gate condition indicator score**
Hoist surfaces and coatings are free of corrosion; no structural damage or cracks; couplings are tight and properly aligned; moving parts are lubricated; gearbox oil is free from contaminants and moisture and tested regularly; no groove wear on drums or sheaves; bearings are checked for wear and lubrication; oil seals do not leak; gears are properly aligned and have no wear; the hoist ropes are inspected for broken strands, hoist chain is free of cracked, deformed, or severely corroded links; the rope/chain is laying properly on the drum; limit switches are properly set and functioning properly; hoist brakes have no wear and operate properly; no unusual noises or binding of the mechanism during operation; electrical components are clean and function; the hoist system has been tested and exercised regularly.	3
Hoist surfaces and coatings have minor defects or corrosion; no structural damage or cracks; couplings are tight and properly aligned. moving parts are lubricated; gearbox oil is not tested regularly or minor contaminates noted; no groove wear on drums or sheaves; oil seals do not leak; gears are properly aligned and have no wear; hoist ropes have no broken strands or evidence of corrosion; hoist chain has some corrosion but no cracks or deformed links; the rope/chain is laying properly on the drum; limit switches are properly set and functioning properly; hoist brake pads have ≥ 50% of the lining left and operate properly; no unusual noises or binding of the mechanism during	2

operation; the electrical components are not very clean; the hoist system has been tested and exercised regularly.	
Hoist surfaces and coatings have minor defects or corrosion; minimal structural damage with no cracks; couplings are tight and properly aligned; gearbox oil is not tested regularly or minor contaminates or water is noted; some groove wear on drums or sheaves; oil seals have minor leaks; gears are mis-aligned but no major wear or damage to the gears; hoist ropes have no broken strands or evidence of corrosion; hoist chain has moderate corrosion but no cracks or deformed links; limit switches are properly set and functioning properly; hoist brakes pads have ≥ 20 and < 50% of the lining left and operate properly; some unusual noises are noted during operation; the electrical components are not very clean; the hoist system has not been tested and exercised regularly; there are multiple trouble reports on record such as repairs to the electrical controls.	1
There are serious concerns with the condition such as: major corrosion on the critical components, wire rope corrosion or broken strands; corroded or deformed chain links; < 20% of brake pads left; significant lubricating oil contamination; unusual noises or vibrations during operation; and frequent trouble reports.	0

For the intake gate, we can assign a score of 1. The manual mechanism is very corroded but operates as expected.

For the intake valve, similarly, even though is fully manual, we will evaluate it as if it was electric. HydroAMP does not make distinction between electric or hydraulic operated valve.

Table 40: HydroAMP – Intake Valve Operator (Hydraulic or Electric) Physical Condition

Intake Valve Operator (Hydraulic or Electric) Physical Condition	
Results	**Valve condition indicator score**
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are in good condition with replacement parts available; backup power is available and tested regularly; slow-down mode has been tested and verified; pressure differential indicators up/downstream are operational and tested; operational testing performed on an annual basis; the system is exercised regularly.	3
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are updated or in good condition; backup power is available; slow-down mode functions but could use a minor adjustment; pressure differential indicators up/downstream are operational but not calibrated; the system is exercised frequently.	2
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are in fair condition; backup power is not regularly tested; slow-down mode functions but could use a minor adjustment; pressure differential	1

indicators up/downstream are operational but not calibrated. The timed cycle of operation has changed slightly; the system is exercised rarely.	
Seals, stems, cylinders, hydraulic system, gate position indicators, and controls are in poor condition; backup power is not available or not reliable; slow-down mode and limit switches are out of adjustment; pressure differential indicators up/downstream are not functioning; the timed cycle of operation has changed significantly; the system is never exercised.	0

We will assign a score of 1 to the intake valve operator. There is no indication of pressure in both chambers, even though there is a bypass valve in place. The system was exercised during normal operation. Several improvements can be done to the system. The pressure relief valve is different, it is automated, and there are no know issues to it.

3.7.4 Condition Indicator 4 – Operations History

Table 41: HydroAMP – Gates and Valves - Operations History Scoring

Gates and Valves - Operations History Scoring	
Results	**Gate condition indicator score**
Meets original operational criteria, tested as required, no known design and operational deficiencies.	2
System is functional but may not meet all operating criteria. Tests as required have been performed. No known design deficiencies.	1
Does not meet original operational criteria or not tested as required or has a known design and operational deficiency.	0

We will assign a score of 1. Again, the valves and the intake gate work, but several improvements can be made.

3.7.5 Condition Indicator 5 – Maintenance History

Table 42: HydroAMP – Gates and Valves - Maintenance History Scoring

Gates and Valves - Maintenance History Scoring	
Results	**Gate condition indicator score**
Small	2
Moderate	1
Excessive	0

We will assign a score of 2. The systems do not need too much maintenance to properly operate.

3.7.6 Emergency Closure Gates & Valves Condition Summary

Table 43: Emergency Closure Gates & Valves Condition Summary

Tier 1 Emergency Closure Gates & Valves Condition Summary *(For instructions on indicator scoring, please refer to condition assessment guide)*				
No.	**Condition Indicator**	**Score ×**	**Weighting Factor =**	**Total Score**
1	Age *(Score must be 0, 1, 2, or 3)*	1	0.8	0.8
2	Physical Condition – Gates or Valves *(Score must be 0, 1, 2, or 3)*	2	1	2
3	Physical Condition – Operators *(Score must be 0, 1, 2, or 3)*	1	1	1
4	Operations History *(Score must be 0, 1, or 2)*	1	0.4	0.4
5	Maintenance *(Score must be 0, 1, or 2)*	2	0.4	0.8
Tier 1 Emergency Closure System Condition Index (Sum of individual Total Scores) *(Condition Index should be between 0 and 10)*				5

As per HydroAMP recommendations for a Score of 5, Continue operation but reevaluate O & M practices. Schedule Tier 2 assessment within < 4 years.

3.7.7 Emergency Closure System Data Quality Indicator

Table 44: HydroAMP - Emergency Closure System Data Quality Indicator Scoring

Emergency Closure System Data Quality Indicator Scoring	
Years Since Last Condition Assessment	**Data Quality Indicator Score**
< 8 years	10
≥ 8 and < 17 years	7
≥ 17 and < 25 years	4
≥ 25 years	0

The Score selected in this case is 4, even though there are no registers of a past condition assessment done to the system, we assume that at least one should have been done prior to install the new penstock, to guarantee that the water would remain under control during the construction phase.

3.8 HydroAMP Summary Results

We will summarize the results of the evaluation using HydroAMP in a very simple way.

Table 45: HydroAMP Summary Results per system

System	Total Score	Data Quality Indicator
Turbine	0	4
Generator	7.05	7
Circuit Breakers	6.6672	0
Governor	7.34	0
Batteries	10	0
Cranes	8.133	7
Emergency Closure Gates and Valves	5	4

This reflects in numbers what it can be seen as very evident: the plant is in relatively good condition, except for the turbine and its mechanical components that are destroyed.

3.9 Civil Structure General Condition

As part of the condition assessment, we did an overall assessment of the condition of the civil aspects of the plant.

3.9.1 Ground floor level:

From the civil point of view, this floor is in very good condition. Walls, made of concrete blocks, are in very good shape, with no visible cracks. The floor, concrete as well, is in very good condition.

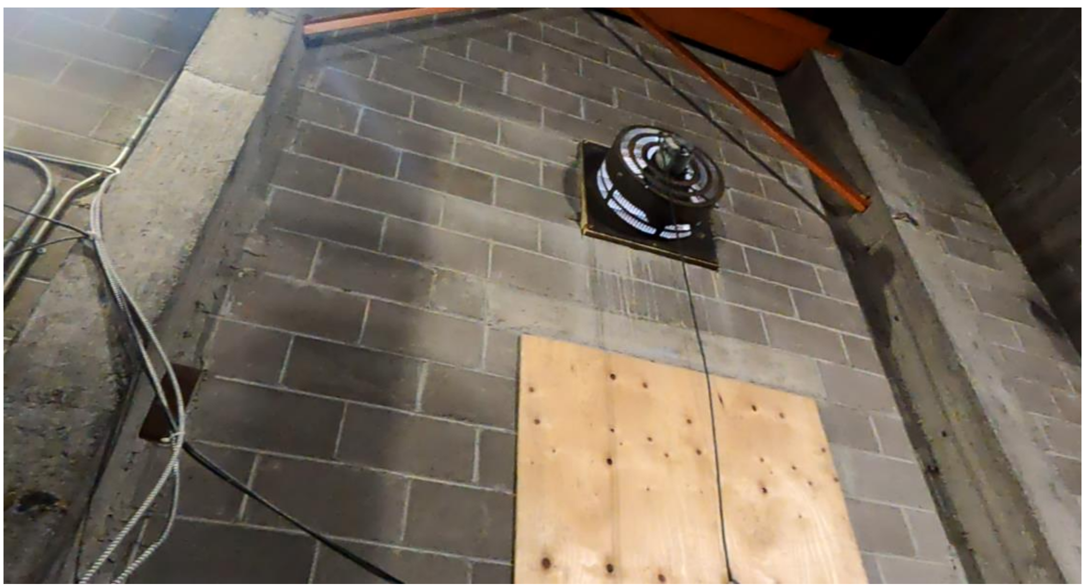


Figure 39: Columns, west side, in very good shape

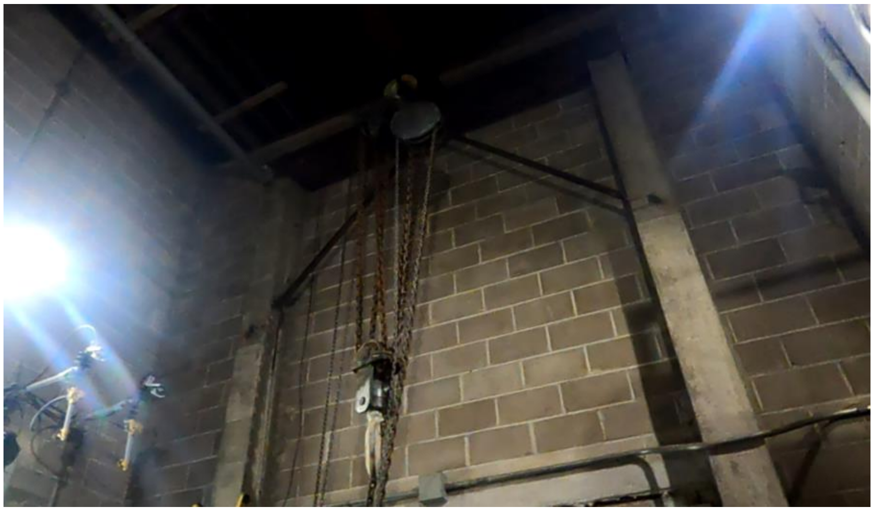


Figure 40: Columns and crane, east side, very good condition

We didn't notice any cracks or damage to the columns on this level.

Now, the crane itself. We noticed that the beams were painted partially at some point, and then the work stopped. We wonder the reason and when this work was initiated. As well, there is a beam welded to the main west support beam that does not hold anything. We wonder why. We have a separate comment on the crane in another section of the report.

Figure 41: Concrete base of the generator

The concrete base of the generator as well is in good shape. Minor wear, expected for many years of service, but nothing that cannot be addressed without major effort. This was in fact checked from the inside of the unit, entering from the turbine floor.

3.9.2 Building annex:

Figure 42: Building annex

This annex was built recently apparently, but we don't have the records of when that was done. Most definitely the construction was performed very professionally, and the design was done by engineers, there must be records. We didn't find issues with the building.

3.9.3 Gravel retainer wall:

Figure 43: Gravel retainer wall

Just below the building annex, a retaining wall is present, which looks like is original from the plant. The only drawing that we had access to does not shown this wall. It has a crack, that has been growing over the years apparently, and basically separated the wall in two.

Figure 44: Crack on the retainer wall

Having said that, this wall is retaining gravel, and the end of the pipe of the pressure relief valve, which is normally empty. We don't think that this an issue at this point, there is no structure linked or attached to this wall. But we will refer this to a structural engineer to look at it. Event with the pipe full of water, the pipe does not maintain the water in place (different case is the penstock), it releases it, so the gravel around it is in fact to stabilize it during an event where water is diverted by the pressure relief valve.

3.9.4 Turbine floor level:

The turbine floor as well doesn't look in bad shape in general, considering the age of the plant (102 years). Most definitively can benefit from additional housekeeping, but it is in general good conditions.

Now we found three cracks on the walls, and one crack in one of the columns. Let's take a look at them.

North wall crack

Figure 45: North wall crack

The crack extends from the entrance door to the east corner. It can be seen from the outside as well, which means that the crack is not superficial. For a plant of this age is not uncommon.

East wall crack

Figure 46: East wall crack

This wall is fully below-grade, we cannot see the other side of the wall to evaluate if goes through the entire section, so we will assume that it goes through. What took our attention is that there is another crack at the upper section on the wall that continues to the south-east column.

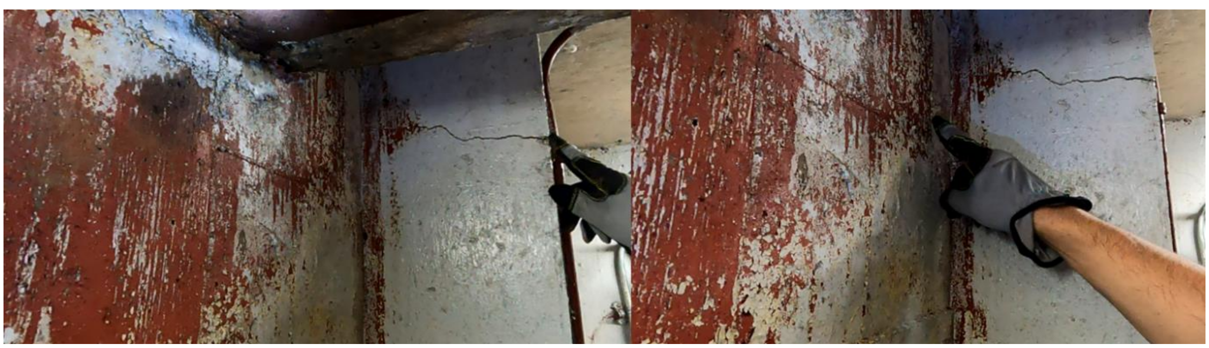


Figure 47: Crack on the east wall, that goes through the south-east column

This crack is the one that makes us to recommend now a full structural engineering analysis of the plant.

South wall crack

This is another crack in a wall that is fully below grade. We cannot see the other side of the wall so we will assume that it goes through the entire section of the wall.

Figure 48: Crack on the South wall

The crack ends close to the penstock. This kind of cracks close to the penstock pipes are not uncommon either.

3.9.5 Draft tube:

Figure 49: Draft tube access hatch

Figure 50: Draft tube exterior, corrosion present, but expected, no damage noticed

Figure 51: Bolts that attach the curb plate/scroll case to the draft tube, nothing out of normal

Figure 52: Areas with concrete and rebar exposed

We noticed that around the draft tube there are areas with rebar and concrete exposed, like if they had fallen at some point on time. But no rest was found in the ground. We think that this was removed during construction, to ease the installation of the draft tube. Because is not attached to the draft tube and there are no loads over that specific area this does not represent a risk.

From the inside, we were able to put the GoPro and reach the bottom of the draft tube, but poor light and the darkness of the water didn't allow us to see if rest of the turbine were at the bottom.

Figure 53: GoPro already under water

Figure 54: Bottom of the penstock. We noticed some algae and debris, expected

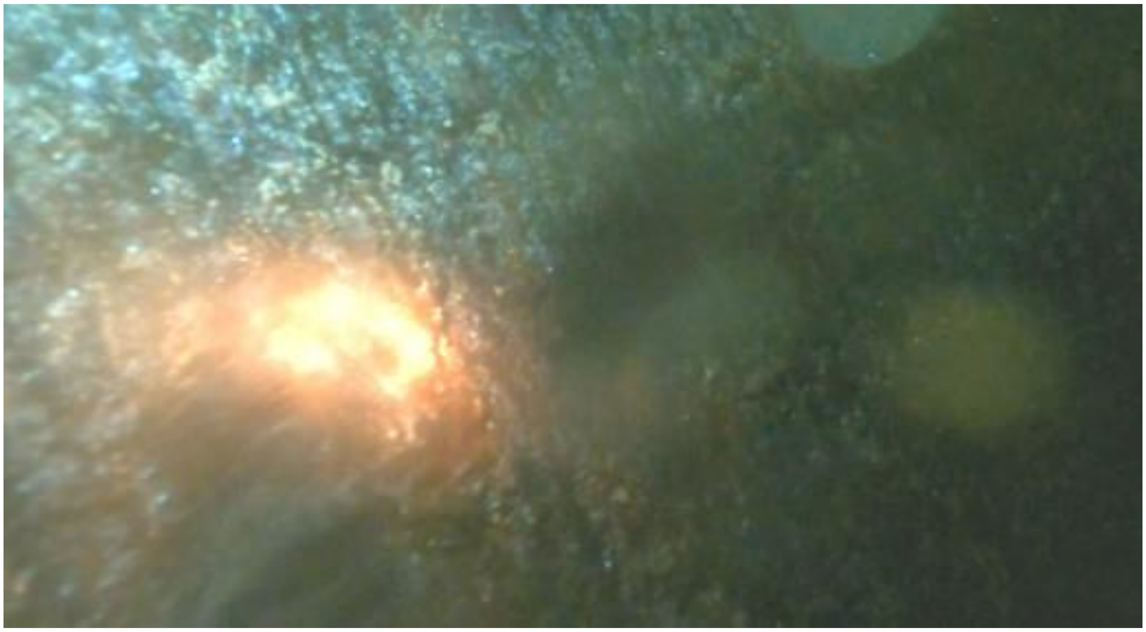


Figure 55: internal walls of the draft tube, we saw the full length and we didn't noticed anything out of normal

3.9.6 Structural engineering observations

To have an even more comprehensive analysis of the civil structure, we hired Pinto Engineering to conduct a high-level structural assessment of the plant. Their findings are in Appendix 2.

Their conclusions were, as stated in their short report:

In summary, deficiencies observed included concrete wall cracking and base slab/foundation undermining. Cause of the cracking cannot be conclusively determined based on the visual site review but may have been initiated by machinery vibrations. A structural analysis is not recommended for the building unless the new machinery is heavier than the current equipment.

The base slab/foundation undermining should be remediated. The extent of the undermining should first be determined so that repair details can be developed. An extension to the discharge tube should also be considered to better direct water flow away from the foundation.

From that point, we will develop recommendations for the future of the plant. It is good news to see that the cracks, being present for many years without change as per recollection from interviews with the personnel at the plant, does not represent a risk at the moment. It is important to note that concrete cracks in walls are common in hydropower plants, especially old plants, and this one is no exception. One very good aspect is that there are no cracks on the floor slabs on the first and second level. The base level was not possible to assess, but its slab is very small, surrounds the draft tube, and apparently doesn't have cracks either.

3.9.7 Dam Inspection

We had the opportunity to do a walkdown on the dam. Some of our observations:

Figure 56: Dam Access points are unsafe

The first observation is that it is not very safe to access the dam itself. From the west side, the stairs are full of debris. And there are a lot of plants and threes that must be cleared to guarantee a proper way to access the area. On the east side, even though the catwalk looks very new, the design forgot to put a step to safely access the crest of the dam. Currently is relatively difficult and increases the chances of slip, trips and falls to access it.

Figure 57: Trash rack

The trash rack is very dirty, and full of debris. Requires cleaning. In a future stage, we would recommend substituting it for a newer non metallic trash rack.

Figure 58: Debris across the dam

There are several dead trees, logs, and debris accumulated in the dam. This must be cleaned properly before conducting a dam safety assessment. As well, lots of brushes cover the east side of the dam, and that should be cleared as well to be able to properly see the concrete on that area.

The rip rap looks recent, and as well the penstock, which is very well designed and shows very good external conditions. We may assume that internal conditions are good as well, but an inspection should be conducted to be able to confirm that.

The rip rap looks recent, and as well the penstock, which is very well designed and shows very good external conditions. We may assume that internal conditions are good as well, but an inspection should be conducted to be able to confirm that.

SECTION 4 - RISK ASSESSMENT

In conducting the risk assessment for the hydroelectric plant, we systematically evaluated the potential risks associated with each major component of the facility. This process involved identifying operational, mechanical, electrical, safety, and environmental risks, and assigning a likelihood and impact rating to each scenario. Given the comprehensive nature of the analysis and the detailed evaluation required, we have decided to include the full risk assessment as an appendix to this report (Appendix X). This approach allows us to keep the main body of the report clear and focused, while still providing the complete analysis for those who wish to review it in detail.

There were two components that were not considered during the risk assessment.

- Civil structure: We will defer that to the structural analysis of the facility. Once that's completed, we can update this assessment.
- Circuit breakers: there is not enough information about the system to conduct a proper risk assessment.
- Transformers: was not part of the scope of work, and we don't have information about them.

To assess each risk, we used a simple evaluation matrix, based on Impact on operations, and Likelihood of occurrence of the risk.

Table 46: Risk evaluation Matrix

	Almost Certain (5)	Likely (4)	Possible (3)	Unlikely (2)	Rare (1)	LIKELIHOOD
Catastrophic (5)	25	20	15	10	5	
Major (4)	20	16	12	8	4	
Moderate (3)	15	12	9	6	3	
Minor (2)	10	8	6	4	2	
Negligible (1)	5	4	3	2	1	
IMPACT						

- **Yellow area: low impact and low likelihood risks, not necessary to put too many resources to mitigate them, but it is important to keep watching them.**
- **Green area: moderate impact and likelihood of occurrence. Monitor the risk, dedicate resources to mitigate them.**
- **Red area: highly likelihood of occurrence and high impact. Highest priority to mitigate.**

Some of the highest priority risks that were identified, and that we think require to be prioritised, are:

Table 47: Some of the highest priority risks identified (table splits between pages)

Risk Number	System	Component	Risk Scenario	Description	Likelihood (1-5)	Impact (1-5)	Risk Level (Likelihood x Impact)	Mitigation Measures
1.1.2	Turbine	Runner	Cavitation-Induced Cracking	Continuous cavitation can lead to stress-induced cracking of the blades, especially near edges or high-stress points	3	5	15	Implement non-destructive testing (NDT) such as dye penetrant or magnetic particle inspection. Repair or replace blades as soon as cracks are detected. Optimize flow conditions to reduce cavitation risk.
1.1.3			Cavitation Erosion Leading to Blade Thinning	Extended exposure to cavitation can cause significant material loss, leading to blade thinning and eventual failure.	3	4	12	Application of erosion-resistant materials. Regular monitoring of blade thickness. Operational changes to reduce cavitation-prone operation.
1.1.8			Pitting Corrosion	Localized corrosion leading to pits on the blade surface, particularly in areas with stagnant water or where debris accumulates.	3	4	12	Focused inspections on areas prone to stagnation or debris accumulation. Use of materials resistant to pitting corrosion. Application of cathodic protection or anodic inhibitors.
1.5.1		Turbine Seal	Maintenance and Reliability: Delayed Maintenance or Inspection	Delayed maintenance or inspection of the turbine seal can result in undetected wear or degradation, increasing the likelihood of sudden failure.	3	5	15	"Implementation of a strict maintenance and inspection schedule, with reminders and tracking. Use of condition monitoring tools to assess the seal's health in real-time and schedule maintenance accordingly. Prioritization of seal maintenance tasks to prevent delays that could lead to failure."
1.6.1		Turbine Assembly	Structural Integrity: Vibration-Induced Damage	Persistent vibrations within the turbine assembly can lead to structural damage, including loosening of bolts or cracking of components.	3	4	12	Continuous vibration monitoring to detect abnormal patterns. Regular tightening and inspection of bolts and other fasteners. Installation of vibration dampers or isolators to reduce the impact of vibrations.
1.6.7			Maintenance and Safety: Inadequate Maintenance Practices	Inadequate or infrequent maintenance of the turbine assembly can lead to undetected wear or damage, increasing the risk of failure.	3	5	15	Implement a rigorous maintenance schedule with detailed checklists. Use of predictive maintenance techniques, such as condition monitoring. Regular training of maintenance personnel to ensure high standards.
1.6.10			Environmental Impact: Oil or Lubricant Leaks	Leaks from the turbine assembly, particularly from bearings or seals, can lead to environmental contamination of the waterway.	3	4	12	Regular inspection and maintenance of seals and lubrication systems. Immediate response and containment procedures for any detected leaks. Use of environmentally friendly lubricants where possible.
1.7.5		Wicket Gates and Wicket Gates Operating Mechanism	Mechanical Integrity: Corrosion of Wicket Gates and Mechanism	Exposure to water and environmental factors can cause corrosion of the wicket gates and their operating mechanism, leading to degradation and potential failure.	3	4	12	Application of anti-corrosion coatings and cathodic protection. Regular inspection and maintenance to identify and address corrosion early. Use of corrosion-resistant materials for wicket gates and associated components.
1.8.1		Scroll Case	Structural Integrity: Cracking Due to Structural Stress	Corrosion due to continuous exposure to water, especially if the water has a high concentration of dissolved salts or is	3	4	12	Regular inspection for signs of corrosion, particularly in areas prone to water stagnation. Application of anti-corrosion coatings or

Risk Number	System	Component	Risk Scenario	Description	Likelihood (1-5)	Impact (1-5)	Risk Level (Likelihood x Impact)	Mitigation Measures
				acidic, can weaken the scroll case and lead to leaks or failure.				cathodic protection systems. Monitoring water chemistry and implementing water treatment if necessary.
2.1.1	Governor System	Governor	Hydraulic Fluid and Pressure System: Hydraulic Leak	Leaks in the hydraulic system can lead to loss of pressure and fluid, impairing the governor's ability to control the turbine speed.	3	5	15	Regular inspection of hydraulic lines, seals, and connections. Immediate repair or replacement of worn or damaged components. Installation of hydraulic fluid level and pressure monitoring systems with alarms.
4.3.1	Intake Valves, Gates and Pressure Relief valve	Pressure relief valve	Operational Performance: Sensor Failure Leading to Incorrect Operation"	The pressure sensors that control the valve may fail, leading to incorrect operation of the pressure relief valve, such as not opening during a pressure surge or opening unnecessarily.	3	5	15	Regular testing and calibration of pressure sensors to ensure accurate readings. Use of redundant sensors to provide backup in case of sensor failure. Continuous monitoring of sensor performance and alarm systems for anomalies.
5.1.23	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Inadequate Maintenance Practices "	Inadequate or infrequent maintenance can lead to undetected wear, insulation degradation, or mechanical failures, increasing the risk of generator failure.	3	5	15	Implementation of a comprehensive maintenance schedule based on the manufacturer's recommendations and industry best practices. Use of predictive maintenance tools, such as vibration analysis and thermography, to detect early signs of issues. Regular training of maintenance personnel to ensure they are aware of the latest techniques and safety protocols.
6.1.4	Cranes	Chain Hoist	Mechanical Integrity: Chain Wear and Tear	Continuous use of the chain hoist can lead to wear and tear on the chain, which may eventually weaken and cause the chain to fail under load.	4	4	16	Regular inspection of the chain for signs of wear, such as elongation, rust, or damaged links. Replace the chain at the first sign of significant wear or according to the manufacturer's recommended schedule. Lubricate the chain regularly to prevent corrosion and reduce friction.

From analyzing the risk assessment, there are a number of recommendations, that will be listed on the Maintenance and Rehabilitation recommendations. But there is one global recommendation: **a proper maintenance program for the entire facility and its assets.**

A detailed maintenance program, with written procedures, a proper registry recording, and study of trends with indicators, will help to keep the operations of the plant not only safe (in fact safer), but as well to help in making decisions over the assets on a more proactive way, rather than a reactive way, saving on costs.

SECTION 5 – OPERATIONS, MAINTENANCE AND REHABILITATION RECOMMENDATIONS

5.1 Operations Recommendations

5.1.1 Immediate Actions

Implement Continuous Monitoring Systems:

Install continuous monitoring systems for critical components such as the turbine, generator, and hydraulic systems. Focus on monitoring vibration, temperature, pressure, and flow rates.

Immediate detection of abnormalities can prevent catastrophic failures and ensure operational safety.

Establish Operational Limits:

Define and enforce strict operational limits based on manufacturer recommendations and the specific conditions observed during the assessment. Ensure that all operators are trained and aware of these limits.

Operating within safe parameters is crucial to avoid conditions that can lead to cavitation, excessive wear, or failure.

Initiate Immediate Inspections:

Conduct thorough inspections of all critical components, particularly those identified as high-risk in the assessments (e.g., turbine seals, generator bearings, and hydraulic systems). Document any findings and address immediate concerns.

Early identification of issues allows for prompt intervention, reducing the risk of unplanned outages or failures.

Emergency Preparedness:

Review and update emergency response procedures, ensuring that all personnel are trained and ready to respond to emergencies. Verify the functionality of all emergency shutdown systems.

Being prepared for emergencies ensures that potential hazards can be managed quickly, minimizing the impact on plant operations and safety.

5.1.2 Short-term Recommendations (1-2 years)

Data Logging and Analysis Implementation:

Implement a robust data logging and analysis system to continuously record operational data. This should include parameters such as load, speed, temperature, pressure, and flow rates.

Analyzing trends over time will enable predictive maintenance and help in optimizing operations for better efficiency and reliability.

Operational Training Programs:

Develop and deliver comprehensive training programs for all operational staff, focusing on best practices, safety protocols, and the latest technology used in the plant.

Well-trained personnel are essential for maintaining safe and efficient operations. Continuous education ensures that staff can adapt to new systems and technologies.

Operational Optimization Studies:

Conduct studies to optimize plant operations, focusing on improving efficiency and reducing operational costs. This could include revisiting turbine settings, flow management, and energy consumption strategies.

Optimization studies can identify opportunities to enhance efficiency, reduce wear on equipment, and lower operational costs.

Remote Monitoring Capabilities:

Begin upgrading systems to include remote monitoring capabilities, particularly for key components like the governor and hydraulic systems. This may involve installing new sensors and integrating them with a central monitoring platform.

Remote monitoring allows for real-time analysis and quick decision-making, improving overall plant management.

5.1.3 Long-term Recommendations (5-10 years)

Full Automation of Key Systems:

Gradually transition key operational systems to full automation. This should include the automation of the governor, hydraulic systems, and safety shutdown mechanisms.

Automation reduces human error, increases reliability, and allows for more precise control of plant operations.

Modernization of Control Systems:

Plan and execute the modernization of the plant's control systems, focusing on upgrading to state-of-the-art digital control technology. Ensure integration with predictive maintenance tools and advanced monitoring systems.

Modern control systems provide enhanced capabilities for monitoring, control, and optimization, extending the life of plant assets and improving operational efficiency.

Periodic Operational Review and Updates:

Establish a periodic review process (every 5 years) to assess and update operational procedures and technologies. This should include reassessment of operational limits, safety protocols, and efficiency targets.

Regular updates ensure that operations stay aligned with technological advancements and evolving industry standards.

5.2 Maintenance Recommendations

5.2.1 Immediate Actions

Urgent Inspections and Repairs:

Install a new inspection platform on the draft tube chamber.

Immediate intervention is necessary to properly understand the scope of work of a full refurbishment, even if it is a complete new unit or a like-for-like replace/repair.

Implementation of a Preventive Maintenance Schedule:

Establish and implement a comprehensive preventive maintenance schedule. This should include routine inspections, lubrication, cleaning, and testing of all critical components, based on manufacturer guidelines and the plant's specific needs.

Regular maintenance is essential for extending the life of equipment, reducing downtime, and avoiding unexpected failures.

Critical Spare Parts Inventory Review:

Review and update the inventory of critical spare parts, ensuring that all necessary components, especially those prone to wear and tear, are readily available. This includes seals, bearing components, and hydraulic components.

Having a well-stocked inventory minimizes downtime in case of failures and allows for quicker repairs.

Immediate Training on Maintenance Protocols:

Conduct immediate training sessions for maintenance personnel, focusing on updated maintenance protocols, safety procedures, and the specific requirements of the plant's critical components.

Ensuring that all maintenance staff are knowledgeable about the latest protocols and safety measures is crucial for effective and safe maintenance operations.

5.2.2 Short-term Recommendations (1-2 years)

Predictive Maintenance Tools Deployment:

Deploy predictive maintenance tools such as vibration analysis, thermography, and non-destructive testing (NDT) to anticipate and address potential issues before they lead to failures. Focus on critical areas like the turbine, generator, and bearings.

Predictive maintenance allows for early detection of issues, reducing the likelihood of unexpected failures and optimizing maintenance schedules.

Comprehensive Overhaul of Key Components:

Schedule comprehensive overhauls for key components identified as high-risk, such as the turbine runner, generator, and hydraulic systems. This may include rebalancing, re-lubrication, and replacement of worn parts.

Regular overhauls are necessary to restore equipment to optimal condition, extend lifespan, and prevent future failures.

Enhancement of Maintenance Documentation and Record-Keeping:

Improve the documentation and record-keeping of all maintenance activities. Implement a digital maintenance management system to track inspections, repairs, and part replacements.

Detailed records are essential for tracking equipment history, identifying recurring issues, and planning future maintenance.

Routine Condition Monitoring Program:

Establish a routine condition monitoring program that includes regular checks of operating parameters such as vibration, temperature, pressure, and lubrication levels.

Ongoing condition monitoring helps in identifying trends that could indicate potential issues, allowing for proactive maintenance.

Supplier and Contractor Review:

Review and evaluate the performance of current suppliers and contractors, ensuring that they provide high-quality parts and services. Establish long-term relationships with reliable vendors.

Reliable suppliers and contractors are key to ensuring that maintenance activities are carried out effectively and that high-quality parts are used.

5.2.3 Long-term Recommendations (5-10 years)

Lifecycle Analysis and Replacement Planning:

Conduct a lifecycle analysis of all major components and develop a long-term replacement plan. This should include budgeting and scheduling for the replacement of components nearing the end of their operational life.

Proactively planning for component replacement ensures that the plant remains operational without the risk of unexpected breakdowns.

Advanced Maintenance Training Programs:

Develop and implement advanced training programs for maintenance personnel, focusing on new technologies, advanced diagnostic tools, and best practices in maintenance.

Continuous education and skill development for maintenance staff will keep them up-to-date with the latest maintenance technologies and techniques, improving the overall effectiveness of maintenance operations.

Periodic Overhauls and Upgrades:

Plan for periodic overhauls and upgrades of critical systems, including the turbine, generator, and control systems, based on operational data and condition assessments.

Regular overhauls and upgrades help maintain efficiency, extend the life of the plant's assets, and reduce the risk of major failures.

Maintenance Process Optimization:

Review and optimize maintenance processes regularly, using data analytics to identify inefficiencies and areas for improvement. Consider adopting lean maintenance practices to minimize waste and downtime.

Continuous process improvement ensures that maintenance activities are as efficient and effective as possible, reducing costs and improving equipment reliability.

Sustainability and Environmental Compliance:

Integrate sustainability and environmental compliance into maintenance practices, including the use of eco-friendly lubricants and proper disposal of hazardous materials.

Ensuring that maintenance practices align with environmental regulations and sustainability goals helps the plant operate responsibly and avoid potential fines or penalties.

5.3 Rehabilitation and Upgrade Recommendations

5.3.1 Immediate Actions

Complete Turbine Replacement:

Given that the turbine is described as "completely destroyed," an immediate and complete replacement of the turbine is required. This includes the turbine runner, blades, seals, and any associated components that have suffered irreversible damage.

The turbine is the core of the hydroelectric plant. A compromised turbine cannot be repaired to a reliable state and must be replaced to restore the plant's operational capacity.

Inspection and Reinforcement of Structural Components:

Conduct a detailed inspection of all structural components related to the turbine, including the scroll case, draft tube, and foundation. Reinforce or replace any components showing signs of severe corrosion, cracking, or other structural weaknesses. The civil structural analysis will help to understand the structural soundness of the plant, but NDE for the scroll case, draft tube and the curb plate will help to get a proper understanding of the condition of those items. A full disassembly, and the sandblast of the items may be necessary, it is important to notice that for time and cost estimates. This should be and will be included in the costed option analysis.

Structural integrity is crucial for the safe operation of the new turbine. Any weaknesses must be addressed to prevent further damage or failure.

5.3.2 Short-term Recommendations (1-2 years)

Upgrade Control and Automation Systems:

Following the turbine replacement, upgrade the control systems to include modern digital controls, remote monitoring, and automated safety shutdowns. Integrate these systems with the new turbine for optimal performance.

Modern control systems will improve the operational efficiency, safety, and reliability of the plant, ensuring that the new turbine operates within safe parameters. The current control system, even though it was installed in 2020 and tested in 2023, it is in fact already outdated, and miss several capabilities, especially remote control.

5.3.3 Long-term Recommendations (5-10 years)

Periodic Overhaul and Upgrades of Plant Equipment:

Plan for periodic overhauls of the new turbine, generator, and associated systems every 5-10 years. This should include comprehensive inspections, non-destructive testing, and the replacement of any components showing wear.

Regular overhauls ensure that the plant remains in optimal condition, preventing long-term degradation and extending the lifespan of the equipment.

Capacity Expansion and Efficiency Improvements:

Explore opportunities for capacity expansion, such as upgrading to higher-efficiency turbines or adding additional units. Also, consider installing energy storage systems to optimize energy production and distribution.

Expanding capacity and improving efficiency will help the plant meet future energy demands and regulatory requirements, while also increasing revenue potential.

Comprehensive Plant Modernization:

Plan for a comprehensive modernization of the plant, including potential automation of manual processes, upgrading of safety systems, and integration of advanced analytics for predictive maintenance.

Modernization will keep the plant competitive in a rapidly evolving energy market, ensuring that it remains efficient, safe, and profitable.

SECTION 6 – COSTED OPTION ANALYSIS

During the definition of the scope of work for this project, we identified three major phases and three paths that the project could follow.

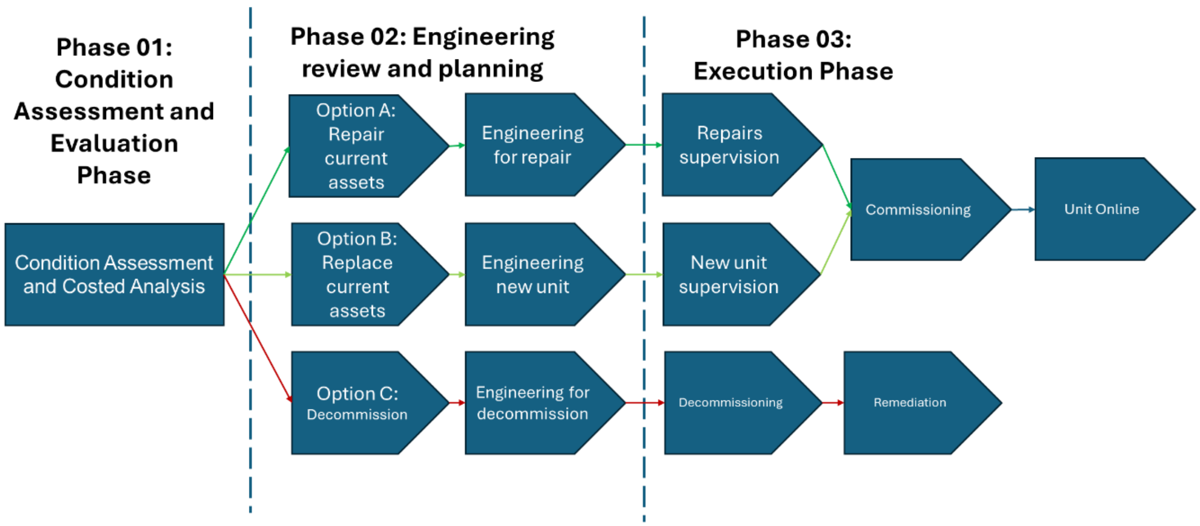


Figure 59: Project phases and options

The three options are:

- **Option A - Repair current assets:** This option, after the condition assessment performed, is more a like-for-like replacement than a full repair. The main mechanical parts of the unit are totally destroyed, and the rest are in such poor condition that it is not worth to repair. The energy output and efficiency are expected to be the same, the generator is not aimed to be replaced.
- **Option B - Replace Current assets:** this option presents the opportunity to fully replace the entire existing electromechanical assets, including the generator, switchgear, governor system, etc. with a full Water-to-Wire solution, that increases the efficiency and the energy output of the plant.
- **Option C – Decommission:** this option comprises the full decommissioning of the powerhouse, and by consequence the decommissioning of the dams, because there will be no need of them without a powerhouse. This is the most technically challenging option of all three.

6.1 Methodology

To obtain costs references for the three options, we went to the market and ask for quotes, as well as run short cost research to determine decommissioning costs of dams based on size.

We consulted three OEMs to get us quotes for repairs/like for like replacements and brand-new units. Those OEMS are Norcan Hydro, Canyon Hydro and Dive Turbines, all of them specialized in small hydro units.

For options A and B we used RETScreen Expert, to perform energy and financial models that allow the Berwick Electric Commission to take a decision on which path to follow. For option C we did a research to determine the cost per cubic meter of volume of dams to be decommissioned.

6.1.1 RETScreen Hydropower feasibility tool

The RETScreen Expert software, developed by Natural Resources Canada, has an excellent tool that helps to perform feasibility studies for different power generation technologies, including hydropower. There are several inputs that are necessary for the module to give an accurate result. The level of detail that we will use for our analyses will be Level 2, the one with more detail.

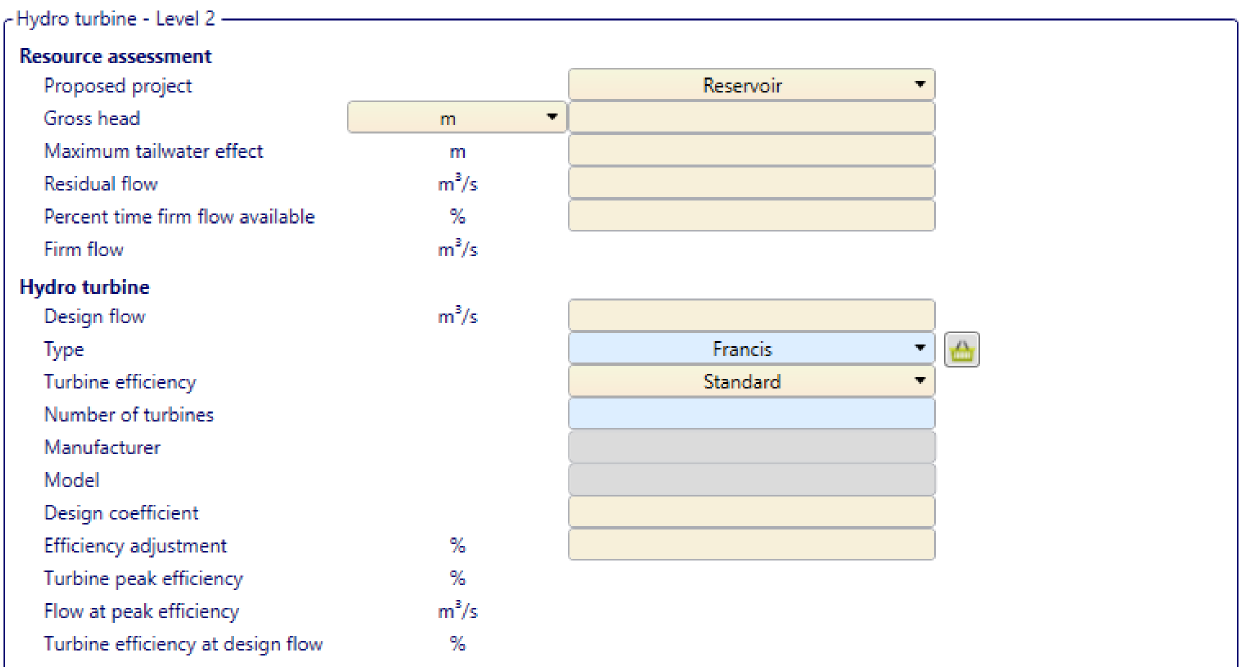


Figure 60: Main set of values for the hydropower feasibility module

The first two sets of values are the Resource Assessment and the Hydro Turbine itself.

The resource assessment values, are related to the water availability:

- Proposed project: in this case, is a reservoir
- Gross Head: is the drop in elevation at the site
- Maximum tailwater effect: the maximum reduction in available gross head that will occur during times of high flows in the river.
- Residual flow: also known as ecological flow. Is the flow that must be left in the river throughout the year for environmental reasons. The residual flow is deducted from the available flow as part of the calculation of available energy.
- Firm flow: The model calculates the firm flow that will be available for electricity production based on the flow-duration curve data (entered later), the percentage of time

the firm flow should be available and the residual flow. The firm flow is often defined as the flow available at least 95% of the time.

The hydro turbine values are related to technical specifications of the proposed turbine:

- Design flow: The user enters the design flow, which is defined as the maximum flow that can be used by the turbine(s). The selection of the design flow depends, primarily, on the available flow (hydrology) at the site. For central-grid connected run-of-river projects the optimum design flow is usually close to the flow that is equalled or exceeded about 30% of the time. For isolated-grid and off-grid applications, the flow required to meet the peak load may be the deciding factor for selecting the design flow, provided that this flow is available.
- Type: is the type of turbine, in this case will be a Francis turbine.
- Turbine Efficiency: normally the standard efficiency is selected unless a specific efficiency curve is available.
- Manufacturer and Model: identification information only.
- Design Coefficient: it is an internal value to evaluate the quality of the manufacturing for the turbine.
- Efficiency adjustment: The turbine efficiency adjustment can be varied as part of a sensitivity analysis to determine the effect of possible differences in turbine efficiency and to make adjustments to the calculated turbine efficiency curve, if required.

The second set of values are related to the flow duration and turbine efficiency curve data

Flow-duration and turbine efficiency curve data

%	Flow m³/s	Turbine efficiency	Number of turbines	Combined efficiency
0%		0.00		
5%		0.00		
10%		0.00		
15%		0.00		
20%		0.00		
25%		0.00		
30%		0.00		
35%		0.00		
40%		0.00		
45%		0.00		
50%		0.00		
55%		0.00		
60%		0.00		
65%		0.00		
70%		0.00		
75%		0.00		
80%		0.00		
85%		0.00		
90%		0.00		
95%		0.00		
100%		0.00		

Figure 61: Flow duration and efficiency curve data

Here, we establish what percentage of the time how much flow goes through the pipe (or the river, in case of a run-of-the-river unit), and then with the efficiency data for the turbine, a curve is generated.

Unfortunately, for the Factorydale reservoir, we don't have a hydrology study or historical records that allows us to build an accurate flow duration curve. So, we did an extrapolation, using hydrologic data from the Kelley River (Mill Creek) at Eight Mile Ford as a base.

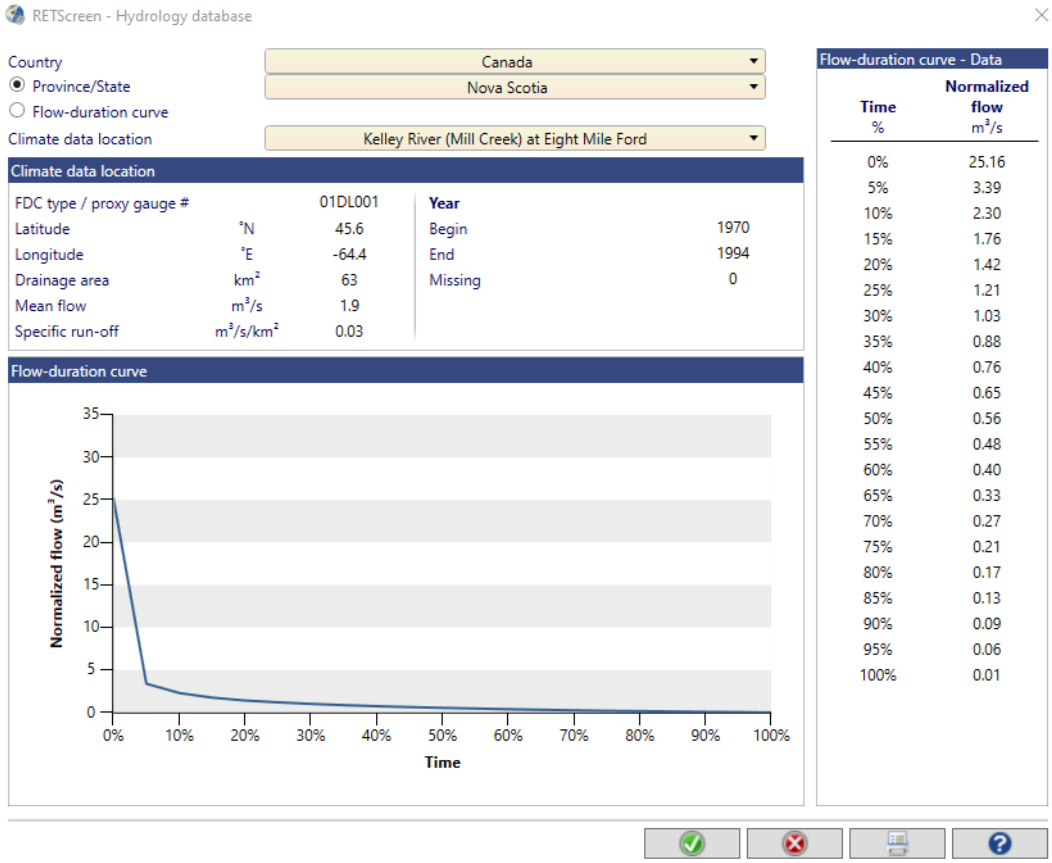


Figure 62: Hydrology data used as a base

We first established a flow of 3.39 m3/s as a design flow (120 cfs) assuming that will work 70% of the time.

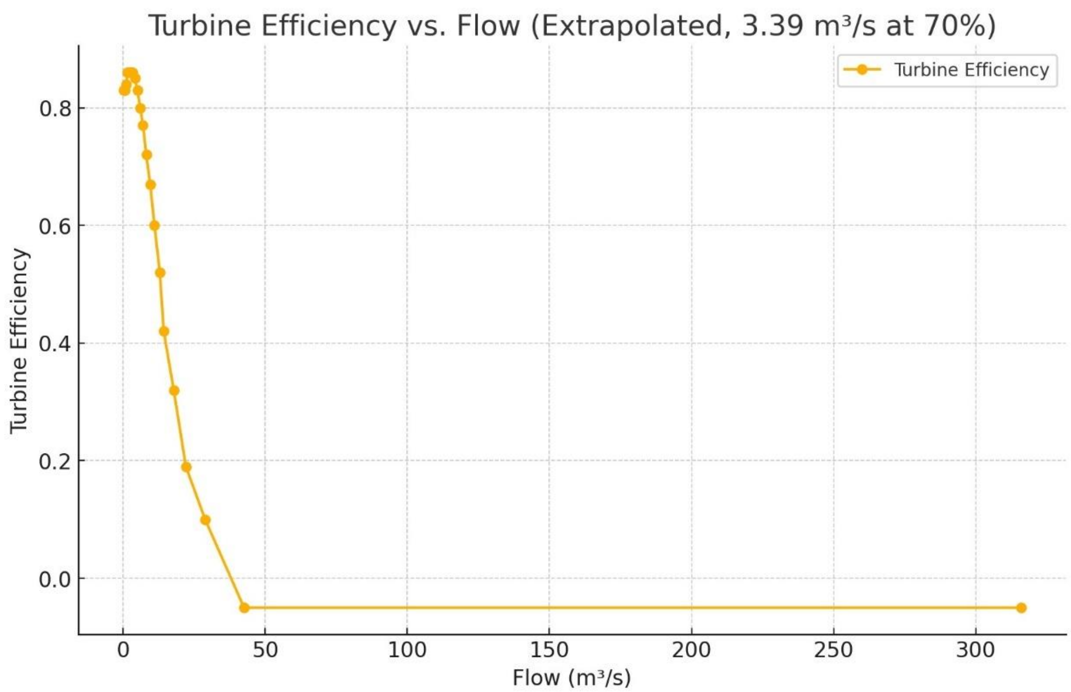


Figure 63: Extrapolated data, assuming 3.39 m3/s at 70% of the time

And then, we did the same, but assuming that the flow will be present 80% of the time

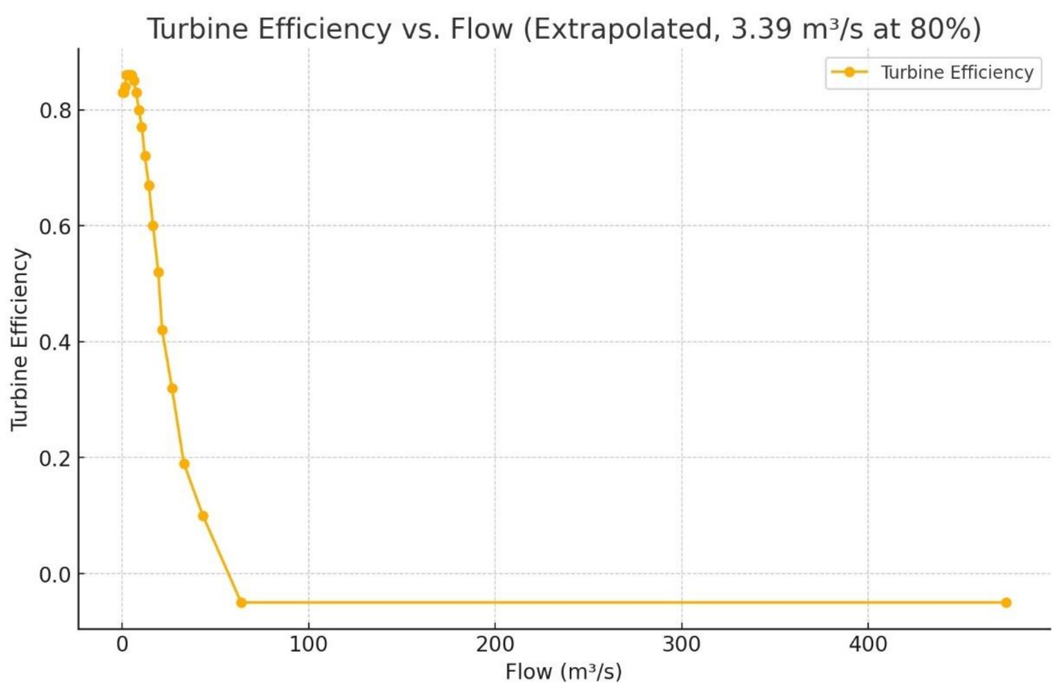


Figure 64: Extrapolated data, assuming 3.39 m3/s at 70% of the time

Additional data that goes into the model are the losses and the final summary.

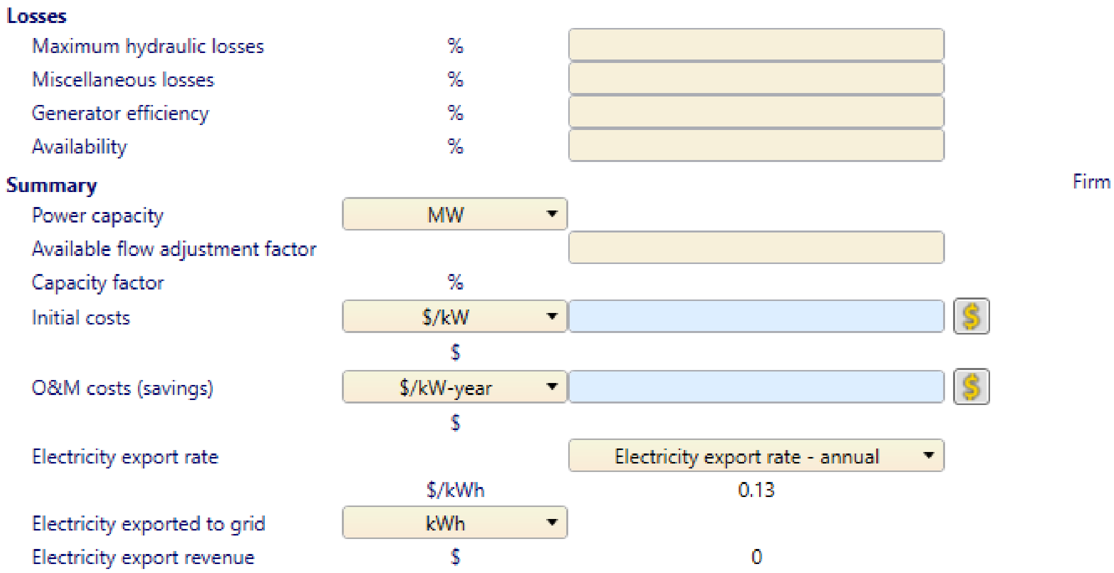


Figure 65: Additional values that go into the model

Regarding Loses:

- Maximum Hydraulic loses: The user enters a value that represents the estimated equivalent hydraulic losses (%) in the water passages. In a hydro plant, energy is lost as water flows through the water passages.
- Miscellaneous Losses: This value accounts for transformer losses, parasitic electricity losses, etc.
- Generator efficiency: is the efficiency of the generator
- Availability: Downtime losses are a result of scheduled maintenance, hydro turbine failures, station outage and utility outage.

Regarding the Summary, one value is the important one here, the available flow adjustment factor. The user enters the available flow adjustment factor which provides the user with a means to adjust the capacity factor, the electricity exported to the grid and is provided primarily for purpose of conducting sensitivity analyses. Using this adjustment factor, the user can easily check the effect of changes in these values on the project's financial viability. The available flow adjustment factor is applied to each value in the flow-duration curve table above during the calculation of the capacity factor, the electricity exported to the grid (e.g. a value of 1.1 increases each value in the flow-duration curve by 10%). Note that the available flow adjustment factor does not change the values in the flow-duration curve.

We built then, individual energy and financial models for the option A and B, based on the quotes received by the OEMs. On separate documents, available in the shared folder with the BEC, financial sensitivity risk analyses are available, for all cases.

6.1.2 Civil decommissioning cost estimate

Determining these costs was quite an interesting challenge, because it is not something that is common practice to do. Big contractors require a lot of information that is not readily available for them at the moment. So we took a different approach. We asked for the help of the folks from Singularity Process Engineering, to run a query through different cost databases and information databases:

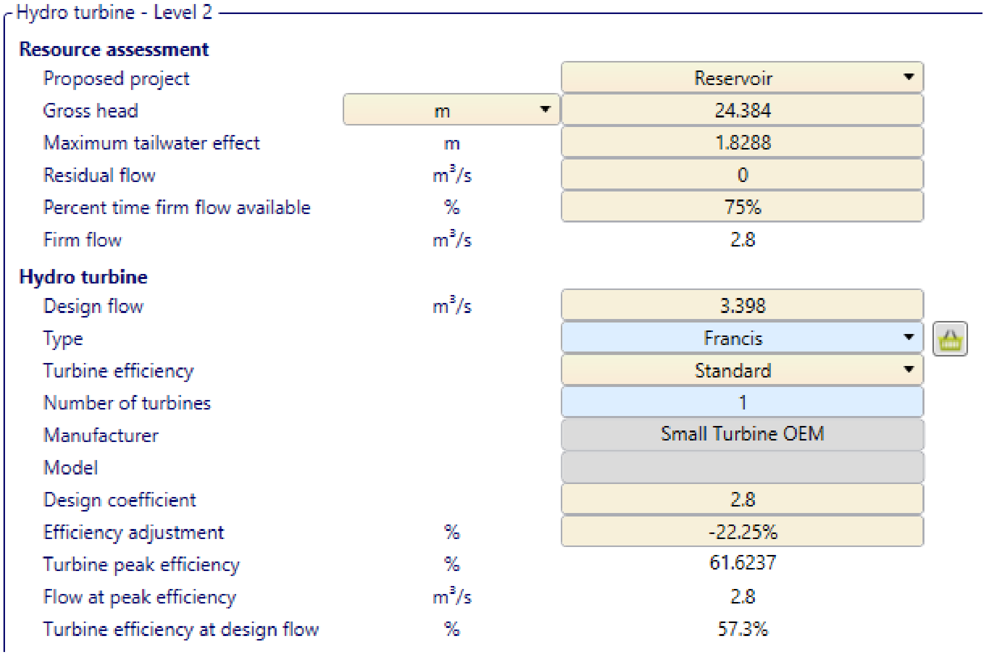
- RSMeans. (2024). RSMeans Construction Cost Data, Chapter 7, Section 5. RSMeans. Available at: https://www.rsmeans.com/
- U.S. Environmental Protection Agency. (2000). A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, Chapter 3, Section 4. EPA 540-R-00-002. Available at: https://www.epa.gov/superfund/superfund-cost-estimating-guidance
- Project Management Institute. (2021). PMBOK® Guide – Seventh Edition, Chapter 11. PMI. Available at: https://www.pmi.org/
- Engineers Canada. (2021). Canadian Infrastructure Report Card, Chapter 6. Engineers Canada. Available at: https://www.engineerscanada.ca/publications/canadian-infrastructure-report-card

They use a proprietary artificial intelligence language model to be able to run searches for specific information on large databases. This allowed them to do a global calculation of the costs, based on the volume of the dam. We will show the results when we analyze the Option C.

6.2 Individual option analyses

6.2.1 Option A – Like for Like replacement

For this case, we will opt to enter the following parameters into RETScreen, as the Resource Assessment and Hydro Turbine specs.



Hydro turbine - Level 2

Resource assessment		
Proposed project		Reservoir
Gross head	m	24.384
Maximum tailwater effect	m	1.8288
Residual flow	m^3/s	0
Percent time firm flow available	%	75%
Firm flow	m^3/s	2.8
Hydro turbine		
Design flow	m^3/s	3.398
Type		Francis
Turbine efficiency		Standard
Number of turbines		1
Manufacturer		Small Turbine OEM
Model		
Design coefficient		2.8
Efficiency adjustment	%	-22.25%
Turbine peak efficiency	%	61.6237
Flow at peak efficiency	m^3/s	2.8
Turbine efficiency at design flow	%	57.3%

Figure 66: Resource Assessment and Hydro Turbine parameters for Like for Like option

As well, we will assume that 70% of the time, the flow of 3.39 m3/s (120 cfs) is available, so the flow duration and turbine efficiency curve data is as follows:

Flow-duration and turbine efficiency curve data

%	Flow m^3/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	315.90	-0.23	0	0.00
5%	42.56	-0.23	1	-0.23
10%	28.88	-0.23	1	-0.23
15%	22.10	-0.19	1	-0.19
20%	17.83	-0.12	1	-0.12
25%	14.31	-0.04	1	-0.04
30%	12.93	0.03	1	0.03
35%	11.05	0.10	1	0.10
40%	9.54	0.17	1	0.17
45%	8.16	0.24	1	0.24
50%	7.03	0.30	1	0.30
55%	6.03	0.36	1	0.36
60%	5.02	0.42	1	0.42
65%	4.14	0.47	1	0.47
70%	3.39	0.52	1	0.52
75%	2.76	0.56	1	0.56
80%	2.26	0.60	1	0.60
85%	1.63	0.61	1	0.61
90%	1.00	0.61	1	0.61
95%	0.75	0.59	1	0.59
100%	0.13	0.57	1	0.57

Figure 67: Flow duration and turbine efficiency curve data assuming 3.39 m3/s at 70% of the time

Now, we know that the maximum output of the current generator is 416 kW, understanding that it is a 520 kVA generator with a power factor of 0.8. A like-for-like replacement will allow the generator to work at peak performance, but no more. That's why our model is configured to produce a unit with a maximum output of 416 kW.

The energy output is the same on each case, 2,647 MWh, at a maximum output. The capacity factor of the plant as well is the same, 72.6%.

Losses			
Maximum hydraulic losses	%	5%	
Miscellaneous losses	%	1%	
Generator efficiency	%	95%	
Availability	%	90%	
Summary			Firm
Power capacity	kW	416	364
Available flow adjustment factor		1	
Capacity factor	%	72.6%	
Initial costs	$/kW		
	$		
O&M costs (savings)	$/kW-year		
	$		
Electricity export rate		Electricity export rate - annual	
	$/kWh	0.13	
Electricity exported to grid	MWh	2,647	
Electricity export revenue	$	347,072	

Figure 68: Like for Like energy production

We received two quotes for a Like-for-Like replacement:

- Norcan Hydro: 2,150,000 CAD +/- 15%, less assume the +15% = 2,472,500 CAD
- Canyon Hydro: 930,000 USD +/- 50%... less assume the +50% and an exchange rate of $1.4 CAD/USD = $1,953,000 CAD.

Let's build then financial models for both cases. Let's as well clarify what it is not included:

- Accurate removal costs
- Engineering costs for the Owner's Engineer team
- Shipping costs
- There is no government aid on these scenarios, because we are not increasing the output.
- Insurance funds are unknown to us at the moment, so we will assume that they are part of the equity that the BEC needs to put on the project.

As well, it is important to note that the efficiency curves and the flow duration and power curves will be the same independently of the manufacturer.

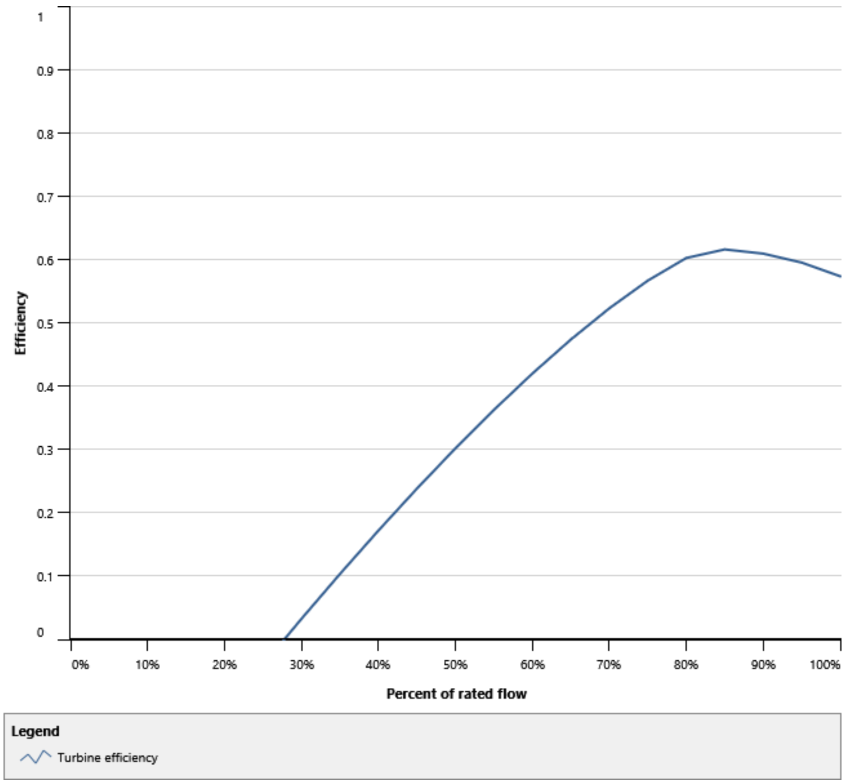


Figure 69: Turbine Efficiency - Like for Like option

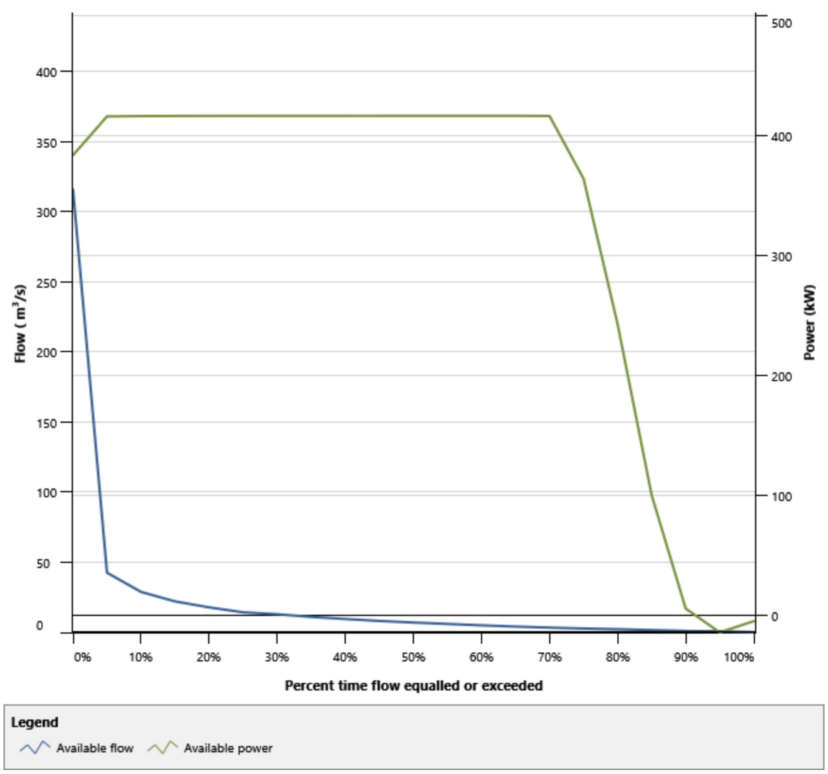


Figure 70: Like for Like Flow-duration and power curves

As well, the emissions reduction from using this energy instead of Nova Scotia's grid is the same in both cases:

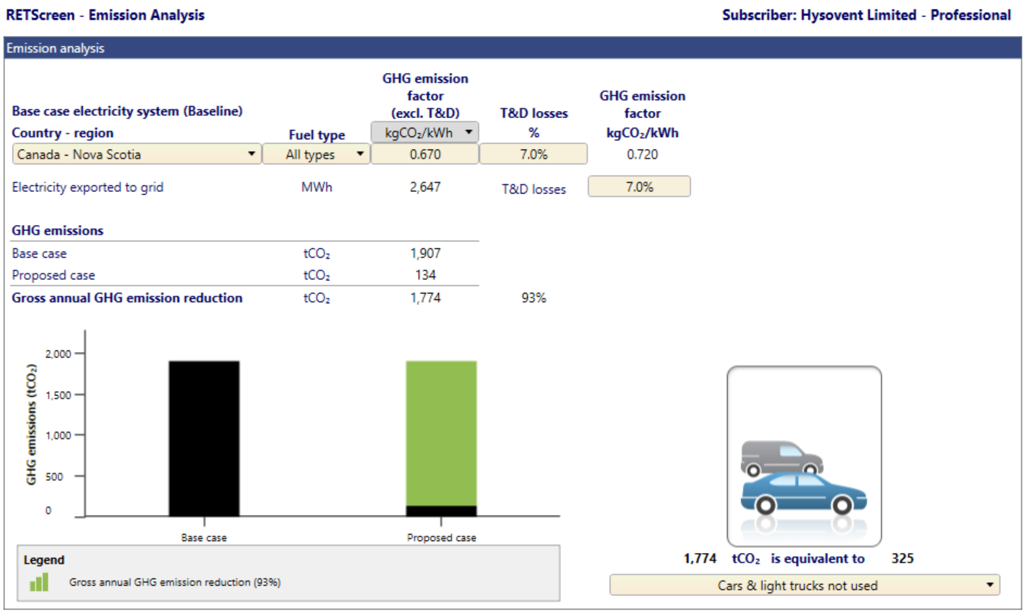


Figure 71: Emissions analysis - Like for Like option

NORCAN Option = 2,472,500 CAD

These are the summary results from the model:

Losses				
Maximum hydraulic losses	%	5%		
Miscellaneous losses	%	1%		
Generator efficiency	%	95%		
Availability	%	90%		
Summary				Firm
Power capacity	kW	416		364
Available flow adjustment factor		1		
Capacity factor	%	72.6%		
Initial costs	$	2,472,500	$	
O&M costs (savings)	$/kW-year	181	$	
	$	75,356		
Electricity export rate		Electricity export rate - annual		
	$/kWh	0.13		
Electricity exported to grid	MWh	2,647		
Electricity export revenue	$	347,072		

Figure 72: Summary Results - NORCAN Option

The financial Analysis is as follows:

RETScreen - Financial Analysis

Financial parameters		
General		
Fuel cost escalation rate		2%
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	50
Finance		
Incentives and grants	$	0
Debt ratio	%	50%
Debt	$	1,236,250
Equity	$	1,236,250
Debt interest rate	%	8%
Debt term	yr	20
Debt payments	$/yr	125,915
Income tax analysis		☐

Costs | Savings | Revenue			
Initial costs			
Initial cost	100%	$	2,472,500
Total initial costs	**100%**	**$**	**2,472,500**
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		$	75,356
Debt payments - 20 yrs		$	125,915
Total annual costs		**$**	**201,271**
Annual savings and revenue			
Electricity export revenue		$	347,072
GHG reduction savings		$	0
CE production revenue		$	0
Total annual savings and revenue		**$**	**347,072**
Net yearly cash flow - Year 1		**$**	**145,801**

Annual savings and revenue		
Electricity export revenue		
Electricity exported to grid	MWh	2,647
Electricity export rate	$/MWh	131
Electricity export revenue	$	347,072
Electricity export escalation rate	%	2%
GHG reduction savings		
Gross GHG reduction	tCO_2/yr	1,774
Gross GHG reduction - 50 yrs	tCO_2	88,687
GHG reduction savings	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Financial viability		
Pre-tax IRR - equity	%	15.9%
Pre-tax MIRR - equity	%	10.7%
Pre-tax IRR - assets	%	9.5%
Pre-tax MIRR - assets	%	9.2%
Simple payback	yr	9.1
Equity payback	yr	7.3
Net Present Value (NPV)	$	1,430,302
Annual life cycle savings	$/yr	130,482
Benefit-Cost (B-C) ratio		2.2
Debt service coverage		2.2
GHG reduction cost	$/$tCO_2$	-69.10
Energy production cost	$/kWh	0.119

Figure 73: Financial Analysis - Like for Like NORCAN Option

We are assuming that the BEC will borrow through a private lender 50% of the cost of the project, at 8%, with a 20 year loan, as well as an escalation rate for the electricity rates equal to the inflation, 2%.

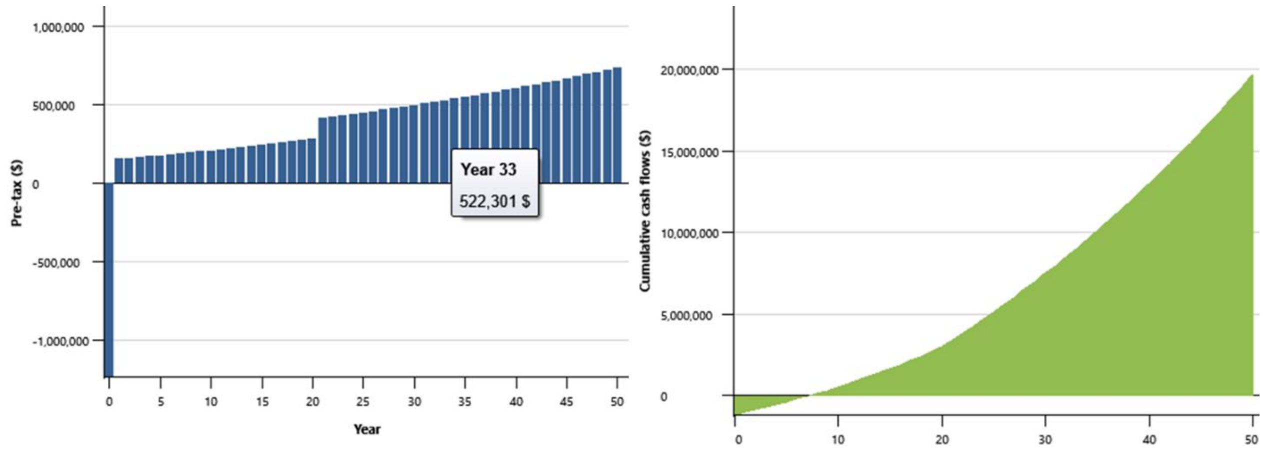


Figure 74: Yearly Cash Flows - NORCAN Option

The ROI on the project is 9.1 years.

CANYON Hydro Option = $1,953,000 CAD

These are the summary results of the model:

Losses			
Maximum hydraulic losses	%	5%	
Miscellaneous losses	%	1%	
Generator efficiency	%	95%	
Availability	%	90%	
Summary			Firm
Power capacity	kW	416	364
Available flow adjustment factor		1	
Capacity factor	%	72.6%	
Initial costs	$	1,953,000	
O&M costs (savings)	$/kW-year	181	
	$	75,356	
Electricity export rate		Electricity export rate - annual	
	$/kWh	0.13	
Electricity exported to grid	MWh	2,647	
Electricity export revenue	$	347,072	

Figure 75: Summary Results - CANYON Option

RETScreen - Financial Analysis

Financial parameters		
General		
Fuel cost escalation rate		2%
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	50
Finance		
Incentives and grants	$	0
Debt ratio	%	50%
Debt	$	976,500
Equity	$	976,500
Debt interest rate	%	8%
Debt term	yr	20
Debt payments	$/yr	99,459
Income tax analysis		☐

Costs | Savings | Revenue			
Initial costs			
Initial cost	100%	$	1,953,000
Total initial costs	**100%**	**$**	**1,953,000**
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		$	75,356
Debt payments - 20 yrs		$	99,459
Total annual costs		**$**	**174,815**
Annual savings and revenue			
Electricity export revenue		$	347,072
GHG reduction savings		$	0
CE production revenue		$	0
Total annual savings and revenue		**$**	**347,072**
Net yearly cash flow - Year 1		**$**	**172,257**

Annual savings and revenue		
Electricity export revenue		
Electricity exported to grid	MWh	2,647
Electricity export rate	$/MWh	131
Electricity export revenue	$	347,072
Electricity export escalation rate	%	2%
GHG reduction savings		
Gross GHG reduction	tCO_2/yr	1,774
Gross GHG reduction - 50 yrs	tCO_2	88,687
GHG reduction savings	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Financial viability		
Pre-tax IRR - equity	%	21.3%
Pre-tax MIRR - equity	%	11.4%
Pre-tax IRR - assets	%	12.2%
Pre-tax MIRR - assets	%	9.9%
Simple payback	yr	7.2
Equity payback	yr	5.2
Net Present Value (NPV)	$	1,931,558
Annual life cycle savings	$/yr	176,210
Benefit-Cost (B-C) ratio		3
Debt service coverage		2.8
GHG reduction cost	$/$tCO_2$	-95.82
Energy production cost	$/kWh	0.101

Figure 76: Financial Analysis - Like for Like CANYON Option

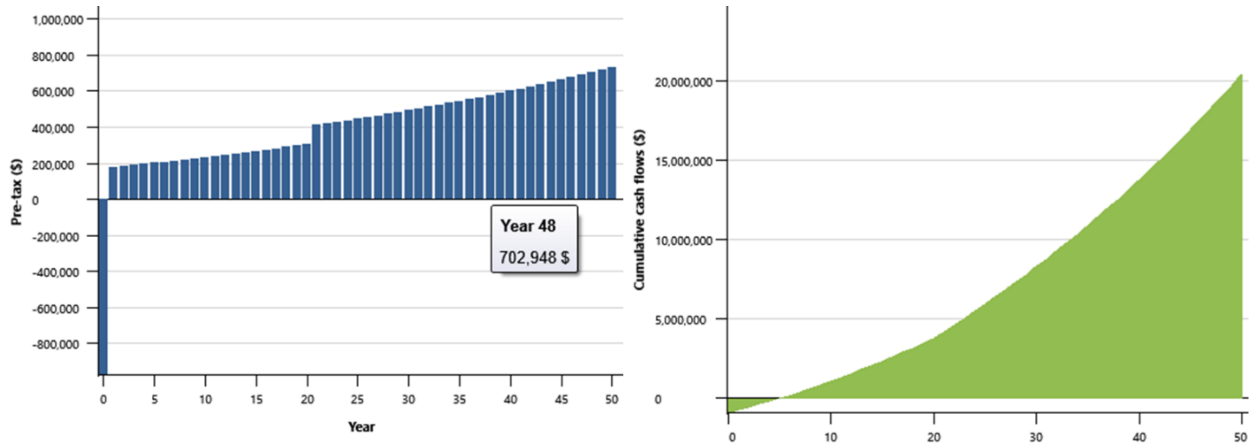


Figure 77: Yearly Cash Flows - CANYON Option

The ROI of the project with this option is 7.2 years.

6.2.2 Option B – New unit

In this case, the potential for new units is different depending on the manufacturer. We will analyze then each high-level quote individually.

- Norcan Hydro: They estimate that they can reach 1,129 kW with their design, the estimated cost is 3,625,000 +/- 15%, we will take the +15% = $4,168,750 CAD.
- Canyon Hydro: they estimate that they can reach 750 kW with their design, the estimated cost is $2,325,460 USD +/- 50%, let's take the +50% = $3,488,190 USD = $4,883,466 CAD.
- Dive turbine: They estimate that they can reach 616 kW with their design, their estimated cost is $2,500,000 CAD +/- 25%, we will take the +25% = 3,125,000 CAD.

On all scenarios, we will add $500,000 for a new draft tube, including the necessary civil work on that case. As well, we will need to replace the transformer, so we will add $500,000 more for a new transformer.

As well, this scenario qualifies for a loan of 80% of the cost, plus a grant of 15% over that loan, through the Green Municipal Fund. This will be applied on all financial models.

NORCAN Option – 1,129 kW - $4,168,750 CAD.

Norcan took an approach more radical than the other OEMs, configuring their unit as close as possible to the maximum flow that the pipe can handle, in this case they choose to go to 4.9 m3/s. But their unit can go higher than that.

Hydro turbine - Level 2

Resource assessment

Proposed project		Reservoir
Gross head	m	24.384
Maximum tailwater effect	m	1.8288
Residual flow	m^3/s	0
Percent time firm flow available	%	70%
Firm flow	m^3/s	3.4

Hydro turbine

Design flow	m^3/s	4.9
Type		Francis
Turbine efficiency		Standard
Number of turbines		1
Manufacturer		Dive Turbinen
Model		
Design coefficient		6.1
Efficiency adjustment	%	13.3%
Turbine peak efficiency	%	99.3%
Flow at peak efficiency	m^3/s	4.1
Turbine efficiency at design flow	%	94.9%

Unit Discharge		Turbine Efficiency	Turbine Shaft Power
[cms]	[cfs]	[%]	[kW]
1.40	49	67.4%	220
1.63	58	71.6%	273
1.87	66	75.2%	327
2.10	74	78.4%	384
2.33	82	81.2%	442
2.57	91	83.7%	501
2.80	99	85.8%	560
3.03	107	87.8%	621
3.27	115	89.5%	681
3.50	124	91.0%	742
3.73	132	92.2%	803
3.97	140	93.3%	863
4.20	148	94.1%	922
4.43	157	94.7%	979
4.67	165	95.0%	1033
4.90	173	94.9%	1084
5.13	181	94.3%	1129
5.37	190	93.3%	1167
5.60	198	91.6%	1195
5.83	206	89.2%	1213
6.07	214	86.0%	1216

Figure 78: New Turbine - NORCAN Resource and technical Specs, including provided turbine efficiency curve

Flow-duration and turbine efficiency curve data

%	Flow m^3/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	315.90	0.13	0	0.00
5%	42.56	0.13	1	0.13
10%	28.88	0.13	1	0.13
15%	22.10	0.16	1	0.16
20%	17.83	0.24	1	0.24
25%	14.31	0.32	1	0.32
30%	12.93	0.39	1	0.39
35%	11.05	0.47	1	0.47
40%	9.54	0.54	1	0.54
45%	8.16	0.61	1	0.61
50%	7.03	0.67	1	0.67
55%	6.03	0.73	1	0.73
60%	5.02	0.79	1	0.79
65%	4.14	0.85	1	0.85
70%	3.39	0.90	1	0.90
75%	2.76	0.94	1	0.94
80%	2.26	0.98	1	0.98
85%	1.63	0.99	1	0.99
90%	1.00	0.99	1	0.99
95%	0.75	0.97	1	0.97
100%	0.13	0.95	1	0.95

Figure 79: NORCAN - Flow duration and efficiency curve - estimate

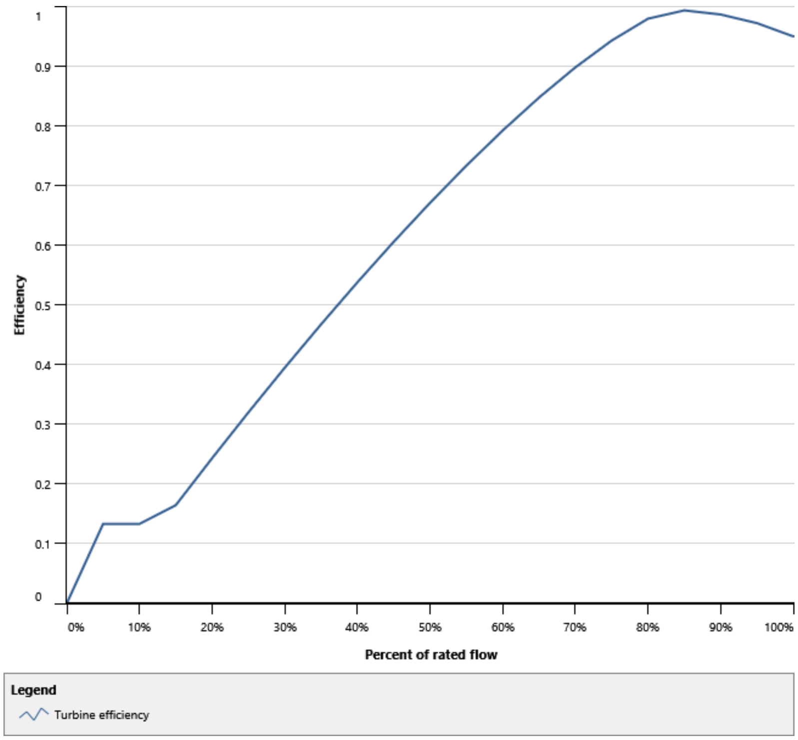


Figure 80: New turbine - NORCAN - Turbine Efficiency

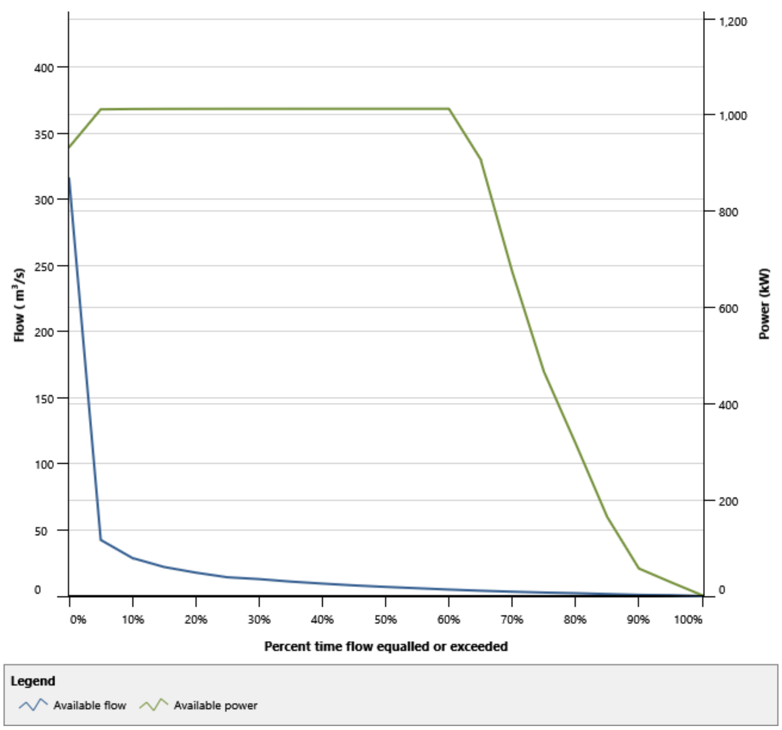


Figure 81: Flow duration and power curves - CANYON - New turbine

Losses			
Maximum hydraulic losses	%	5%	
Miscellaneous losses	%	1%	
Generator efficiency	%	96.8%	
Availability	%	90%	
Summary			Firm
Power capacity	kW	1,013	674
Available flow adjustment factor		1	
Capacity factor	%	67.7%	
Initial costs	$	4,168,750	
O&M costs (savings)	$/kW-year	90.50	
	$	91,657	
Electricity export rate		Electricity export rate - annual	
	$/kWh	0.13	
Electricity exported to grid	MWh	6,009	
Electricity export revenue	$	787,801	

Figure 82: Summary results - New Unit - CANYON Hydro

We are adding the cost of a new draft tube on this case, as mentioned before, $500,000 CAD, and the new transformer estimate of $500,000 CAD.

RETScreen - Financial Analysis | **Subscriber: Hysovent Limited - Professional**

Financial parameters

General		
Fuel cost escalation rate		2%
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	50
Finance		
Incentives and grants	$	775,312.50
Debt ratio	%	80%
Debt	$	4,135,000
Equity	$	1,033,750
Debt interest rate	%	4.95%
Debt term	yr	30
Debt payments	$/yr	267,457
Income tax analysis		☐

Annual savings and revenue

Electricity export revenue		
Electricity exported to grid	MWh	6,009
Electricity export rate	$/MWh	131
Electricity export revenue	$	787,801
Electricity export escalation rate	%	2%
GHG reduction savings		
Gross GHG reduction	tCO_2/yr	4,026
Gross GHG reduction - 50 yrs	tCO_2	201,307
GHG reduction savings	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Costs | Savings | Revenue

Initial costs			
Initial cost	80.7%	$	4,168,750
New Transformer	9.7%	$	500,000
New Draft tube	9.7%	$	500,000
Total initial costs	**100%**	$	**5,168,750**
Incentives and grants		$	775,313
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		$	91,657
Debt payments - 30 yrs		$	267,457
Total annual costs		**$**	**359,113**
Annual savings and revenue			
Electricity export revenue		$	787,801
GHG reduction savings		$	0
CE production revenue		$	0
Total annual savings and revenue		**$**	**787,801**
Net yearly cash flow - Year 1		**$**	**428,688**

Financial viability

Pre-tax IRR - equity	%	174%
Pre-tax MIRR - equity	%	16.4%
Pre-tax IRR - assets	%	13%
Pre-tax MIRR - assets	%	10%
Simple payback	yr	6.3
Equity payback	yr	0.58
Net Present Value (NPV)	$	6,770,436
Annual life cycle savings	$/yr	617,646
Benefit-Cost (B-C) ratio		7.5
Debt service coverage		2.7
GHG reduction cost	$/tCO_2$	-122
Energy production cost	$/kWh	0.065

Yearly cash flows

Year	Pre-tax	Cumulative
#	$	$
0	-258,438	-258,438
1	442,611	184,173
2	456,812	640,985
3	471,297	1,112,282
4	486,072	1,598,354
5	501,143	2,099,497
6	516,515	2,616,012
7	532,194	3,148,206
8	548,187	3,696,394
9	564,500	4,260,894
10	581,139	4,842,033
11	598,111	5,440,144
12	615,423	6,055,567
13	633,080	6,688,647
14	651,091	7,339,738
15	669,462	8,009,200
16	688,200	8,697,400
17	707,313	9,404,713
18	726,809	10,131,522
19	746,694	10,878,216
20	766,977	11,645,193
21	787,666	12,432,859
22	808,768	13,241,627
23	830,293	14,071,920
24	852,248	14,924,167
25	874,642	15,798,809
26	897,484	16,696,293
27	920,783	17,617,075
28	944,547	18,561,623
29	968,787	19,530,410
30	993,512	20,523,922
31	1,286,188	21,810,110
32	1,311,912	23,122,022
33	1,338,150	24,460,172
34	1,364,913	25,825,085
35	1,392,211	27,217,297
36	1,420,056	28,637,352
37	1,448,457	30,085,809
38	1,477,426	31,563,235
39	1,506,974	33,070,209

Figure 83: Financial Analysis – NORCAN - New unit

The simple payback of the project is 6.3 years, and the equity payback is 0.58 years.

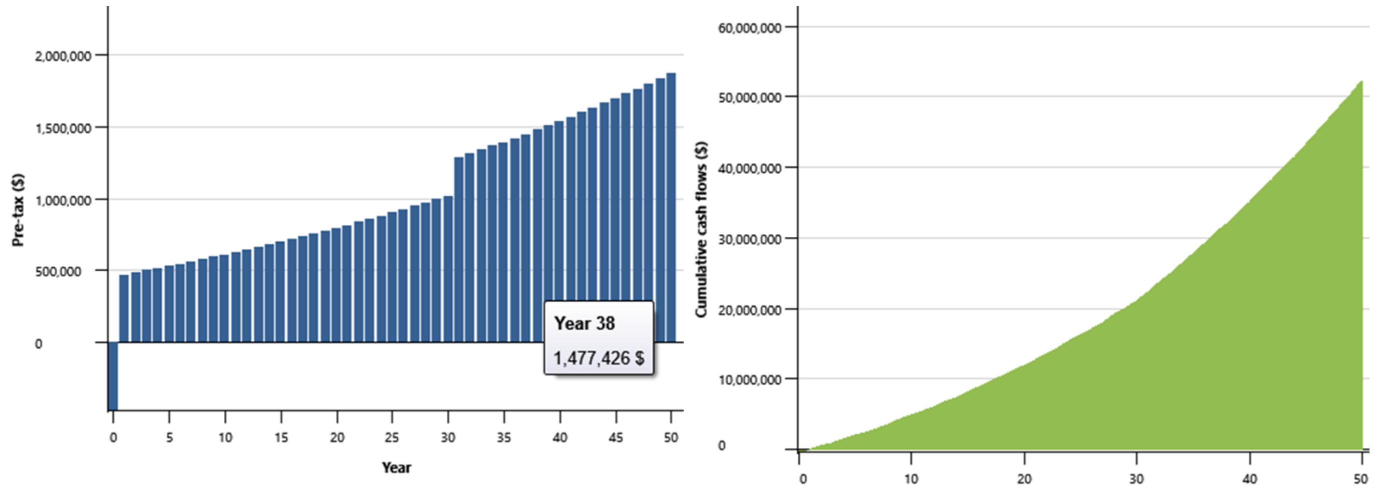


Figure 84: Yearly Cash Flows – NORCAN Option – New unit

Of all the options, NORCAN is presenting the most optimistic one, but it shows the potential of the site with proper engineering and enough resources.

CANYON Option – 750 kW - $4,883,466 CAD

It is important to note that Canyon estimates that, because the current design is quite ill (something that we agree with) the flow through the penstock is in fact restrained. The penstock has the capacity to direct flows from 3.5 to 5 m3/s, and currently only had managed to peak 3.39 m3/s as per the recollections from interviews (no historical logs available). In this case, CANYON estimates that if there is a flow of 4 m3/s through the pipe, the unit can reach 750 kW. This is something that we believe can be achieved during the freshet season. The unit can work of course with less water.

Hydro turbine - Level 2

Resource assessment		
Proposed project		Reservoir
Gross head	m	24.384
Maximum tailwater effect	m	1.8288
Residual flow	m^3/s	0
Percent time firm flow available	%	70%
Firm flow	m^3/s	4
Hydro turbine		
Design flow	m^3/s	4
Type		Francis
Turbine efficiency		User-defined
Number of turbines		1
Manufacturer		CANYON
Model		
Design coefficient		6.1
Efficiency adjustment	%	6.4%
Turbine peak efficiency	%	92.1%
Flow at peak efficiency	m^3/s	3.3
Turbine efficiency at design flow	%	87.8%

Figure 85: New Turbine - CANYON Resource and technical Specs

Flow-duration and turbine efficiency curve data

%	Flow m^3/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	372.74	-0.05	0	0.00
5%	50.22	-0.05	1	-0.05
10%	34.07	0.10	1	0.10
15%	26.07	0.19	1	0.19
20%	21.04	0.32	1	0.32
25%	16.89	0.42	1	0.42
30%	15.26	0.52	1	0.52
35%	13.04	0.60	1	0.60
40%	11.26	0.67	1	0.67
45%	9.63	0.72	1	0.72
50%	8.30	0.77	1	0.77
55%	7.11	0.80	1	0.80
60%	5.93	0.83	1	0.83
65%	4.89	0.85	1	0.85
70%	4.00	0.86	1	0.86
75%	3.26	0.86	1	0.86
80%	2.67	0.86	1	0.86
85%	1.93	0.86	1	0.86
90%	1.19	0.84	1	0.84
95%	0.89	0.83	1	0.83
100%	0.15	0.83	1	0.83

Figure 86: CANYON - Flow duration and efficiency curve - estimate

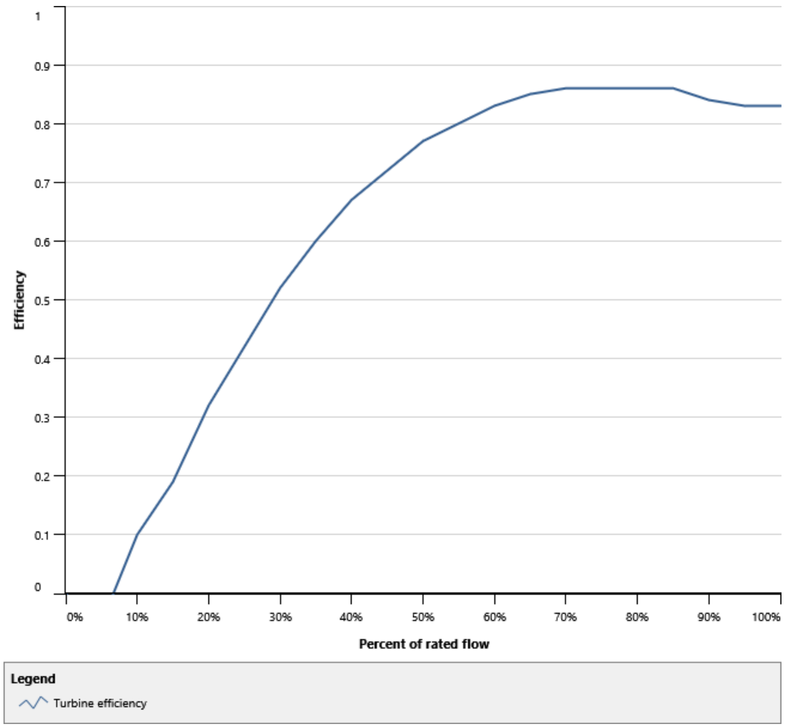


Figure 87: New turbine - CANYON - Turbine Efficiency

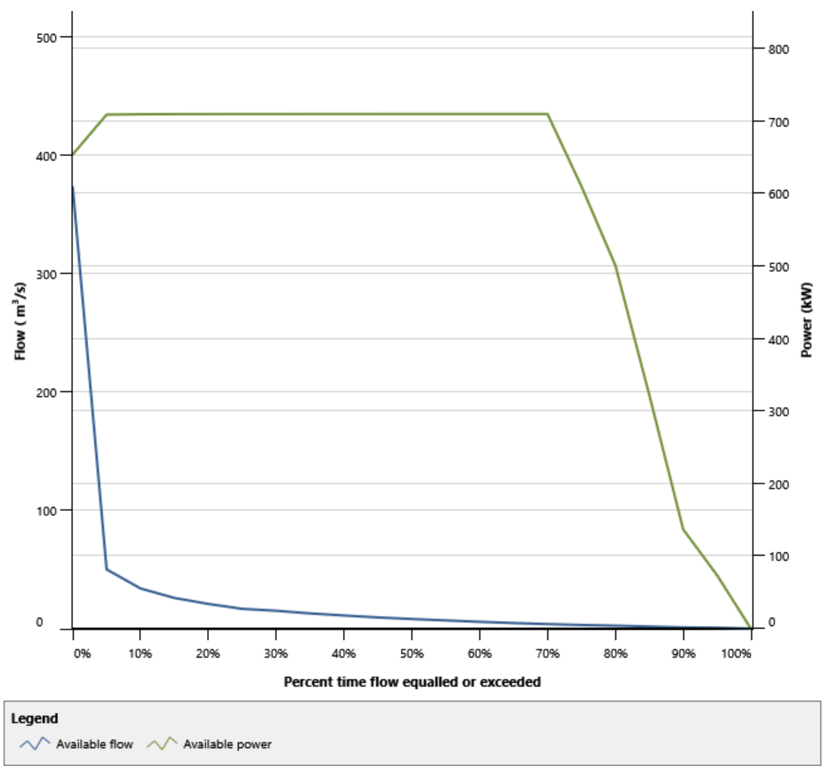


Figure 88: Flow duration and power curves - CANYON - New turbine

Losses			
Maximum hydraulic losses	%	5%	
Miscellaneous losses	%	1%	
Generator efficiency	%	95%	
Availability	%	95%	
Summary			Firm
Power capacity	kW	750	694
Available flow adjustment factor		1	
Capacity factor	%	74.6%	
Initial costs	$	4,883,466	
O&M costs (savings)	$/kW-year	90.50	
	$	67,893	
Electricity export rate		Electricity export rate - annual	
	$/kWh	0.13	
Electricity exported to grid	kWh	4,903,440	
Electricity export revenue	$	642,841	

Figure 89: Summary results - New Unit - CANYON Hydro

Note that we are adding the additional $500,000 for a new draft tube, and the $500,000 for the new transformer on the cost page, not here, and that we are reducing the maintenance costs to a half. This will be applied on all options.

RETScreen - Financial Analysis — Subscriber: Hysovent Limited - Professional

Financial parameters

General		
Fuel cost escalation rate		2%
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	50
Finance		
Incentives and grants	$	882,519.90
Debt ratio	%	80%
Debt	$	4,706,773
Equity	$	1,176,693
Debt interest rate	%	4.95%
Debt term	yr	30
Debt payments	$/yr	304,439
Income tax analysis		☐

Annual savings and revenue

Electricity export revenue			
Electricity exported to grid	MWh		5,082
Electricity export rate	$/MWh		131
Electricity export revenue		$	666,301
Electricity export escalation rate		%	2%
GHG reduction savings			
Gross GHG reduction		tCO_2/yr	3,405
Gross GHG reduction - 50 yrs		tCO_2	170,260
GHG reduction savings		$	0
Other revenue (cost)			☐
Clean Energy (CE) production revenue			☐

Costs | Savings | Revenue

Initial costs			
Initial cost	83%	$	4,883,466
New Transformer	8.5%	$	500,000
New Draft tube	8.5%	$	500,000
Total initial costs	**100%**	**$**	**5,883,466**
Incentives and grants		$	882,520
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		$	67,893
Debt payments - 30 yrs		$	304,439
Total annual costs		**$**	**372,332**
Annual savings and revenue			
Electricity export revenue		$	666,301
GHG reduction savings		$	0
CE production revenue		$	0
Total annual savings and revenue		**$**	**666,301**
Net yearly cash flow - Year 1		**$**	**293,969**

Financial viability

Pre-tax IRR - equity	%	108%
Pre-tax MIRR - equity	%	15.5%
Pre-tax IRR - assets	%	9.4%
Pre-tax MIRR - assets	%	9.1%
Simple payback	yr	8.4
Equity payback	yr	0.96
Net Present Value (NPV)	$	4,982,151
Annual life cycle savings	$/yr	454,506
Benefit-Cost (B-C) ratio		5.2
Debt service coverage		2
GHG reduction cost	$/$tCO_2$	-91.17
Energy production cost	$/kWh	0.079

Yearly cash flows

Year #	Pre-tax $	Cumulative $
0	-294,173	-294,173
1	305,937	11,764
2	318,145	329,908
3	330,596	660,505
4	343,297	1,003,801
5	356,252	1,360,053
6	369,466	1,729,519
7	382,944	2,112,462
8	396,691	2,509,153
9	410,714	2,919,867
10	425,017	3,344,884
11	439,606	3,784,490
12	454,487	4,238,977
13	469,666	4,708,643
14	485,148	5,193,790
15	500,939	5,694,730
16	517,047	6,211,777
17	533,477	6,745,253
18	550,235	7,295,488
19	567,328	7,862,817
20	584,764	8,447,581
21	602,548	9,050,128
22	620,688	9,670,816
23	639,190	10,310,006
24	658,063	10,968,069
25	677,313	11,645,382
26	696,948	12,342,330
27	716,976	13,059,305
28	737,404	13,796,709
29	758,241	14,554,950
30	779,494	15,334,444
31	1,105,612	16,440,057
32	1,127,725	17,567,781
33	1,150,279	18,718,061
34	1,173,285	19,891,345
35	1,196,750	21,088,096
36	1,220,686	22,308,781
37	1,245,099	23,553,881
38	1,270,001	24,823,882
39	1,295,401	26,119,283

Figure 90: Financial Analysis - CANYON - New unit

The ROI of the project is 8.4 Years, and the equity payback is less than a year. This is thanks to the favourable conditions of a loan that the GMF can provide for this case.

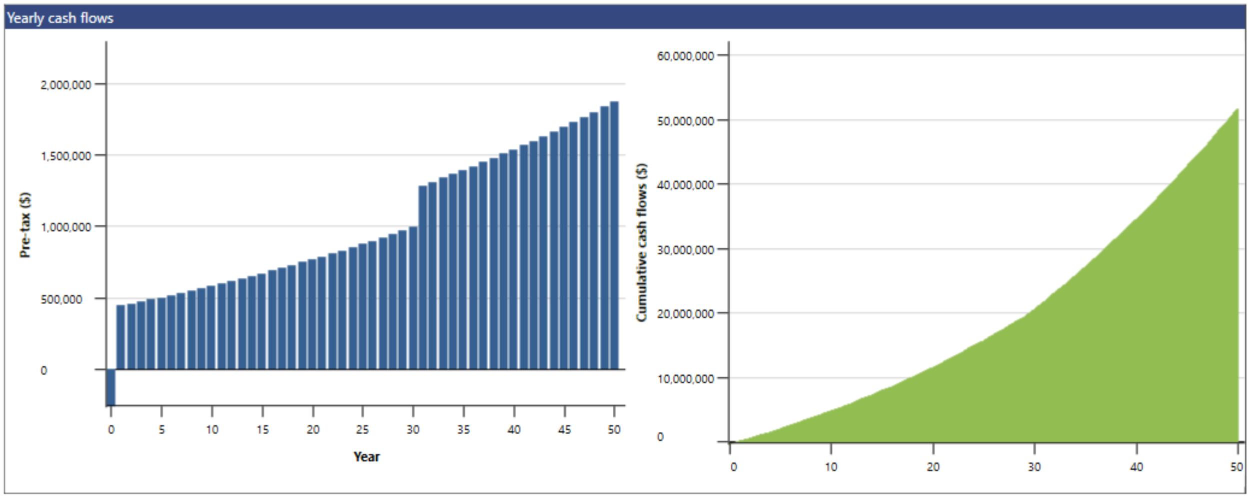


Figure 91: Yearly Cash Flows - CANYON Option – New unit

DIVE TURBINEN Option – 616 kW - $2,500,000 CAD

Dive Turbinen took a little bit more conservative approach, reducing the gross head, and keeping the design flow at 3.398 m3/s.

Hydro turbine - Level 2

Resource assessment		
Proposed project		Reservoir
Gross head	m	23.77
Maximum tailwater effect	m	1.8288
Residual flow	m^3/s	0
Percent time firm flow available	%	70%
Firm flow	m^3/s	3.4
Hydro turbine		
Design flow	m^3/s	3.398
Type		Francis
Turbine efficiency		User-defined
Number of turbines		1
Manufacturer		Dive Turbinen
Model		
Design coefficient		6.1
Efficiency adjustment	%	4.3%
Turbine peak efficiency	%	89.5%
Flow at peak efficiency	m^3/s	2.8
Turbine efficiency at design flow	%	85.4%

Figure 92: New Turbine – Dive Turbinen Resource and technical Specs

Flow-duration and turbine efficiency curve data

%	Flow m³/s	Turbine efficiency	Number of turbines	Combined efficiency
0%	315.90	-0.05	0	0.00
5%	42.56	-0.05	1	-0.05
10%	28.88	0.10	1	0.10
15%	22.10	0.19	1	0.19
20%	17.83	0.32	1	0.32
25%	14.31	0.42	1	0.42
30%	12.93	0.52	1	0.52
35%	11.05	0.60	1	0.60
40%	9.54	0.67	1	0.67
45%	8.16	0.72	1	0.72
50%	7.03	0.77	1	0.77
55%	6.03	0.80	1	0.80
60%	5.02	0.83	1	0.83
65%	4.14	0.85	1	0.85
70%	3.39	0.86	1	0.86
75%	2.76	0.86	1	0.86
80%	2.26	0.86	1	0.86
85%	1.63	0.86	1	0.86
90%	1.00	0.84	1	0.84
95%	0.75	0.83	1	0.83
100%	0.13	0.83	1	0.83

Figure 93: CANYON - Flow duration and efficiency curve - estimate

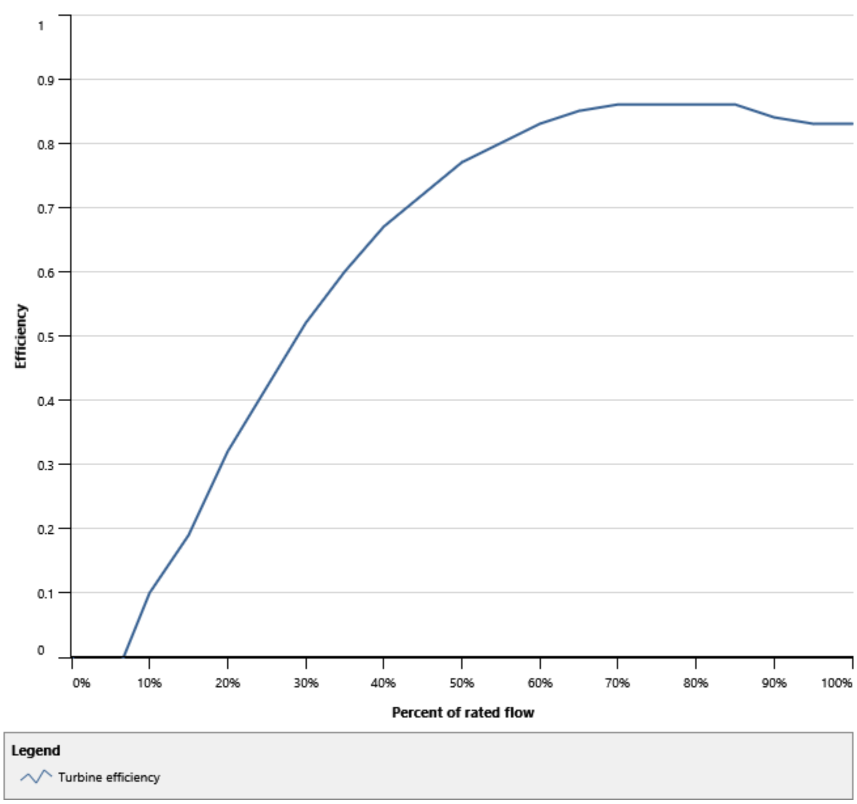


Figure 94: Turbine Efficiency - DIVE Turbine - New Turbine

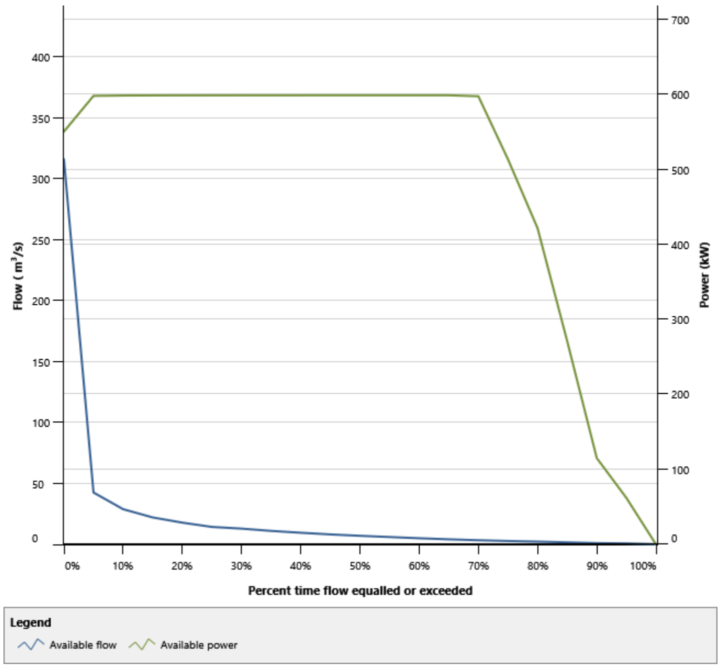


Figure 95: Flow duration and power curves – Dive Turbinen - New turbine

Losses			
Maximum hydraulic losses	%	5%	
Miscellaneous losses	%	1%	
Generator efficiency	%	96.8%	
Availability	%	90%	
Summary			Firm
Power capacity	kW	614	597
Available flow adjustment factor		1	
Capacity factor	%	73.6%	
Initial costs	$	2,500,000	
O&M costs (savings)	$/kW-year	90.50	
	$	55,551	
Electricity export rate		Electricity export rate - annual	
	$/kWh	0.13	
Electricity exported to grid	MWh	3,956	
Electricity export revenue	$	518,611	

Figure 96: Summary results - New Unit - CANYON Hydro

RETScreen - Financial Analysis | **Subscriber: Hysovent Limited - Professional**

Financial parameters

General		
Fuel cost escalation rate		2%
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	50
Finance		
Incentives and grants	$	525,000
Debt ratio	%	80%
Debt	$	2,800,000
Equity	$	700,000
Debt interest rate	%	4.95%
Debt term	yr	30
Debt payments	$/yr	181,107
Income tax analysis		☐

Annual savings and revenue

Electricity export revenue		
Electricity exported to grid	MWh	3,956
Electricity export rate	$/MWh	131
Electricity export revenue	$	518,611
Electricity export escalation rate	%	2%
GHG reduction savings		
Gross GHG reduction	tCO_2/yr	2,650
Gross GHG reduction - 50 yrs	tCO_2	132,521
GHG reduction savings	$	0
Other revenue (cost)		☐
Clean Energy (CE) production revenue		☐

Costs | Savings | Revenue

Initial costs			
Initial cost	71.4%	$	2,500,000
New Transformer	14.3%	$	500,000
New Draft tube	14.3%	$	500,000
Total initial costs	**100%**	**$**	**3,500,000**
Incentives and grants		$	525,000
Yearly cash flows - Year 1			
Annual costs and debt payments			
O&M costs (savings)		$	55,551
Debt payments - 30 yrs		$	181,107
Total annual costs		**$**	**236,658**
Annual savings and revenue			
Electricity export revenue		$	518,611
GHG reduction savings		$	0
CE production revenue		$	0
Total annual savings and revenue		**$**	**518,611**
Net yearly cash flow - Year 1		**$**	**281,954**

Financial viability

Pre-tax IRR - equity	%	170%
Pre-tax MIRR - equity	%	16.4%
Pre-tax IRR - assets	%	12.8%
Pre-tax MIRR - assets	%	10%
Simple payback	yr	6.4
Equity payback	yr	0.6
Net Present Value (NPV)	$	4,467,580
Annual life cycle savings	$/yr	407,563
Benefit-Cost (B-C) ratio		7.4
Debt service coverage		2.6
GHG reduction cost	$/$tCO_2$	-121
Energy production cost	$/kWh	0.065

Yearly cash flows

Year	Pre-tax	Cumulative
#	$	$
0	-175,000	-175,000
1	291,215	116,215
2	300,661	416,876
3	310,297	727,172
4	320,125	1,047,297
5	330,149	1,377,446
6	340,374	1,717,821
7	350,804	2,068,625
8	361,442	2,430,067
9	372,293	2,802,360
10	383,361	3,185,722
11	394,651	3,580,372
12	406,166	3,986,538
13	417,911	4,404,449
14	429,892	4,834,341
15	442,112	5,276,452
16	454,576	5,731,028
17	467,290	6,198,318
18	480,258	6,678,575
19	493,485	7,172,060
20	506,977	7,679,037
21	520,738	8,199,775
22	534,775	8,734,551
23	549,093	9,283,644
24	563,697	9,847,340
25	578,593	10,425,933
26	593,787	11,019,720
27	609,285	11,629,005
28	625,093	12,254,098
29	641,217	12,895,315
30	657,663	13,552,978
31	855,546	14,408,524
32	872,657	15,281,181
33	890,110	16,171,290
34	907,912	17,079,203
35	926,070	18,005,273
36	944,592	18,949,865
37	963,484	19,913,348
38	982,753	20,896,101
39	1,002,408	21,898,510

Figure 97: Financial Analysis – Dive Turbinen - New unit

With this option, even though the energy production is lower, the ROI is 6.4 year, and the equity payback is almost immediate.

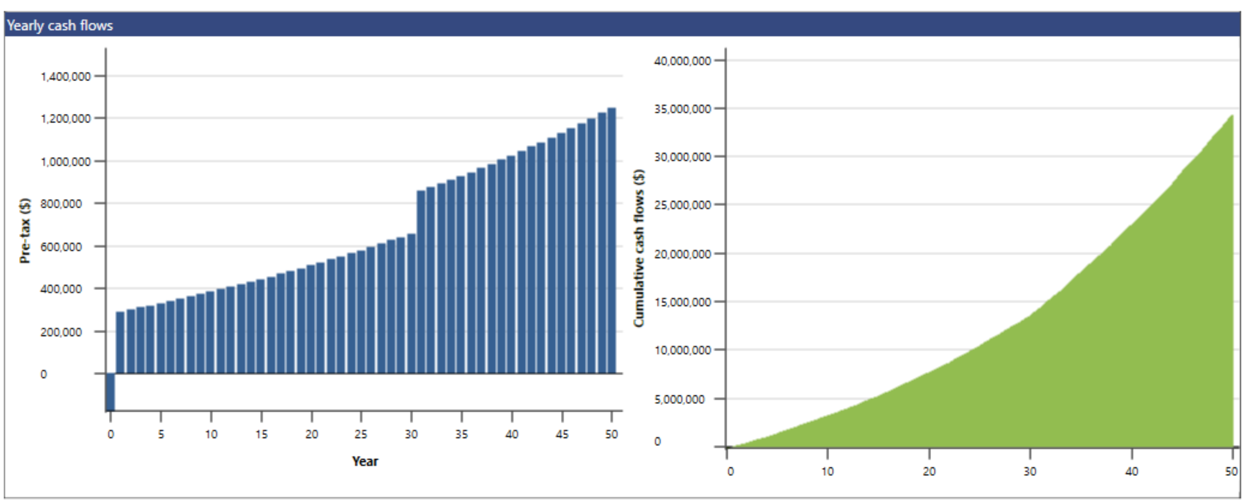


Figure 98: Yearly Cash Flows – Dive Turbinen Option – New unit

6.2.3 Option C – Full Decommissioning

As it was explained in a previous section (6.1.2) we use the help of an advanced language model to research on several databases for costs of decommission. The majority of the data was referred to, in fact, projects in British Columbia, but the costs of decommission are not significantly different across the country. It is important to note as well that the decommission does not produce any income, only savings on maintenance costs.

Table 48: Inputs for the language model

INPUTS AND ASSUMPTIONS		
Dam Height, H_dam	20	meters
Dam Length, L_dam	150	meters
Average Crest Width, W_crest	6.5	meters
Base Width, W_base	50	meters
Material Removal Unit Cost, U_removal	35	CAD/m³
Environmental Remediation Percentage, P_env	0.3	%
Engineering and Project Management Percentage, P_eng	0.1	%
Contingency Percentage, P_cont	0.1	%

Table 49: Calculation, based on the research

CALCULATION			
Material Volume of Dam, V_dam	84,750	cubic meters	V_dam = 565 square meters * 150 meters = 84,750 cubic meters
Material Removal Cost, C_removal	296,6250	CAD	C_removal = V_dam * U_removal
Environmental Remediation Cost, C_env	889,875	CAD	C_env = P_env * C_removal
Engineering and Project Management Cost, C_eng	385,,613	CAD	C_eng = P_eng * (C_removal + C_env)
Contingency Cost, C_cont	424174	CAD	C_cont = P_cont * (C_removal + C_env + C_eng)
Total Cost, C_total	**4,665,911.25**	**CAD**	**C_total = C_removal + C_env + C_eng + C_cont**

Decommissioning each dam on the system will cost roughly $4,700,000 CAD, for a total of $18,800,000 if all the dams need to be decommissioned. We are including here the cost to decommission the powerhouse as well. It is very important to note that a project like this make take years to complete, especially due to the significant environmental studies and planning required. There are no federal or municipal funding programs for this kind of endeavour either. The benefits are only the savings on annual maintenance costs.

6.3 Summary - costed option analysis

Option to analyze	Capacity (kW)	Electricity (kWh)	Initial costs CAD	Electricity export revenue CAD	O&M costs (savings) CAD	Simple payback YEARS
Like for Like - 3.39 m3/s (70%) - NORCAN	416	2,647,384	$2,472,500	$347,072	$75,356	9.09
Like for Like - 3.39 m3/s (70%) - CANYON	416	2,647,384	$1,953,000	$347,072	$75,356	7.19
NEW - 3.39 m3/s (70%) - NORCAN	1013	6,009,158	$5,168,750	$787,801	$91,657	6.3
NEW - 4 m3/s (70%) - CANYON	750	4,951,247	$5,883,466	$649,109	$67,893	8.4
NEW - 3.39 m3/s (70%) - DIVE	616	3,955,845	$3,500,000	$518,611	$55,780	6.4
Decommission	0	0	$18,800,000	$0	$0	N/A

From this analysis, at a high-level, and after checking the quotes and options available, we think that a new unit presents the most attractive option for the Berwick Electric Commission. We can discuss that during the decision workshop but the preliminary numbers, being in fact conservative, indicate that, especially taking advantage of the government loan and grant available, plus it can be stacked with other government programs.

CONCLUSION

The condition assessment of the Factorydale Hydropower Plant reveals that while certain components remain operational, the plant's overall health is compromised by aging infrastructure and significant damage to critical components, particularly the turbine. The full replacement of the turbine is necessary for the continued operation of the plant. The generator's recent rewind has extended its lifespan, though continuous monitoring and routine maintenance are essential to prevent future failures.

Given the plant's age and the current condition of its components, immediate actions are required to address the most pressing issues, such as turbine replacement. Additionally, the cost analysis provides three potential paths forward: a like-for-like replacement of the damaged turbine, installation of a new, modern unit, or complete decommissioning of the facility. Each option carries its own financial and operational implications, and this report serves as a foundation for informed decision-making regarding the future of the Factorydale plant.

The recommended course of action involves replacing the turbine, which will allow the plant to continue generating power efficiently and reliably, with ongoing maintenance to the other plant components to support long-term sustainability.

APPENDIX 1 – METALLOGRAPHY AND METALLURGICAL STUDY OF THE WICKET GATES

AMC - Atlantic Metallurgical Consulting Limited

Chemical Analysis Report

Conducted By:	AMC Atlantic Metallurgical Consulting, Scott MacIntyre, P.Eng.
Client:	Hysovent
Date:	September 3, 2024
AMC Project No.:	24-AMC-252
Purchase Order No.:	Email – Javier Ojeda Yepez
Test Article Description:	**Analysis of wicket gates**
Testing Equipment:	1- Keyence VHX-7000 Digital Microscope 2- MTS Universal testing machine 3- Leco RT370 Rockwell Hardness Tester
Testing Method:	Samples were prepared for examination and testing
Results:	***Chemical analysis:*** The chemical analysis was not performed as both wicket gates appeared to be gray cast iron. Metallography, tensile and hardness results as follow.

Hardness: After removing corrosion and debris from the flat surface of the wicket gates, the hardness of the gates was determined using a Rockwell hardness tester. The hardness values are shown in the table as follows:

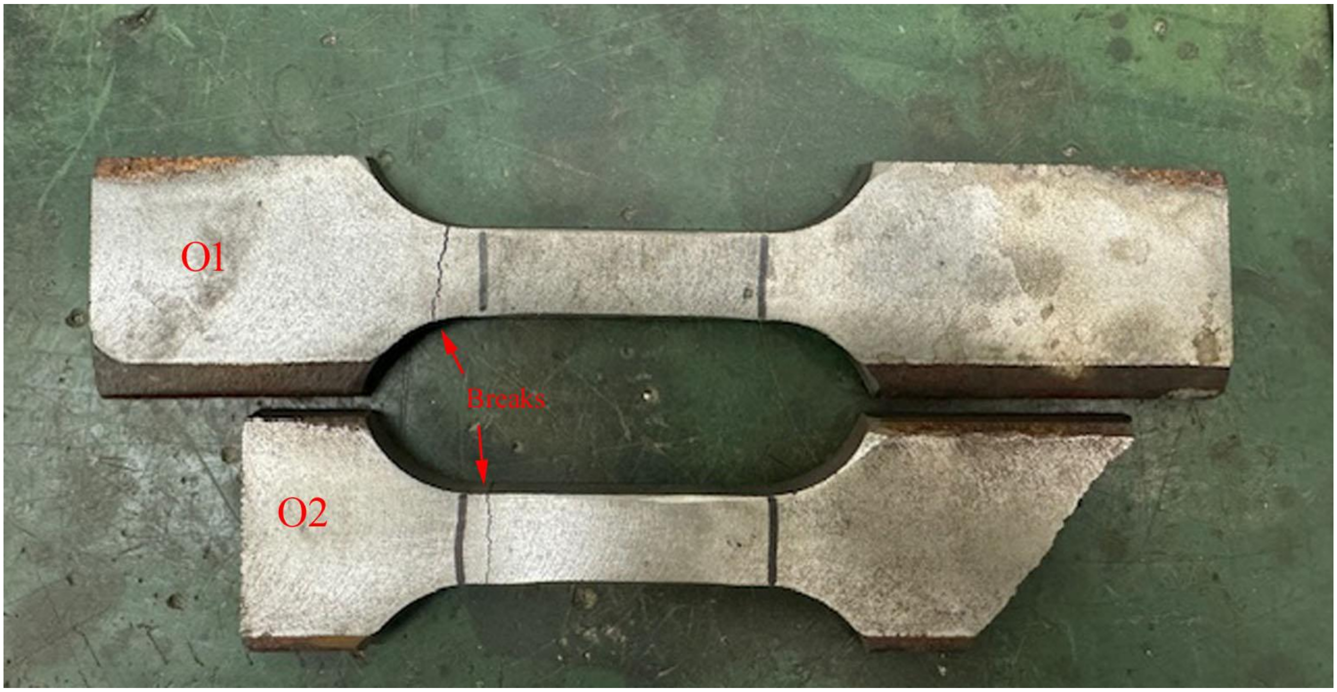
	Readings (HRB)							
	1	2	3	4	5			Average
O1 Wicket Gate Longitudinal	70.2	79.0	75.2	75.2	70.2			74.0
O1 Wicket Gate Transverse	77.4	75.7	76.4	81.4	70.3			76.2
O2 Wicket Gate Longitudinal	62.8	62.7	76.0	74.1	70.1	67.9	70.5	69.1
O2 Wicket Gate Transverse	60.9	64.2	71.5	66.6	67.7	67.7	68.3	66.2

While there was a variation in the hardness between the longitudinal and transverse directions, there was an even greater variation from the O1 wicket gate to the O2 wicket gate. The lower hardness of the wicket gate would likely correlate to a lower strength of the casting. Hardness is commonly used as a quality control measure to ensure adequate strength.

Tensile Testing: Samples from the thin edge of each wicket gate were prepared for tensile testing. The results of the tests are given in the table that follows:

Specimen ID.	Maximum Load (kN)	Tensile Strength (MPa)	Yield Load (kN)	Yield Strength (MPa)	Elong.* (%)	Width (mm)	Thick. (mm)
O1 Wicket Gate	15.904	74.21	NA	NA	0	19.29	11.11
O2 Wicket Gate	12.259	62.24	NA	NA	1	18.74	10.51

The strength of the O2 casting (62.24 MPa, 9,027 psi) was considerably less than that of the O1 casting (74.21 MPa, 10,763 psi). The 10,763 psi strength value for the O1 casting fractured in the shoulder area of the tensile sample as shown in the Figure 1 image. There was no defect or flaw in the casting noted visually, but the microstructure may have been weaker in this area.



It broke on the shoulder of the reduced section indicating it may have had a defect in that area.

The strength of gray cast iron is given as classes as shown in the following table.

Table 12 Typical mechanical properties of as-cast standard gray iron test bars

ASTM A 48 class	Tensile strength MPa	Tensile strength ksi	Torsional shear strength MPa	Torsional shear strength ksi	Compressive strength MPa	Compressive strength ksi	Reversed bending fatigue limit MPa	Reversed bending fatigue limit ksi	Transverse load on test bar B kg	Transverse load on test bar B lb	Hardness, HB
20	152	22	179	26	572	83	69	10	839	1850	156
25	179	26	220	32	669	97	79	11.5	987	2175	174
30	214	31	276	40	752	109	97	14	1145	2525	210
35	252	36.5	334	48.5	855	124	110	16	1293	2850	212
40	293	42.5	393	57	965	140	128	18.5	1440	3175	235
50	362	52.5	503	73	1130	164	148	21.5	1630	3600	262
60	431	62.5	610	88.5	1293	187.5	169	24.5	1678	3700	302

The strength of the materials in both wicket gates was substantially lower than the lowest class of gray cast iron in ASTM A48.

Microstructure:

The microstructure was graphite flakes as expected for gray cast iron but there were undesirable rosette formations and the graphite flake size was larger than desired. The polished cross sections are shown in the unetched condition in figures 1 and 2.

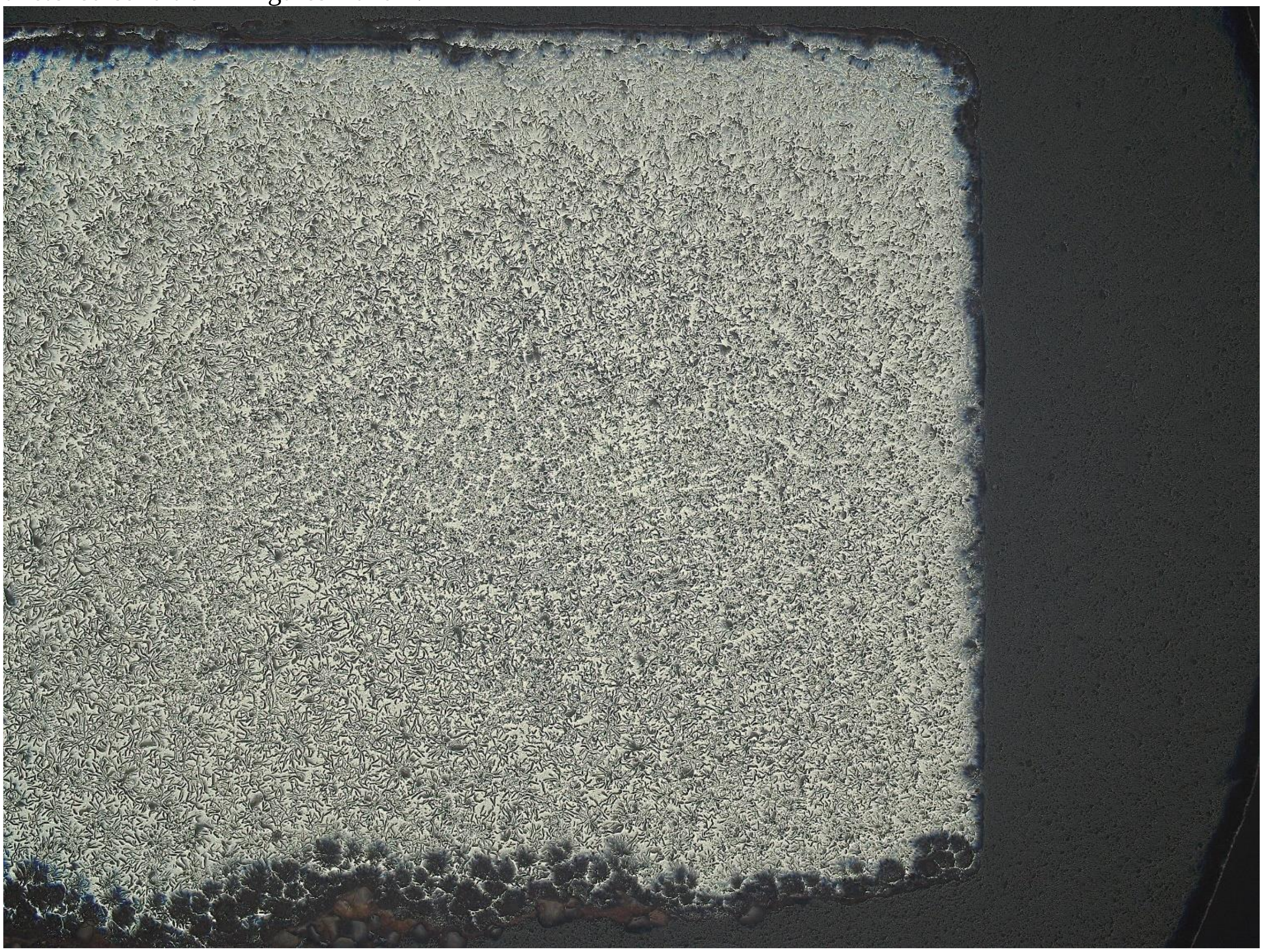


Figure 1 O1 L Unetched microstructure showing dentritic center 20x

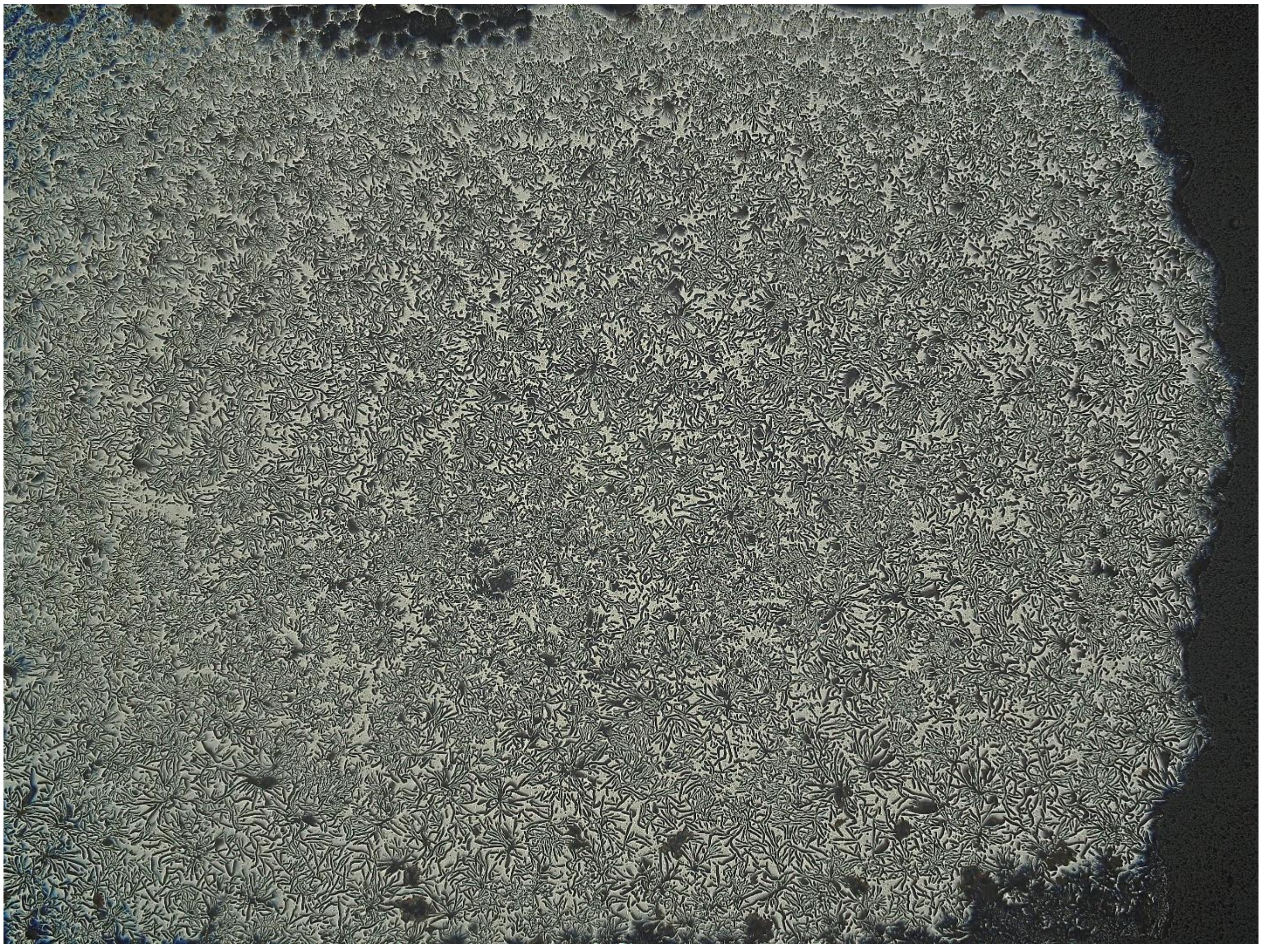


Figure 2 O2 L Unetched microstructure showing dentritic center 20x

These microstructures show clusters of graphite with dendritic areas shown by white lines through the microstructure. This microstructure is less desirable than the fine, randomly oriented graphite flakes.

At 200X magnification in Figures 2 and 3 the dark graphite flakes can be seen in the rosette pattern in the etched microstructure. The matrix is the dark brown pearlite, along with areas believed to be ferrite. The graphite can be classified as type B, rosette grouping, random orientation or type D, interdendritic segregation, random orientation. The white ferrite is a softer phase that can lead to weakness in the microstructure, particularly if it is continuous.

Figure 3 O1 L etched microstructure showing rosettes 200X

Figure 4 O2 L Unetched microstructure showing rosette formations near outside 200x.jpg

The whiteish lines through the microstructure that indicate dendritic cooling are evident. At greater magnification in Figures 5 and 6 there are phosphides apparent in the microstructure.

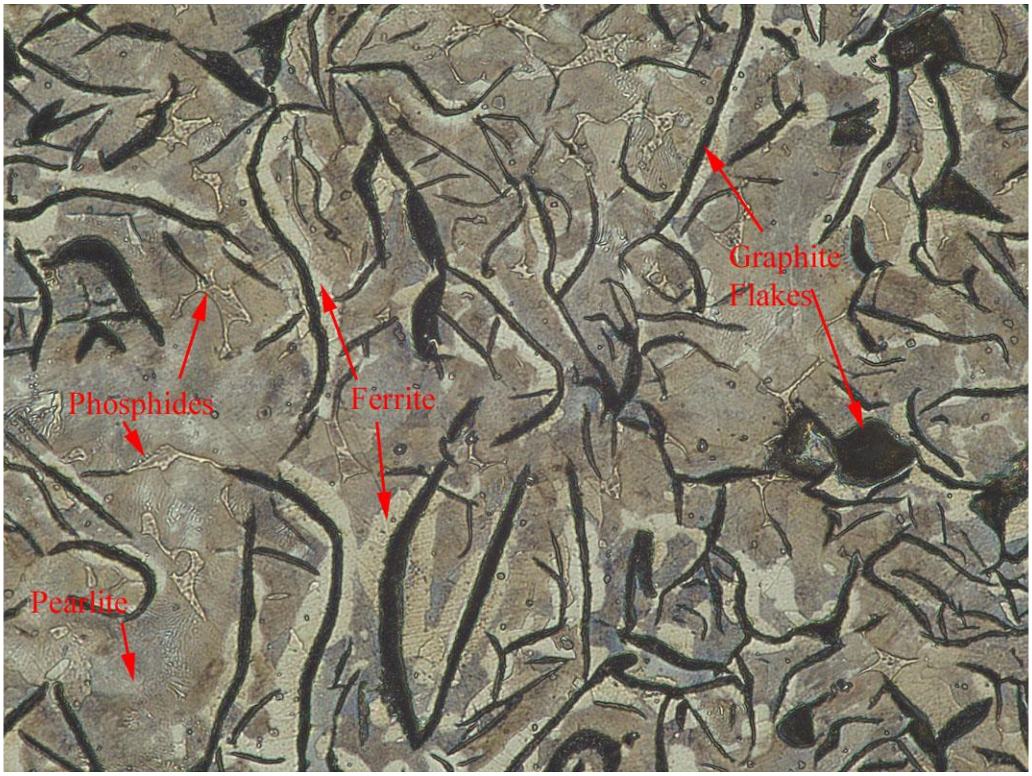


Figure 5 O1 T etched microstructure showing pearlite, phosphides 500x

Figure 6 O2 T etched microstructure showing pearlite, phosphides 500x

The presence of phosphides weakens the microstructure along with the ferrite and larger graphite that is in rosette grouping. It is likely that the cause of the lower strength of the wicket gate materials is from these abnormal microstructures.

REGISTERED PROFESSIONAL ENGINEER
DATE 9/03/24
J. S. MacIntyre
5647
PROVINCE OF NOVA SCOTIA

J. Scott MacIntyre, P.Eng.
Manager, Forensic & Failure Investigation

APPENDIX 2 – STRUCTURAL ENGINEERING HIGH-LEVEL REPORT

malcolm PINTO ENGINEERING LTD.
3480 Joseph Howe Drive Suite 401, Halifax, NS

T (902) 420-9800
F (902) 484-7288
www.consultpinto.com
peng@consultpinto.com
P. O. Box 2555, Halifax, NS, B3J 3N5

September 12, 2024

HYSOVENT Sustainable Engineering
103 – 287 Lacewood Drive, Suite 121,
Halifax, NS, B3M 3Y7

ATT: **Javier Ojeda, P.Eng.**

RE: **Berwick Electric Commission, Factorydale Plant Structural Review**

Dear Mr. Ojeda,

Following is a summary of observations from the structural review of the Factorydale Electrical Plant that was completed on August 30, 2024, by the undersigned with your assistance. The observations were limited to a visual review only and a structural evaluation has not been carried out. The building is comprised of three levels. For the purposes of reporting, the side of the building adjacent to the river will be considered the North side. A sketch of the North Face of the building is included as well as a series of reference photographs.

1) **Ground/Main Level**: The interior dimensions of the Ground Level are approximately 6,495 mm x 5,315 mm. Walls are constructed with concrete block masonry with an approximate wall height of 7,430 mm, as shown on the attached elevation sketch of the North side of the building. Due to the height of the block masonry, it is likely that the masonry is partially or fully grouted and may be reinforced. There were no cracks visible on the interior surfaces of the block walls and the masonry is in good condition.

   Roof structure (Photo 1) is constructed of 2x10 (38x240) wood joists spaced at about 300 mm c/c, running west to east, supported by a steel beam at the center of the building and the masonry walls at each end. The roof slopes down toward the North wall.

   A W460 hoist beam runs from east to west at the center of the building. The beam is supported at each end by a cross beam on two concrete columns. The columns are 250 x 280 mm and appeared to be in good condition. The chain hoist on the hoist beam had been previously load tested and had a posted load limit of 9,991 kg.

   The Ground Level floor is a 535 mm (21”) thick concrete slab. There is an opening in the center of the floor with a concrete perimeter curb that supports an electrical generator (Photo 2). On north and south sides of the opening, a W460 steel beam runs east to west and is supported on the concrete end walls. Running east to west on either side of the opening between the two W460 beams are two W360 beams. The underside of these four beams is 230 mm below the bottom of the slab. Steel beams are in good condition with only minor surface corrosion. The floor slab also appears to be in good condition.

2) **Intermediate Level**: The level below Ground Level has an approximate ceiling height of 2150 mm with concrete side walls. The concrete columns on the east and west walls supporting the hoist beam continue down from the level above.

   There are diagonal cracks in the north wall that start near the top of the northeast corner, with maximum crack widths varying from 1.5 mm to 3 mm. Photo 3 shows the cracks on the interior wall face and Photo 4 shows the same cracks on the exterior building face. From the latter photo, it can be seen that the cracks propagate from a spalled area at the northeast corner. Efflorescence stains are visible near the bottom of the cracks, indicating water transmission, however, minimal or no rust stains from corrosion of reinforcing steel is visible. The cracks are roughly plotted on the attached sketch of the North Elevation. The cracks continue onto the east wall as shown in Photo 5.

   There are also diagonal cracks on the east wall (Photo 6) starting at floor level between the two columns and propagating upwards to the south column. Photograph 7 shows where the top crack continues through the column and beyond. Crack width at the column is approximately 2 mm. The crack terminates to the south of the column at a spalled area.

   The Owner’s representative stated that the noted cracks on the north and east walls have been there for many years.

   The concrete floor slab at this level is 305 mm (12”) thick. The slab appears to be in good condition. As shown on the North Elevation sketch, the east wall does not continue down to the Base Level but bears on bedrock at that level. The east wall for the level below shifts about 1207 mm to the west, to fit the profile of the bedrock.

3) **Base Level:** Access to the Base Level is limited to a single floor opening at the north wall and, therefore, the area is considered a confined space and was not entered during this site review. Floor to ceiling height was measured to be approximately 3096 mm. The north concrete wall is approximately 50 mm (2”) thicker than the wall of the level above. Thickness was estimated to be between 300 and 325 mm (12” to 13”). As can be seen in Photos 9 and 10, there is a large diagonal crack in the north wall, extending from top of base slab or footing to the east side wall. Smaller cracks are also present.

   The thickness of the base slab (or footing) was measured to be 460 mm (18”). The slab was found to be undermined, due to erosion of the weak bedrock caused by the discharging of water directly beside the building. Lateral extent of the undermining could not be determined during the site review, but a pole mounted camera could be inserted below the slab (Photo 10).

   Structural steel is present on this level, but it appears to be limited to lateral bracing to support the draft tube. Although surface corrosion was observed by video inspection, extent of corrosion could not be determined.

In summary, deficiencies observed included concrete wall cracking and base slab/foundation undermining. Cause of the cracking cannot be conclusively determined based on the visual site review but may have been initiated by machinery vibrations. A structural analysis is not recommended for the building unless the new machinery is heavier than the current equipment.

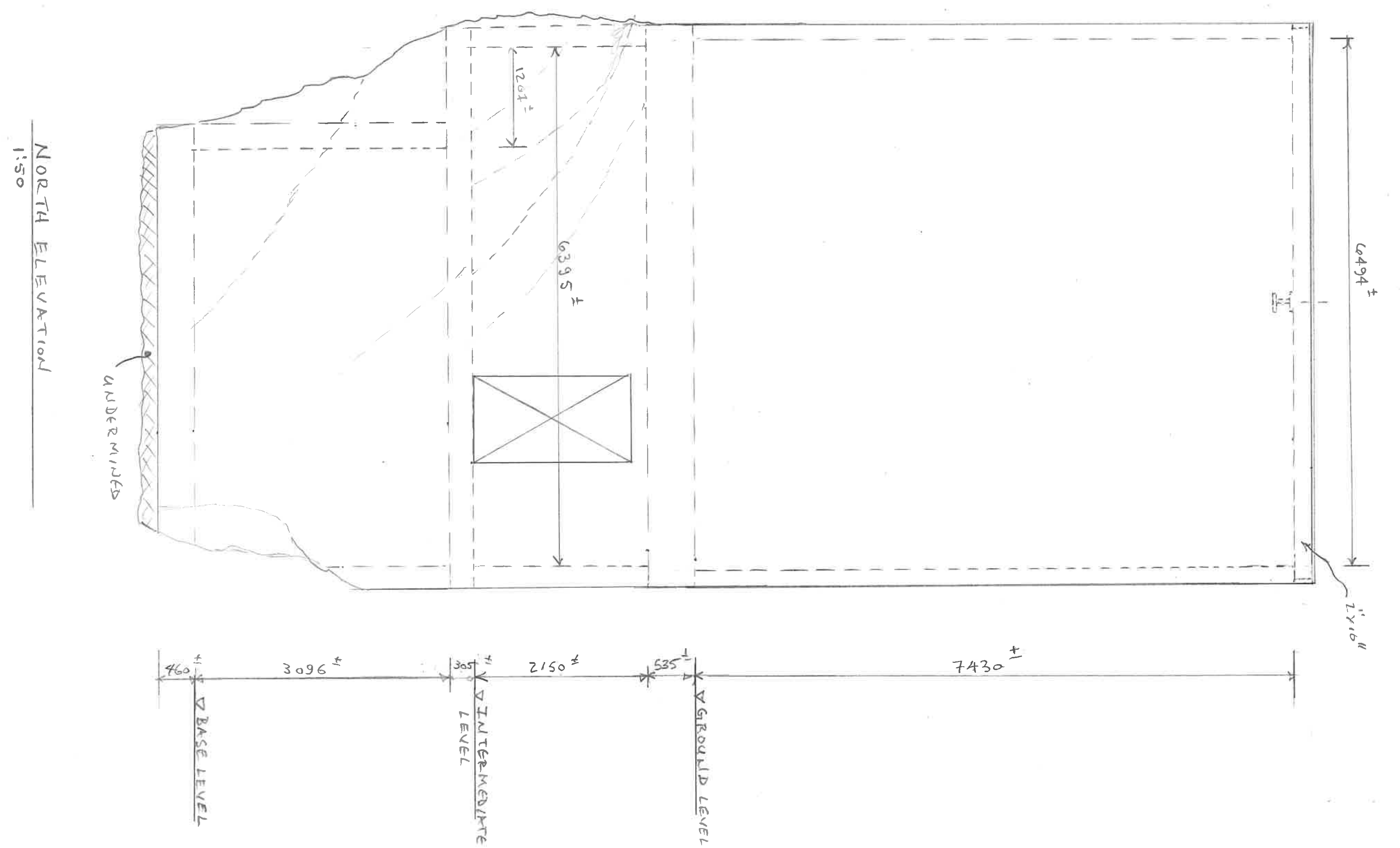
The base slab/foundation undermining should be remediated. The extent of the undermining should first be determined so that repair details can be developed. An extension to the discharge tube should also be considered to better direct water flow away from the foundation.

Please advise us if you require any further assistance or have any questions.

Sincerely,
Malcolm Pinto Engineering Limited, per

Howard Allen

Howard Allen, M.Sc., P.Eng.



No.	Revision	Apr.	Date

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Revision Date	CHK
DRAWN:	APPROVED:
DRW	APR

PROJECT
FACTORYDALE POWER PLANT

SUBJECT
NORTH ELEVATION

DWG. No.
A101

PLOTTED 14/12/2011 9:25:43 AM

MPEL PROJ # Project Number

1. Roof framing, hoist beam and chain hoist.

2. Steel beams around floor opening below generator.

3. Cracks in North concrete wall at intermediate level.

4. Wall cracks from previous photo on the exterior surface of the wall.

5. Interior wall cracks at northeast corner, Intermediate level.

6. Interior cracks on east wall, intermediate level.

7. Wall cracks shown in previous photo that continue into column.

8. North face of building.

9. North face at Base Level.

10. Probing undermined area below base slab.

APPENDIX 3 – OEM QUOTES

August 27, 2024

Javier Ojeda
Hysovent
902-2106828
javier@hysovent.com

Dear Mr. Ojeda,

Thank you for the opportunity to assist you with evaluating hydroelectric equipment for the Factorydale project in New Brunswick, Nova Scotia. Canyon Hydro specializes in manufacturing and refurbishing Francis turbines. We also offer complete powerhouse equipment packages for the conditions at this site. Please find below budget estimates for potential equipment options.

Canyon Hydro has been building high quality turbine systems in the USA for over 48 years. From day one, we have remained committed to three guiding principles:

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

Option 1 – Refurbish Existing Barber Turbine

Supply new parts and assembly as follows: runner, wicket gates, curb plate, head cover, shaft, thrust bearing, guide bearing. Sandblast the turbine housing and epoxy coat it. Removal and reinstallation of the existing generator. On-site machining to properly align curb plate with the draft tube. Re-install generator.

Budget estimate equipment refurbishment package, as described……..…………………..$750,000.00 USD

Estimate FOB Deming, Washington, USA

Normal Terms	15% to begin work onsite
	25% to order runner and wicket gate materials
	25% mid-project
	20% upon notice of readiness to ship
	10% upon completion of re-assembly
	5% upon successful startup or 90 days following notice of readiness to ship, whichever is first
Normal Delivery	10-12 months from receipt of initial 15% payment

*We suggest budgeting $10,000.00 for freight to the site.
*We suggest budgeting $20,000.00 for startup, commissioning and training services.

Option 2 – New Leffel Gate Case Assembly

Supply new parts and assembly as follows: runner, wicket gates, curb plate, head cover, shaft, thrust bearing, guide bearing. Removal and reinstallation of the existing generator. On-site machining to properly align curb plate with the draft tube. Re-install generator.

Budget estimate Leffel equipment package, as described……..……………..…………...$900,000.00 USD

Estimate FOB Deming, Washington, USA

Normal Terms	15% to begin final design
	30% to begin construction following final design approval
	25% mid-project
	20% upon notice of readiness to ship
	10% upon successful startup or 90 days following notice of readiness to ship, whichever is first
Submittals	3-4 months following receipt of final design payment
Normal Delivery	10-12 months following design approval and receipt of construction payment

*We suggest budgeting $10,000.00 for freight to the site.
*We suggest budgeting $20,000.00 for startup, commissioning and training services.

Option 3 – New Custom Turbine and Equipment Package

Based on your correspondence, we are considering a net head of 74 feet at the design flow rate of 4 m3/s. For these conditions, we offer an equipment package based on a Canyon Hydro custom Francis turbine. Our proposed equipment package includes: 48" butterfly type turbine inlet valve with hydraulic open and counterweight closure, 48" dismantling joint, Canyon Hydro custom Francis turbine with hydraulic actuation, 800kW-2300VAC-3ph-60Hz synchronous generator, hydraulic power unit, medium voltage switchgear to parallel the generator with the local electrical grid and PLC based controls panel with OIU and utility grade protective relays. Expected system production for this equipment package is 750 kW.

Budget estimate 750 kW equipment package, as described……..……………..………$2,325,460.00 USD

Estimate FOB Deming, Washington, USA

Normal Terms	15% to begin final design
	30% to begin construction following final design approval
	25% mid-project
	20% upon notice of readiness to ship
	10% upon successful startup or 120 days following notice of readiness to ship, whichever is first
Submittals	3-4 months following receipt of final design payment
Normal Delivery	10-12 months following design approval and receipt of construction payment

*We suggest budgeting $20,000.00 for freight to the site.
*We suggest budgeting $50,000.00 for startup, commissioning and training services.

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

This estimate does not include equipment installation, beyond that described, or electrical wiring required to connect the equipment in the powerhouse or to the electrical grid. Transformer equipment is not included in this estimate. Our estimate is based on typical requirements for a project this size. Special requirements may affect pricing.

We thank you for your interest in working with Canyon Hydro and we appreciate the opportunity to work with the Hysovent. Please contact me as questions arise or as additional project information becomes available.

Sincerely,

Eric Melander
Vice President of Sales

Canyon Hydro - 'Generating a Clean Future' - 5500 Blue Heron Lane - P.O. Box 36 - Deming, WA 98244
Phone: 360-592-5552 - Fax: 360-592-2235 - Email: info@canyonhydro.com - www.canyonhydro.com

Outlook

RE: Berwick Hydropower plant - lie-for-like replacement and repair

From Ian Shea <ishea@norcanhydro.com>
Date Fri 2024-09-20 15:51
To Javier Ojeda <javier@hysovent.com>

Hi Javier,

Please use the following performance table for the replacement turbine. At this stage, I don't have performance curves from the generator supplier, so please consider applying a 95% factor to account for the generator losses at full load.

Unit Discharge		Turbine Efficiency	Turbine Shaft Power
[cms]	*[cfs]*	*[%]*	*[kW]*
1.40	49	67.4%	220
1.63	58	71.6%	273
1.87	66	75.2%	327
2.10	74	78.4%	384
2.33	82	81.2%	442
2.57	91	83.7%	501
2.80	99	85.8%	560
3.03	107	87.8%	621
3.27	115	89.5%	681
3.50	124	91.0%	742
3.73	132	92.2%	803
3.97	140	93.3%	863
4.20	148	94.1%	922
4.43	157	94.7%	979
4.67	165	95.0%	1033
4.90	173	94.9%	1084
5.13	181	94.3%	1129
5.37	190	93.3%	1167
5.60	198	91.6%	1195
5.83	206	89.2%	1213
6.07	214	86.0%	1216

Have a great weekend,

Ian Shea
Technical Business Development Manager

Norcan Hydraulic Turbine Inc.
50 Bruce Crescent, Carleton Place, Ontario, CA K7C 3V6
T: +1 (613) 257-4755 ext. 18 | **F:** +1 (613) 257-4215 | **E:** ishea@norcanhydro.com

From: Javier Ojeda <javier@hysovent.com>
Sent: September 20, 2024 1:20 PM
To: Ian Shea <ishea@norcanhydro.com>
Subject: Re: Berwick Hydropower plant - lie-for-like replacement and repair

Glad to chat with you Ian!!

I had to take a call sorry for cutting the call so quick. Yes! I just noticed that for the new unit, we don't have the estimated power output, that's the only thing missed and needed at this time.

Looking forward to chat soon again! cheers,
Javier

Javier Ojeda

P.Eng, MBA, PMP, CEM, REP

Owner, Principal Engineer | HYSOVENT Sustainable Engineering

+1-902-2106828

javier@hysovent.com

www.hysovent.com

Book a meeting with me at your earliest convenience here!

From: Javier Ojeda <javier@hysovent.com>
Sent: Wednesday, September 18, 2024 14:33
To: Ian Shea <ishea@norcanhydro.com>
Subject: Re: Berwick Hydropower plant - lie-for-like replacement and repair

Hello señor Ian!

Glad to hear from you! Sure thing I'll call you tomorrow. Hope you had everything solved at the jobsite in Northern Ontario. Great, this is the level of estimate that we need for now, this will help to build the energy and financial models that the customer is requiring to move to the next phase of the project. I'll call you tomorrow to chat.

Many thanks!!

Javier Ojeda

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Book a meeting with me at your earliest convenience here!

From: Ian Shea <ishea@norcanhydro.com>
Sent: Wednesday, September 18, 2024 11:17
To: Javier Ojeda <javier@hysovent.com>
Subject: RE: Berwick Hydropower plant - lie-for-like replacement and repair

Hi Javier,

My apologies on the delayed response – I have been in northern Ontario on a emergency jobsite requirements and have been extremely busy transitioning back into the office. I am available tomorrow if you'd like to catch up and discuss – please feel free to give me a call.

Thank you for all of the additional information, this project should be a great benefit and success for the customer in the long run. Please find my preliminary estimates below for each scenario.

1. **"Like-for-like" Replacement/Repair – $2,150,000 CAD +/- 15%**

   Equipment Supply:
   - Main Shaft Assembly
     - Francis Runner
     - Turbine Shaft
   - Main Shaft Seal Assembly
   - Turbine Guide Bearing Assembly
   - Distributor Assembly
     - Headcover
     - Bottom Ring
     - Wicket Gates
     - Wicket Gate Linkage Assemblies
     - Regulating Ring
   - Generator Thrust Bearing Assembly
   - HPU Assembly
   - Digital Speed Governor

   Equipment Refurbishment
   - Sandblast/Paint Existing Penstock Inlet & Pressure Case

   Field Services
   - Equipment Disassembly, Removal, and Disposal
     - Removal of Existing Generator to local storage facility
     - Disposal of Obsolete Equipment
   - Embedment Alignment Inspection
   - On-site Machining (Contingency)
   - Equipment Installation
   - Unit Alignment & Final Inspection
   - Unit Commissioning

2. **W2W Complete New Unit – $3,625,000 CAD +/- 15%**

   Equipment Supply:
   - Main Shaft Assembly
     - Francis Runner
     - Turbine Shaft
   - Main Shaft Seal Assembly
   - Turbine Guide Bearing Assembly
   - Distributor Assembly
     - Headcover
     - Bottom Ring
     - Wicket Gates
     - Wicket Gate Linkage Assemblies

    - Regulating Ring
  - Spiral Case + Inlet Penstock Transition
  - Discharge Cone + Draft Tube Elbow
  - HPU Assembly
  - Digital Speed Governor
  - Generator Assembly + Exciter + Speed Increaser
  - Excitation Cabinet
  - Switchgear & Controls Cabinet

Field Services
  - Equipment Disassembly, Removal, and Disposal
    - Disposal of Obsolete Equipment
  - Embedment Alignment Inspection
  - On-site Machining (Contingency)
  - Equipment Installation
  - Unit Alignment & Final Inspection
  - Unit Commissioning

Ian Shea
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From: Javier Ojeda <javier@hysovent.com>
Sent: September 4, 2024 4:44 PM
To: Ian Shea <ishea@norcanhydro.com>
Subject: Re: Berwick Hydropower plant - lie-for-like replacement and repair

Hello señor Ian!

Hope you are doing well. Any updates regarding the very high level quote for this project? Any additional information that you may need? Looking forward to chat with you soon!

Cheers,
Javier

Javier Ojeda

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Book a meeting with me at your earliest convenience here!

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E1N-4R5
Email ken.cripps@bridge-executive.com
Phone (506)-259-4944

September 20, 2024

Re: Quote Berwick Hydro Station - Factorydale

Dear Javier,

Thank you for the opportunity to provide a quote subject to change as information is updated or modified.

I want to summarize the quote as follows:

- We would design a DIVE-Turbine suitable for connection to the current draft tube, incorporating an 888mm runner.
- It is anticipated the runner would be an axial runner, with approximately seven blades.
- The design, combined with the speed variable option, guarantees cavitation-free operation over a wide range of operating parameters from 10% to 100% of flow.
- The operating range of 10%-100% is a critical advantage over fixed-speed Francis or Kaplan turbine, which will experience cavitation at part load.

Preliminary operating points for speed-variable DIVE0800-700nVar:

- Mechanical turbine power: 667kW
- Net electrical output: 616kW

We estimate a head loss of 1.36m and a net head of 22.41m. (Preliminary calculations)

The complete DIVE Turbine is pretested and preassembled, which reduced installation costs and timelines. Upon receipt of the complete turbine and generator the next step is to place the new unit onto the old draft tube, connect to the penstock, and pour a second layer of concrete around it.

Installation and all electrical work including inverters is excluded. Electrical components can be sourced locally in Canada.

Quote range **$2,050,000 - $2,150,000**

Excluding all permits, fees and applicable taxes.

<u>Advantages of DIVE Turbine are as follows:</u>

- Cavitation free design
- Wide operating ranges from 10%-100% of flow
- Pre-tested and pre-assembled
- Compact for easy transport and installation
- Simple interface
- Flood-secure turbine-generator unit by design
- Reduced fish mortality due to the fixed-blade, speed-variable runner with few blades compared to a Francis Turbine.
- Low noise and vibration
- Maintenance-free cooling via river water
- Runaway secure design

The quote includes a comprehensive site-specific Phase 1 and Phase 11 detailed engineering package.

If you have any questions, contact me at your convenience.

Best Regards,

Ken

Kenneth Cripps, CPA, CGA, CMA – CEO
Bridge Executive Renewable Solutions Ltd.

Bridge Executive Renewable Solutions Ltd.

Berwick - Factorydale Refurbishment Project

September 20,2024

	POS Scope	Quote
1	Turbine & Generator DIVE0888-700	$ 1,455,000
2	Meetings fee engineering	$ 17,000
3	Turbine Casing	$ 273,000
4	Supervision of installation & start-up	$ 58,000
5	Project management	$ 30,000
6	Engineering Electrical Interface	$ 67,000
	SUBTOTAL	$ 1,900,000
7	Shipping preparation	$ 42,000
8	Pressure test on Turbine Casing	$ 28,000
9	Complete factory assembly of TG unit	$ 21,000
10	Load Test Generator	$ 31,000
11	Hydraulic Power Units	$ 48,000
12	Shipping, Amorbach to Site - Allowance (Note 1)	$ 50,000
	SUBTOTAL	$ 220,000
	TOTAL - EXCLUDING HST	**$ 2,120,000**

Quote excludes HST and any applicable import fees and duties

Note 1 - Shipping allowance and estimate subject to change

Project	Hydro Power Plant - Berwick - Factorydale		
Head gross	23,77	m	
Max. Discharge Power Plant	3,40	m3/s	
Numbers of Turbines	1	piece	
Turbine type:	DIVE0888-700	nVAR	
Cos φ Generator	0,96		
Max. Active power (Generator)	649	kW	
Max. Voltage (Generator)	420	V	or ~ 600V
Max. Current (Generator)	930	A	~ 690A
Max. Speed	360	1/min	

Operation Points double regulated - guide vanes and speed variation / Preliminary Generator Values:

Operation Point	Q (m^3/s)	Q Runner (%)	Head net^^ (m)	Efficiency Turbine (%)	Mechanical power Turbine (kW)	Efficiency Generator (%)	Efficiency Inverter (%)	Overall efficiency* (%)	Overall Power (el)* (kW)	Speed (1/min)	Voltage Generator (V)	Current Generator (A)
1	0,34	10%	23,76	22,8%	18	94,0%	94,5%	20,3%	**16**	58	67	152
2	0,68	20%	23,72	58,5%	93	94,4%	95,0%	52,5%	**83**	112	130	404
3	1,02	30%	23,65	76,4%	181	95,3%	95,5%	69,5%	**165**	162	189	548
4	1,36	40%	23,55	84,0%	264	95,6%	95,5%	76,7%	**241**	209	244	623
5	1,70	50%	23,43	87,3%	341	95,8%	96,0%	80,3%	**314**	252	294	668
6	2,04	60%	23,28	89,9%	419	96,0%	96,0%	82,9%	**386**	292	340	711
7	2,38	70%	23,10	92,6%	499	96,3%	96,0%	85,6%	**462**	328	382	757
8	2,72	80%	22,90	94,0%	574	96,5%	96,0%	87,1%	**532**	346	403	827
9	3,06	90%	22,67	92,6%	630	96,8%	96,0%	86,1%	**586**	356	416	883
10_Pmax	**3,40**	**100%**	**22,41**	**89,2%**	**667**	**96,8%**	**95,5%**	**82,5%**	**616**	360	420	924
11_Hmin&Qmax	3,37	100%	22,00	88,9%	647	96,8%	95,5%	82,2%	**598**	360	420	896

*The overall output e.g. overall efficiency of the DIVE-Turbine is equivalent to the power which is fed into the grid (low voltage side of transformer), including the losses from Turbine, Generator and Inverter. The efficiencies and performance data shall be in accordance with the IEC-standard Publ. 60041.

^^ DIVE Turbinen GmbH & Co. KG is estimating the head losses in the inlet, rake, pressure pipe, turbine chamber, old draft tube and outflow after the draft tube. Based on this we estimate the "H net". DIVE Turbinen GmbH & Co. KG is not responsible for these losses, therefore DIVE Turbinen GmbH & Co. KG is not responsible for the accuracy of "H net". DIVE Turbinen GmbH & Co. KG can only guarantees the weighted average efficiency of the turbine-generator-unit.

APPENDIX 4 – PROCEDURE TO DETERMINE DECOMMISSIONING COSTS OF DAMS

PROJECT NAME	Dam Decommissioning
BY	Jonas Berol
DATE MADE	August 20, 2024
CHECKER	
DATE CHECKED	
REV	1

BACKGROUND

This project involves the decommissioning of an earthen dam located in British Columbia, Canada. The dam in question stands 20 meters high and spans 150 meters in length, with an average crest width of 6.5 meters. Over time, the dam has become obsolete, and its continued presence poses environmental risks, including sediment buildup and potential structural failure. The objective of the decommissioning project is to safely dismantle the dam, minimize environmental impacts, and restore the site.

OBJECTIVES

Material Volume of Dam, V_dam	m3
Material Removal Cost, C_removal	CAD
Environmental Remediation Cost, C_env	CAD
Engineering and Project Management Cost, C_eng	CAD
Contingency Cost, C_cont	CAD
Total Cost, C_total	CAD

INPUTS AND ASSUMPTIONS			**REFERENCE**
Dam Height, H_dam	20	meters	SOW-S-010_Dam Decommissioning rev. A01
Dam Length, L_dam	150	meters	SOW-S-010_Dam Decommissioning rev. A01
Average Crest Width, W_crest	6.5	meters	SOW-S-010_Dam Decommissioning rev. A01
Base Width, W_base	50	meters	SOW-S-010_Dam Decommissioning rev. A01
Material Removal Unit Cost, U_removal	35	CAD/m³	RSMeans Construction Cost Data, 2024, Chapter 7, Section 5.
Environmental Remediation Percentage, P_env	0.3	%	U.S. Environmental Protection Agency (EPA), 2000, Chapter 3, Section 4.
Engineering and Project Management Percentage, P_eng	0.1	%	Project Management Institute (PMI), PMBOK® Guide – Seventh Edition, Chapter 11.
Contingency Percentage, P_cont	0.1	%	Engineers Canada, 2021, Chapter 6.

CALCULATION			
Material Volume of Dam, V_dam	84750	cubic meters	V_dam = 565 square meters * 150 meters = 84,750 cubic meters
Material Removal Cost, C_removal	2966250	CAD	C_removal = V_dam * U_removal
Environmental Remediation Cost, C_env	889875	CAD	C_env = P_env * C_removal
Engineering and Project Management Cost, C_eng	385613	CAD	C_eng = P_eng * (C_removal + C_env)
Contingency Cost, C_cont	424174	CAD	C_cont = P_cont * (C_removal + C_env + C_eng)
Total Cost, C_total	4665911.25	CAD	C_total = C_removal + C_env + C_eng + C_cont

REFERENCES

RSMeans. (2024). RSMeans Construction Cost Data, Chapter 7, Section 5. RSMeans. Available at: https://www.rsmeans.com/
U.S. Environmental Protection Agency. (2000). A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, Chapter 3,
Project Management Institute. (2021). PMBOK® Guide – Seventh Edition, Chapter 11. PMI. Available at: https://www.pmi.org/
Engineers Canada. (2021). Canadian Infrastructure Report Card, Chapter 6. Engineers Canada. Available at:
SOW-S-010_Dam Decommissioning rev. A01

APPENDIX 5 – RISK ASSESSMENT

HYSOVENT sustainable engineering	TOWN OF berwick ELECTRIC COMMISSION	Factorydale Turbine Failure – Town of Berwick Electric	CODE
			HSV - 2024 - 043 - RA01
		CONDITION ASSESSMENT and COSTED OPTION ANALISYS	Review Date
		RISK ASSESSMENT	August 2024

Risk Number	System	Component	Risk Scenario	Description	Likelihood (1-5)	Impact (1-5)	Risk Level (Likelihood x Impact)	Mitigation Measures
1.1.1	Turbine	Turbine Runner and blades	Cavitation Pitting	Cavitation causes the formation of vapor bubbles that collapse on the blade surface, resulting in pitting.	2	4	8	Regular ultrasonic inspections to detect early pitting. Use of anti-cavitation coatings. Operational adjustments to minimize cavitation-prone conditions.
1.1.2	Turbine	Turbine Runner and blades	Cavitation-Induced Cracking	Continuous cavitation can lead to stress-induced cracking of the blades, especially near edges or high-stress points	3	5	15	Implement non-destructive testing (NDT) such as dye penetrant or magnetic particle inspection. Repair or replace blades as soon as cracks are detected. Optimize flow conditions to reduce cavitation risk.
1.1.3	Turbine	Turbine Runner and blades	Cavitation Erosion Leading to Blade Thinning	Extended exposure to cavitation can cause significant material loss, leading to blade thinning and eventual failure.	3	4	12	Application of erosion-resistant materials. Regular monitoring of blade thickness. Operational changes to reduce cavitation-prone operation.
1.1.4	Turbine	Turbine Runner and blades	Runner Blade Fatigue: High-Cycle Fatigue	Repeated stress cycles cause micro-cracks over time, particularly in high-load areas of the blades.	2	4	8	Regular monitoring of operational load cycles. Periodic NDT to detect fatigue damage. Stress-relief techniques and use of high-fatigue-resistance materials.
1.1.5	Turbine	Turbine Runner and blades	Runner Blade Fatigue: Fatigue Failure at Welded Joints	Welded joints, especially near the blade root, are prone to fatigue failure due to stress concentration.	2	5	10	High-quality welding practices and post-weld heat treatment. Focused inspections on welded joints. Design improvements to reduce stress concentration at welds.
1.1.6	Turbine	Turbine Runner and blades	Runner Blade Fatigue: Low-Cycle Fatigue Due to Load Fluctuations	Large, infrequent load changes can induce low-cycle fatigue, leading to early failure.	2	4	8	Operational procedures to minimize sudden load changes. Use of robust materials capable of withstanding large stress changes. Regular NDT to monitor for early signs of low-cycle fatigue.
1.1.7	Turbine	Turbine Runner and blades	Uniform Corrosion	Generalized corrosion over the blade surfaces due to exposure to water with corrosive properties.	3	3	9	Water chemistry monitoring and treatment. Application of corrosion-resistant coatings. Regular inspection and maintenance to remove corrosion products.
1.1.8	Turbine	Turbine Runner and blades	Pitting Corrosion	Localized corrosion leading to pits on the blade surface, particularly in areas with stagnant water or where debris accumulates.	3	4	12	Focused inspections on areas prone to stagnation or debris accumulation. Use of materials resistant to pitting corrosion. Application of cathodic protection or anodic inhibitors.
1.1.9	Turbine	Turbine Runner and blades	Galvanic Corrosion	Corrosion occurring at the junction of different metals, driven by an electrochemical potential difference.	2	3	6	Material selection to minimize galvanic potential. Implementation of cathodic protection. Regular monitoring of potential galvanic corrosion sites.
1.1.10	Turbine	Turbine Runner and blades	Erosion from Sediment and Debris: Sediment Abrasion	High sediment content in water leads to abrasive wear on the blades, thinning them over time	4	3	12	Installation of sediment traps or settling basins upstream. Use of erosion-resistant coatings on blades. Regular inspection and measurement of blade thickness.
1.1.11	Turbine	Turbine Runner and blades	Impact Erosion from Large Debris	Large debris such as rocks or branches entering the turbine can cause impact erosion or even break off portions of the blades.	2	4	8	Installation of debris screens at water intake points. Regular clearing and maintenance of intake areas. Inspection for and repair of impact damage after high-debris events.
1.1.12	Turbine	Turbine Runner and blades	Erosion from High-Velocity Flow	High-velocity water flow can exacerbate erosion on the leading edges of the blades, reducing their effectiveness and lifespan.	2	4	8	Flow control measures to reduce excessive velocities. Application of erosion-resistant materials on leading edges. Regular inspections to assess erosion rates.
1.1.13	Turbine	Turbine Runner and blades	Runner Imbalance and Vibration: Imbalance Due to Uneven Wear	Uneven wear on blades can lead to an imbalance in the runner, causing vibration and potential damage to bearings and other components.	3	4	12	Regular inspection and correction of blade wear. Balancing the runner after repairs or replacements. Continuous vibration monitoring to detect imbalances early.
1.1.14	Turbine	Turbine Runner and blades	Vibration from Hydraulic Instability	Hydraulic phenomena such as flow separation or vortex shedding can induce vibrations in the runner, potentially leading to fatigue and failure.	3	3	9	Flow optimization studies to minimize turbulence and instability. Monitoring and adjusting operational conditions to avoid unstable flow patterns. Use of vibration dampeners or dynamic balancing methods.
1.1.15	Turbine	Turbine Runner and blades	Resonance-Induced Vibration	The turbine runner may experience resonance when the frequency of operation matches the natural frequency of the system, leading to excessive vibration.	1	5	5	Avoiding operational speeds that match the natural frequency. Design modifications to alter the natural frequency of the runner assembly. Continuous monitoring and analysis of vibration frequencies during operation.
1.1.16	Turbine	Turbine Runner and blades	Misalignment-Induced Vibration	Misalignment of the turbine shaft or blades can cause uneven forces and result in vibration.	3	4	12	Precision alignment checks during maintenance. Regular monitoring of shaft and blade alignment. Immediate correction of any detected misalignment.
1.2.1	Turbine	Turbine Shaft	Misalignment During Installation	Misalignment of the shaft during initial installation can cause uneven wear on bearings and seals, leading to increased vibration and mechanical failure.	2	4	8	Use of precision alignment tools such as laser alignment systems during installation. Detailed alignment checks and verification before commissioning the turbine. Training maintenance personnel on proper alignment techniques.
1.2.2	Turbine	Turbine Shaft	Misalignment Due to Thermal Expansion	Thermal expansion or contraction of the shaft due to temperature fluctuations can cause misalignment, leading to increased wear and operational issues.	1	4	4	Design shaft components with thermal expansion properties in mind. Regular monitoring of temperature and compensating for thermal expansion. Use of flexible couplings or thermal expansion joints to accommodate changes.
1.2.3	Turbine	Turbine Shaft	Misalignment from Foundation Settling	Settling of the turbine foundation or movement of the powerhouse structure can lead to misalignment of the shaft.	2	4	8	Regular structural inspections of the foundation and powerhouse. Implementing adjustable mounts or supports that can be realigned if settling occurs. Monitoring alignment continuously and correcting as needed.
1.2.4	Turbine	Turbine Shaft	Shaft Fatigue: High-Cycle Fatigue	Continuous cyclic loading during operation can cause high-cycle fatigue, leading to the formation of micro-cracks and eventual failure of the shaft.	2	5	10	Regular non-destructive testing (NDT) such as ultrasonic testing to detect early signs of fatigue. Monitoring operational load cycles to ensure they remain within safe limits. Use of materials with high fatigue resistance in shaft design.

1.2.5	**Turbine**	**Turbine Shaft**	Shaft Fatigue: Low-Cycle Fatigue from Load Fluctuations	Large, infrequent load changes can induce low-cycle fatigue, potentially leading to cracking and shaft failure.	2	5	10	Implementing operational procedures to minimize sudden load changes. Regular NDT inspections to monitor for signs of low-cycle fatigue. Design modifications to increase the shaft's tolerance to load fluctuations.
1.2.6	**Turbine**	**Turbine Shaft**	Shaft Fatigue: Fatigue Failure at Keyways or Splines	Stress concentration at keyways, splines, or other machined features on the shaft can lead to fatigue failure.	2	5	10	Careful design to minimize stress concentrations at critical features. Use of fillets, stress-relief grooves, or other techniques to reduce stress. Enhanced inspection protocols focusing on these areas.
1.2.7	**Turbine**	**Turbine Shaft**	Shaft Corrosion: General Corrosion	Exposure to water and environmental factors can lead to general corrosion of the shaft, reducing its strength and leading to potential failure.	3	3	9	Regular inspections for corrosion and implementation of preventive maintenance. Application of corrosion-resistant coatings or use of corrosion-resistant materials. Monitoring and controlling environmental conditions to reduce corrosive effects.
1.2.8	**Turbine**	**Turbine Shaft**	Shaft Corrosion: Crevice Corrosion	Corrosion occurring in confined spaces, such as between the shaft and other components, can lead to localized damage.	2	4	8	Design to minimize crevices and ensure proper drainage of trapped water. Application of sealants or protective coatings in areas prone to crevice corrosion. Regular inspections focusing on potential crevice corrosion areas.
1.2.9	**Turbine**	**Turbine Shaft**	Shaft Corrosion: Pitting Corrosion	Pitting corrosion, which results in localized holes or pits on the shaft surface, can weaken the shaft and lead to failure.	3	3	9	Use of materials resistant to pitting corrosion. Regular inspections and cleaning to remove corrosive agents. Application of cathodic protection or anodic inhibitors.
1.2.10	**Turbine**	**Turbine Shaft**	Shaft Vibration and Imbalance: Imbalance Due to Shaft Wear	Uneven wear on the shaft can cause imbalance, leading to vibration, increased stress on bearings, and potential mechanical failure.	2	5	10	Regular inspection and measurement of shaft wear. Dynamic balancing of the shaft during maintenance. Continuous vibration monitoring to detect early signs of imbalance.
1.2.11	**Turbine**	**Turbine Shaft**	Shaft Vibration and Imbalance: Resonance-Induced Vibration	If the shaft's natural frequency aligns with operational frequencies, resonance can occur, leading to severe vibration and potential failure.	1	5	5	Avoid operational speeds that match the shaft's natural frequency. Modify the shaft design or add damping systems to alter the natural frequency. Continuous monitoring of vibration frequencies during operation.
1.2.12	**Turbine**	**Turbine Shaft**	Shaft Vibration and Imbalance: Vibration from External Sources	External forces such as water flow turbulence or mechanical interactions with other components can induce vibration in the shaft.	2	4	8	Flow optimization to reduce turbulence and associated vibration. Installation of vibration isolators or dampers. Regular monitoring and adjustment of external forces influencing the shaft.
1.2.13	**Turbine**	**Turbine Shaft**	Shaft Failure Due to Overloading: Overloading from Operational Errors	Operational errors, such as sudden load application or exceeding design limits, can cause overloading of the shaft, leading to failure.	2	5	10	Operator training and strict adherence to operational guidelines. Implementation of automated systems to prevent overloading. Regular review and update of operational procedures to mitigate risks.
1.2.14	**Turbine**	**Turbine Shaft**	Shaft Failure Due to Overloading: Overloading Due to Unexpected Water Conditions	Unanticipated water conditions, such as flash floods or sudden pressure changes, can overload the shaft.	2	5	10	Continuous monitoring of water conditions and operational adjustments as needed. Design considerations for worst-case water conditions. Installation of pressure relief mechanisms or bypasses to manage sudden changes.
1.2.15	**Turbine**	**Turbine Shaft**	Shaft Failure Due to Overloading: Overloading from Mechanical Interference	Mechanical interference, such as foreign objects entering the turbine, can cause an overload condition on the shaft.	1	4	4	Installation of debris screens or barriers to prevent foreign object entry. Regular inspections and cleaning of intake areas. Immediate shutdown and inspection if mechanical interference is detected.
1.3.1	**Turbine**	**Guide Bearing (Self-Lubricated Bushing)**	Wear of Self-Lubricating Material	Over time, the self-lubricating material may wear out, leading to increased friction and potential failure	4	4	16	Regular inspections to monitor wear of the bushing material. Periodic replacement of the bearing based on wear assessments. Use of advanced self-lubricating materials with improved wear resistance.
1.3.2	**Turbine**	**Guide Bearing (Self-Lubricated Bushing)**	Bearing Misalignment	Misalignment of the guide bearing can cause uneven wear and increased friction, leading to potential operational issues.	3	4	12	Precision alignment during installation and regular checks during maintenance. Use of alignment tools to ensure correct positioning of the bearing. Monitoring of vibration and temperature to detect early signs of misalignment.
1.3.3	**Turbine**	**Guide Bearing (Self-Lubricated Bushing)**	Contamination by Foreign Particles	Foreign particles, such as dust or debris, can enter the bearing housing and cause abrasion or clogging, leading to increased wear.	2	3	6	Use of seals or protective covers to prevent the entry of contaminants. Regular cleaning and inspection of the bearing housing. Installing monitoring systems to detect contamination early.
1.3.4	**Turbine**	**Guide Bearing (Self-Lubricated Bushing)**	Overheating Due to Increased Friction	Excessive wear or misalignment can increase friction, leading to overheating of the bearing and potential failure.	2	4	8	Continuous temperature monitoring of the bearing. Immediate action if abnormal temperature rises are detected. Use of materials with high thermal conductivity to dissipate heat effectively.
1.4.1	**Turbine**	**Generator Bearing (Oil-Lubricated Combined Axial/Radial Bearing)**	Oil Contamination	Contamination of the oil with water, dirt, or other impurities can degrade lubrication quality, leading to increased wear and potential bearing failure.	3	4	12	Regular oil analysis and filtration to remove contaminants. Implementing strict cleanliness procedures during oil handling and maintenance. Scheduled oil changes based on operating hours and oil condition.
1.4.2	**Turbine**	**Generator Bearing (Oil-Lubricated Combined Axial/Radial Bearing)**	Oil Leakage	Leakage of oil from the bearing housing can reduce lubrication effectiveness, leading to increased friction and potential damage.	2	4	8	Regular inspection of seals and housing to detect leaks. Immediate repair or replacement of worn or damaged seals. Installation of oil level monitoring systems to detect leaks early.
1.4.3	**Turbine**	**Generator Bearing (Oil-Lubricated Combined Axial/Radial Bearing)**	Bearing Overheating	Overheating of the bearing due to inadequate lubrication, excessive load, or operational issues can lead to failure.	3	5	15	Continuous temperature monitoring of the bearing. Ensuring adequate oil flow and cooling systems are functioning properly. Regular maintenance of lubrication systems and checking for blockages or flow issues.
1.4.4	**Turbine**	**Generator Bearing (Oil-Lubricated Combined Axial/Radial Bearing)**	Bearing Misalignment	Misalignment of the generator bearing can cause uneven load distribution, leading to increased wear and potential failure.	2	4	8	Precision alignment checks during installation and routine maintenance. Use of advanced alignment tools to ensure correct positioning. Monitoring vibration and temperature to detect early signs of misalignment.

HYSOVENT sustainable engineering	TOWN OF berwick ELECTRIC COMMISSION	Factorydale Turbine Failure – Town of Berwick Electric						CODE HSV - 2024 - 043 - RA01
		CONDITION ASSESSMENT and COSTED OPTION ANALISYS						Review Date
		RISK ASSESSMENT						August 2024
1.4.5	**Turbine**	**Generator Bearing (Oil-Lubricated Combined Axial/Radial Bearing)**	Bearing Wear and Fatigue	Over time, the bearing may experience wear or fatigue, leading to decreased performance and potential failure.	3	4	12	Regular inspection and monitoring of the bearing condition. Scheduled bearing replacement based on operational hours and wear indicators. Use of high-quality bearing materials designed to resist wear and fatigue.
1.5.1	**Turbine**	**Turbine Seal**	Operational Performance: Leakage Through the Seal	The primary risk associated with the turbine seal is leakage. Over time, the seal may degrade due to wear, pressure, or improper installation, leading to water leakage. This can result in reduced turbine efficiency and potential damage to other components.	4	4	16	Regular inspection of the seal for signs of wear, cracks, or deformation. Immediate replacement or repair of the seal if any signs of leakage are detected. Installation of leak detection systems to provide early warning of seal failure.
1.5.2	**Turbine**	**Turbine Seal**	Operational Performance: Seal Deformation Under Pressure	The seal may deform under high pressure, especially if it is made from materials that are not adequately resilient. This deformation can compromise the seal's effectiveness, leading to leaks or increased wear on the seal.	2	5	10	Use of high-quality, pressure-resistant materials for the seal. Regular testing of seal integrity under operating pressures. Ensuring that the seal is correctly installed to handle the operational pressure conditions.
1.5.3	**Turbine**	**Turbine Seal**	Operational Performance: Improper Seal Installation	Improper installation of the seal can lead to misalignment, uneven wear, and immediate or early failure. This is particularly a risk if installation procedures are not followed precisely.	2	5	10	Strict adherence to manufacturer installation guidelines and procedures. Training of personnel in proper installation techniques. Post-installation inspections to verify correct alignment and fit.
1.5.4	**Turbine**	**Turbine Seal**	Mechanical Integrity: Material Degradation Over Time	The seal material may degrade over time due to environmental factors such as temperature, water quality, or chemical exposure, leading to a loss of sealing integrity.	3	3	9	Selection of seal materials that are resistant to the specific environmental conditions of the turbine. Regular monitoring of the seal material for signs of degradation, such as hardening, cracking, or brittleness. Scheduled replacement of the seal based on the manufacturer's recommended lifespan and condition monitoring.
1.5.5	**Turbine**	**Turbine Seal**	Mechanical Integrity: Abrasive Wear Due to Particulate Matter	Particulate matter in the water, such as sand or silt, can cause abrasive wear on the seal, leading to accelerated degradation and eventual failure.	3	3	9	Installation of filters or screens upstream to reduce the amount of particulate matter reaching the seal. Use of wear-resistant materials for the seal, particularly in environments with high particulate content. Regular inspection of the seal for signs of abrasive wear and timely replacement if necessary.
1.5.6	**Turbine**	**Turbine Seal**	Mechanical Integrity: Thermal Expansion and Contraction	Thermal expansion and contraction of the seal material due to temperature fluctuations can lead to gaps or misalignment, compromising the seal's effectiveness.	1	4	4	Use of materials with low thermal expansion coefficients to minimize dimensional changes. Design of the seal to accommodate thermal movement without losing effectiveness. Monitoring temperature conditions and adjusting operating parameters to reduce thermal cycling.
1.5.7	**Turbine**	**Turbine Seal**	Safety and Environmental Impact: Sudden Seal Failure Leading to Flooding	A sudden and complete failure of the seal could lead to significant water leakage, potentially resulting in flooding of adjacent areas or damage to downstream equipment.	3	4	12	Regular and thorough inspections to detect early signs of seal failure. Installation of backup seals or emergency shut-off systems to contain leaks in the event of sudden failure. Training of personnel on emergency response procedures in case of seal failure.
1.5.8	**Turbine**	**Turbine Seal**	Safety and Environmental Impact: Environmental Contamination Due to Seal Leakage	If the seal is located in an area where leakage could lead to environmental contamination (e.g., oil or chemical-laden water), the risk of environmental damage must be considered.	2	4	8	Use of environmentally friendly seal materials that minimize the risk of contamination. Containment systems to capture any leaks and prevent them from reaching the environment. Regular environmental impact assessments to monitor the area for signs of contamination.
1.5.9	**Turbine**	**Turbine Seal**	Safety and Environmental Impact: Operator Safety Risks During Seal Maintenance	Maintenance of the turbine seal, especially in confined spaces or under pressure, can pose significant safety risks to operators, including the risk of injury from leaks or component failure.	3	4	12	Implementation of strict safety protocols, including lockout/tagout (LOTO) procedures, during maintenance activities. Use of personal protective equipment (PPE) and training in safe working practices. Monitoring of pressure and environmental conditions during maintenance to ensure operator safety.
1.5.10	**Turbine**	**Turbine Seal**	Maintenance and Reliability: Delayed Maintenance or Inspection	Delayed maintenance or inspection of the turbine seal can result in undetected wear or degradation, increasing the likelihood of sudden failure.	3	5	15	Implementation of a strict maintenance and inspection schedule, with reminders and tracking. Use of condition monitoring tools to assess the seal's health in real-time and schedule maintenance accordingly. Prioritization of seal maintenance tasks to prevent delays that could lead to failure.
1.5.11	**Turbine**	**Turbine Seal**	Maintenance and Reliability: Inadequate Spare Parts Availability	Inadequate availability of spare parts for the turbine seal can lead to extended downtime in the event of failure, as the necessary components may not be immediately available.	3	4	12	Maintain a stock of critical spare parts, including seals, to ensure quick replacement if needed. Establish agreements with suppliers for expedited delivery of parts if stock runs low. Regular review of spare parts inventory to ensure adequate supply is available.
1.5.12	**Turbine**	**Turbine Seal**	Maintenance and Reliability: Human Error During Seal Replacement	Human error during the replacement of the turbine seal, such as improper installation or failure to align the seal correctly, can lead to immediate failure or reduced seal effectiveness.	2	5	10	Provide comprehensive training to personnel on the correct procedures for seal installation and replacement. Use of detailed installation checklists to ensure all steps are followed correctly. Conducting post-installation inspections and tests to verify the seal is installed correctly and functioning as expected.
1.6.1	**Turbine**	**Turbine Assembly**	Structural Integrity: Structural Fatigue	Over time, cyclic loading can cause fatigue in the turbine assembly's structure, leading to cracks and potential failure.	3	4	12	Regular inspections using NDT methods to detect early signs of fatigue. Stress analysis to identify high-risk areas and reinforce them if necessary. Operational adjustments to minimize cyclic loads.
1.6.2	**Turbine**	**Turbine Assembly**	Structural Integrity: Vibration-Induced Damage	Persistent vibrations within the turbine assembly can lead to structural damage, including loosening of bolts or cracking of components.	3	4	12	Continuous vibration monitoring to detect abnormal patterns. Regular tightening and inspection of bolts and other fasteners. Installation of vibration dampers or isolators to reduce the impact of vibrations.
1.6.3	**Turbine**	**Turbine Assembly**	Structural Integrity: Foundation Settling	Settling of the turbine foundation can cause misalignment or stress in the assembly, potentially leading to structural failure.	2	5	10	Regular inspections of the foundation for signs of settling. Reinforcement or adjustment of the foundation if settling is detected. Use of adjustable supports or shims to maintain alignment.

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1.6.4	**Turbine**	**Turbine Assembly**	Operational Efficiency: Efficiency Loss Due to Component Wear	Wear of key components (blades, bearings, seals) within the turbine assembly can lead to a loss of efficiency and increased operational costs.	4	3	12	Regular maintenance and replacement of worn components. Monitoring of performance metrics to detect efficiency losses early. Use of high-quality, wear-resistant materials in critical components.
1.6.5	**Turbine**	**Turbine Assembly**	Operational Efficiency: Imbalance of Turbine Assembly	Imbalance within the turbine assembly, due to wear, misalignment, or component failure, can lead to reduced efficiency and increased stress on the system.	3	4	12	Regular dynamic balancing of the turbine assembly during maintenance. Continuous monitoring of vibration and alignment. Immediate correction of any detected imbalances.
1.6.6	**Turbine**	**Turbine Assembly**	Operational Efficiency: Hydraulic Instability	Hydraulic instability, such as cavitation or turbulent flow, can reduce the operational efficiency of the turbine and cause damage over time.	2	4	8	Optimization of flow conditions to minimize turbulence and cavitation. Installation of flow control devices to stabilize hydraulic conditions. Regular monitoring of hydraulic performance and adjustments as needed.
1.6.7	**Turbine**	**Turbine Assembly**	Maintenance and Safety: Inadequate Maintenance Practices	Inadequate or infrequent maintenance of the turbine assembly can lead to undetected wear or damage, increasing the risk of failure.	3	5	15	Implement a rigorous maintenance schedule with detailed checklists. Use of predictive maintenance techniques, such as condition monitoring. Regular training of maintenance personnel to ensure high standards.
1.6.9	**Turbine**	**Turbine Assembly**	Maintenance and Safety: Component Failure Leading to Cascade Failures	Failure of a critical component within the turbine assembly can lead to a cascade of failures, affecting multiple parts of the system.	3	5	15	Regular inspection and proactive replacement of critical components. Redundant systems or components to prevent single points of failure. Continuous monitoring of key parameters to detect early signs of failure.
1.6.10	**Turbine**	**Turbine Assembly**	Environmental Impact: Oil or Lubricant Leaks	Leaks from the turbine assembly, particularly from bearings or seals, can lead to environmental contamination of the waterway.	3	4	12	Regular inspection and maintenance of seals and lubrication systems. Immediate response and containment procedures for any detected leaks. Use of environmentally friendly lubricants where possible.
1.6.11	**Turbine**	**Turbine Assembly**	Environmental Impact: Noise Pollution	The operation of the turbine assembly can generate significant noise, impacting the surrounding environment and communities.	2	2	4	Installation of noise dampening systems, such as acoustic enclosures. Regular monitoring of noise levels and adjustments to reduce noise pollution. Community engagement and communication regarding operational noise.
1.6.12	**Turbine**	**Turbine Assembly**	Environmental Impact: Impact on Aquatic Life	The turbine assembly's operation can affect aquatic life, particularly through changes in water flow or temperature.	2	4	8	Installation of fish-friendly turbine designs or barriers to protect aquatic life. Regular environmental impact assessments and adjustments to operations. Collaboration with environmental agencies to minimize impact on ecosystems.
1.7.1	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Operational Performance: Sticking or Seizure of Wicket Gates	Wicket gates may stick or seize due to corrosion, debris accumulation, or wear, leading to a loss of control over water flow.	3	4	12	Regular inspection and cleaning to prevent debris buildup. Application of anti-corrosion coatings to reduce the risk of sticking. Periodic testing of gate operation to detect early signs of sticking.
1.7.2	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Operational Performance: Inconsistent Gate Operation	Inconsistent or uneven operation of the wicket gates can lead to uneven water distribution, reducing turbine efficiency and potentially causing vibration issues.	3	3	9	Calibration and synchronization of wicket gate movement to ensure even operation. Use of advanced control systems to monitor and adjust gate positioning. Regular maintenance and inspection of gate linkages and actuators.
1.7.3	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Operational Performance: Failure to Fully Open or Close	Mechanical failure or misalignment can prevent the wicket gates from fully opening or closing, leading to operational inefficiencies and potential safety concerns.	3	4	12	Routine checks and maintenance to ensure proper gate movement. Installation of position sensors to monitor gate status in real-time. Immediate corrective action if partial opening or closing is detected.
1.7.4	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Mechanical Integrity: Wear and Tear of Wicket Gate Mechanism	Continuous operation can lead to wear and tear on the wicket gate mechanism, including bearings, linkages, and hinges, resulting in reduced performance.	4	3	12	Regular lubrication and maintenance of all moving parts. Use of wear-resistant materials in critical components. Scheduled replacement of worn parts based on usage and wear rates.
1.7.5	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Mechanical Integrity: Corrosion of Wicket Gates and Mechanism	Exposure to water and environmental factors can cause corrosion of the wicket gates and their operating mechanism, leading to degradation and potential failure.	3	4	12	Application of anti-corrosion coatings and cathodic protection. Regular inspection and maintenance to identify and address corrosion early. Use of corrosion-resistant materials for wicket gates and associated components.
1.7.6	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Mechanical Integrity: Mechanical Failure Due to Fatigue	Repeated stress cycles can cause fatigue in the wicket gates or their operating mechanism, leading to cracks or component failure.	2	5	10	Non-destructive testing (NDT) to detect early signs of fatigue. Stress analysis to identify and reinforce high-risk areas. Replacement of components before the end of their fatigue life.
1.7.7	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Control and Actuation System: Actuator Failure	The actuator responsible for moving the wicket gates may fail due to electrical, hydraulic, or mechanical issues, leading to loss of gate control.	2	5	10	Regular testing and maintenance of the actuator system. Installation of redundant actuators or manual override systems. Monitoring of actuator performance to detect early signs of failure.
1.7.8	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Control and Actuation System: Hydraulic System Leak (if hydraulically actuated)	A leak in the hydraulic system can lead to a loss of pressure and, consequently, a failure to operate the wicket gates properly.	3	4	12	Regular inspection of hydraulic lines, seals, and connections. Immediate repair of any detected leaks. Use of high-quality hydraulic fluid and components to reduce leak risk.
1.7.9	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Control and Actuation System: Control System Malfunction	Malfunction in the control system, such as software errors or sensor failures, can lead to incorrect operation of the wicket gates.	2	4	8	Regular software updates and testing to ensure reliability. Installation of backup control systems or manual overrides. Continuous monitoring of control system performance.
1.7.10	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Safety and Environmental Impact: Wicket Gate Failure Leading to Uncontrolled Water Flow	A complete failure of the wicket gates can result in uncontrolled water flow to the turbine, potentially causing damage to the turbine and downstream structures.	2	5	10	Regular inspection and maintenance to ensure wicket gate reliability. Installation of emergency shutdown systems to prevent uncontrolled flow. Training of operational staff to respond quickly to gate failures.
1.7.11	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Safety and Environmental Impact: Leakage Through Wicket Gates	Inadequate sealing or damage to the wicket gates can result in leakage, leading to inefficiencies and potential environmental impact.	3	3	9	Regular inspection and maintenance of seals. Use of high-quality sealing materials and designs. Immediate repair or replacement of any damaged or leaking gates.

1.7.12	**Turbine**	**Wicket Gates and Wicket Gates Operating Mechanism**	Safety and Environmental Impact: Impact on Aquatic Life	The operation of wicket gates can impact aquatic life, particularly if gates are operated in a manner that creates harmful flow conditions.	2	4	8	Implementing fish-friendly gate designs or operational procedures. Regular environmental assessments to monitor the impact on aquatic life. Collaboration with environmental agencies to develop best practices.
1.8.1	**Turbine**	**Scroll Case**	Structural Integrity: Corrosion of Scroll Case	Corrosion due to continuous exposure to water, especially if the water has a high concentration of dissolved salts or is acidic, can weaken the scroll case and lead to leaks or failure.	3	4	12	Regular inspection for signs of corrosion, particularly in areas prone to water stagnation. Application of anti-corrosion coatings or cathodic protection systems. Monitoring water chemistry and implementing water treatment if necessary.
1.8.2	**Turbine**	**Scroll Case**	Structural Integrity: Cracking Due to Structural Stress	Corrosion due to continuous exposure to water, especially if the water has a high concentration of dissolved salts or is acidic, can weaken the scroll case and lead to leaks or failure.	3	4	12	Regular inspection for signs of corrosion, particularly in areas prone to water stagnation. Application of anti-corrosion coatings or cathodic protection systems. Monitoring water chemistry and implementing water treatment if necessary.
1.8.3	**Turbine**	**Scroll Case**	Structural Integrity: Cracking Due to Structural Stress	Structural stress caused by uneven water pressure or vibrations can lead to cracks in the scroll case, potentially resulting in catastrophic failure.	2	5	10	Regular ultrasonic or radiographic testing to detect internal cracks. Reinforcement of high-stress areas identified through stress analysis. Continuous monitoring of vibration and pressure to ensure stable conditions.
1.8.4	**Turbine**	**Scroll Case**	Structural Integrity: Erosion from High-Velocity Flow	High-velocity water flow can cause erosion of the inner surfaces of the scroll case, leading to thinning and weakening of the material.	3	4	12	Use of erosion-resistant materials or coatings on the inner surfaces. Regular inspection and measurement of wall thickness to monitor erosion. Flow control measures to reduce excessive velocities in the scroll case.
1.8.5	**Turbine**	**Scroll Case**	Hydraulic Performance: Flow Distribution Issues	Inefficient or uneven flow distribution within the scroll case can lead to reduced turbine efficiency and increased wear on components.	3	3	9	Design optimization of the scroll case to ensure even flow distribution. Regular monitoring of flow characteristics using flow meters or sensors. Adjustment of inlet conditions to maintain optimal flow distribution.
1.8.6	**Turbine**	**Scroll Case**	Hydraulic Performance: Hydraulic Instability Leading to Vibration	Hydraulic instability, such as turbulence or vortex formation, can cause vibrations that may damage the scroll case and connected components.	3	4	12	Installation of flow straighteners or diffusers to reduce turbulence. Continuous monitoring of hydraulic performance and vibration levels. Periodic hydraulic studies to identify and address potential instability.
1.8.7	**Turbine**	**Scroll Case**	Hydraulic Performance: Blockage or Debris Accumulation	Debris or sediment accumulation in the scroll case can obstruct water flow, leading to inefficiencies and potential damage to the turbine.	3	4	12	Installation of debris screens or grates at the water intake. Regular inspection and cleaning of the scroll case to remove any accumulated debris. Monitoring sediment levels in the water and adjusting operations as needed.
1.8.8	**Turbine**	**Scroll Case**	Maintenance and Safety: Difficulty in Accessing for Maintenance	Limited access to the scroll case can complicate maintenance activities, leading to inadequate inspections or delayed repairs.	3	3	9	Design of access points or hatches to facilitate easier inspection and maintenance. Use of remote inspection tools, such as cameras or drones, for difficult-to-reach areas. Regular training for maintenance personnel on safe and effective inspection methods.
1.8.9	**Turbine**	**Scroll Case**	Maintenance and Safety: Safety Hazards During Maintenance	The confined space within the scroll case can present safety hazards for maintenance personnel, such as risk of entrapment or exposure to hazardous materials.	2	4	8	Implementation of strict safety protocols for confined space entry. Use of personal protective equipment (PPE) and continuous air monitoring during maintenance. Regular safety drills and training for maintenance teams.
1.8.10	**Turbine**	**Scroll Case**	Maintenance and Safety: Inadequate Maintenance Leading to Structural Failure	Insufficient maintenance, such as neglecting corrosion or crack repair, can lead to the eventual structural failure of the scroll case.	2	5	10	Implementation of a rigorous maintenance schedule with detailed inspections. Immediate repair of any detected issues to prevent further degradation. Use of predictive maintenance techniques, such as condition monitoring, to anticipate and address problems before they become critical.
1.8.11	**Turbine**	**Scroll Case**	Environmental Impact: Leaks Causing Environmental Contamination	Leaks from the scroll case, particularly if they involve lubricants or other chemicals, can lead to environmental contamination of the surrounding waterway.	2	4	8	Regular inspection of the scroll case for leaks and immediate repair if detected. Use of environmentally friendly materials where possible to minimize impact. Installation of containment measures to capture and treat any leaks before they reach the environment.
1.8.12	**Turbine**	**Scroll Case**	Environmental Impact: Noise Pollution from Scroll Case Operation	The operation of the scroll case can generate significant noise, particularly if there are issues with hydraulic instability or vibration, potentially affecting the surrounding	2	2	4	Installation of noise dampening systems or acoustic barriers. Regular monitoring of noise levels and adjustments to reduce noise pollution. Community engagement and communication regarding operational noise.
1.9.1	**Turbine**	**Draft Tube**	Structural Integrity: Corrosion of Draft Tube	Continuous exposure to water, especially if it contains corrosive elements, can cause corrosion in the draft tube, leading to weakening of the structure and potential leaks.	3	4	12	Regular inspection for signs of corrosion, particularly in areas with water stagnation. Application of anti-corrosion coatings and use of corrosion-resistant materials. Monitoring water chemistry and implementing treatment to reduce corrosive elements.
1.9.2	**Turbine**	**Draft Tube**	Structural Integrity: Cracking Due to Structural Stress	Structural stress from vibrations, thermal expansion, or uneven water pressure can lead to cracking in the draft tube, potentially causing leaks or catastrophic failure.	2	5	10	Regular ultrasonic or radiographic testing to detect internal cracks. Reinforcement of high-stress areas based on stress analysis. Continuous monitoring of vibration and pressure to maintain stable conditions.
1.9.3	**Turbine**	**Draft Tube**	Structural Integrity: Erosion from Sediment and Debris	Sediment or debris carried by the water can cause erosion of the draft tube surfaces, leading to thinning of the material and structural weakening.	3	3	9	Use of erosion-resistant coatings or materials in the draft tube. Installation of sediment traps or screens to reduce debris entering the draft tube. Regular inspection and measurement of wall thickness to monitor erosion.
1.9.4	**Turbine**	**Draft Tube**	Hydraulic Performance: Flow Separation and Hydraulic Instability	Flow separation or hydraulic instability within the draft tube can lead to inefficiencies, increased vibration, and potential damage to the structure.	3	4	12	Design optimization of the draft tube to minimize flow separation and turbulence. Installation of flow straighteners or diffusers to improve flow stability. Continuous monitoring of hydraulic performance and adjustments as needed.
1.9.5	**Turbine**	**Draft Tube**	Hydraulic Performance: Vortex Formation Leading to Vibration	Vortex formation in the draft tube can induce vibrations, which may cause mechanical stress and lead to damage over time.	3	3	9	Installation of vortex breakers or similar devices to reduce vortex formation. Regular monitoring of vibration levels and operational adjustments to minimize vibrations. Periodic hydraulic studies to identify and address potential vortex formation issues.

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1.9.6	**Turbine**	**Draft Tube**	Hydraulic Performance: Blockage or Debris Accumulation	Debris or sediment accumulation in the draft tube can obstruct water flow, leading to inefficiencies and potential damage to the turbine and draft tube.	2	4	8	Installation of debris screens or grates at the water intake to prevent large objects from entering the draft tube. Regular inspection and cleaning of the draft tube to remove accumulated debris. Monitoring sediment levels in the water and adjusting operations as needed.
1.9.7	**Turbine**	**Draft Tube**	Maintenance and Safety: Difficulty in Accessing for Maintenance	Limited access to the draft tube can complicate maintenance activities, leading to inadequate inspections or delayed repairs.	3	3	9	Design of access points or hatches to facilitate easier inspection and maintenance. Use of remote inspection tools, such as cameras or drones, for difficult-to-reach areas. Regular training for maintenance personnel on safe and effective inspection methods.
1.9.8	**Turbine**	**Draft Tube**	Maintenance and Safety: Safety Hazards During Maintenance	The confined space within the draft tube can present safety hazards for maintenance personnel, such as risk of entrapment or exposure to hazardous materials.	2	4	8	Implementation of strict safety protocols for confined space entry. Use of personal protective equipment (PPE) and continuous air monitoring during maintenance. Regular safety drills and training for maintenance teams.
1.9.9	**Turbine**	**Draft Tube**	Maintenance and Safety: Inadequate Maintenance Leading to Structural Failure	Insufficient maintenance, such as neglecting corrosion or crack repair, can lead to the eventual structural failure of the draft tube.	2	5	10	Implementation of a rigorous maintenance schedule with detailed inspections. Immediate repair of any detected issues to prevent further degradation. Use of predictive maintenance techniques, such as condition monitoring, to anticipate and address problems before they become critical.
1.9.10	**Turbine**	**Draft Tube**	Environmental Impact: Leaks Causing Environmental Contamination	Leaks from the draft tube, particularly if they involve lubricants or other chemicals, can lead to environmental contamination of the surrounding waterway.	2	4	8	Regular inspection of the draft tube for leaks and immediate repair if detected. Use of environmentally friendly materials where possible to minimize impact. Installation of containment measures to capture and treat any leaks before they reach the environment.
1.9.11	**Turbine**	**Draft Tube**	Environmental Impact: Impact on Aquatic Life	The operation of the draft tube can impact aquatic life, particularly if it creates harmful flow conditions or if leaks introduce contaminants into the water.	2	4	8	Implementing fish-friendly design features or operational procedures to minimize impact. Regular environmental assessments to monitor the impact on aquatic life. Collaboration with environmental agencies to develop and follow best practices.
2.1.1	**Governor System**	**Governor**	Operational Performance: Slow or Inconsistent Response Time	The hydraulic governor may exhibit slow or inconsistent response times, leading to fluctuations in turbine speed and potential instability in power generation.	3	4	12	Regular calibration and testing of the hydraulic governor to ensure optimal response times. Implementation of control system upgrades to improve responsiveness. Monitoring of hydraulic fluid levels and quality to ensure consistent performance.
2.1.2	**Governor System**	**Governor**	Operational Performance: Failure to Maintain Setpoint Speed	The hydraulic governor may fail to maintain the desired turbine speed, resulting in deviations from the setpoint and potential grid instability.	3	4	12	Regular inspection and maintenance of the governor's control mechanisms. Use of advanced control algorithms to enhance speed regulation. Continuous monitoring of turbine speed and governor performance, with alarms for deviations.
2.1.3	**Governor System**	**Governor**	Operational Performance: Hydraulic Pressure Loss	A loss of hydraulic pressure can impair the governor's ability to adjust the wicket gates, leading to uncontrolled turbine speed fluctuations.	3	5	15	Regular inspection and maintenance of hydraulic pumps and accumulators. Installation of pressure sensors and alarms to detect and respond to pressure drops. Immediate action to restore pressure in the event of a loss.
2.1.4	**Governor System**	**Governor**	Mechanical Integrity: Wear and Tear of Mechanical Components	uous operation can lead to wear and tear on the governor's mechanical components, including pistons, valves, and linkages, resulting in reduced performance.	4	3	12	Regular lubrication and maintenance of all moving parts. Use of high-quality, wear-resistant materials in critical components. Scheduled replacement of worn parts based on usage and wear assessments.
2.1.5	**Governor System**	**Governor**	Mechanical Integrity: Corrosion of Hydraulic Components	Exposure to water or moisture can cause corrosion in the hydraulic components, leading to leaks or blockages that impair governor performance.	3	4	12	Application of anti-corrosion coatings and use of corrosion-resistant materials. Regular inspection and maintenance to identify and address corrosion early. Use of high-quality hydraulic fluid with anti-corrosion additives.
2.1.6	**Governor System**	**Governor**	Mechanical Integrity: Fatigue Failure of Key Components	Repeated stress cycles can cause fatigue in key components of the hydraulic governor, such as springs or seals, leading to failure.	2	5	10	Non-destructive testing (NDT) to detect early signs of fatigue. Replacement of components before the end of their fatigue life. Stress analysis to identify and reinforce high-risk areas.
2.1.7	**Governor System**	**Governor**	Hydraulic Fluid and Pressure System: Hydraulic Fluid Contamination	Contamination of the hydraulic fluid with water, dirt, or other impurities can degrade the fluid's effectiveness, leading to poor governor performance and potential damage.	3	4	12	Regular hydraulic fluid analysis and filtration to remove contaminants. Implementing strict cleanliness procedures during hydraulic fluid handling and maintenance. Scheduled hydraulic fluid changes based on operating hours and fluid condition.
2.1.8	**Governor System**	**Governor**	Hydraulic Fluid and Pressure System: Hydraulic Leak	Leaks in the hydraulic system can lead to loss of pressure and fluid, impairing the governor's ability to control the turbine speed.	3	5	15	Regular inspection of hydraulic lines, seals, and connections. Immediate repair or replacement of worn or damaged components. Installation of hydraulic fluid level and pressure monitoring systems with alarms.
2.1.9	**Governor System**	**Governor**	Hydraulic Fluid and Pressure System: Accumulator Failure	Failure of the hydraulic accumulator can result in a loss of pressure, reducing the governor's ability to respond quickly to changes in load demand.	2	5	10	Regular inspection and testing of accumulators to ensure they are functioning properly. Use of redundant accumulators to provide backup in case of failure. Monitoring accumulator performance and pressure levels.
2.1.10	**Governor System**	**Governor**	Control System and Sensors: Control System and Sensors: Sensor Failure	Failure of sensors that provide feedback to the hydraulic governor can lead to incorrect operation and potential instability in turbine speed.	3	4	12	Regular testing and calibration of all sensors used in the governor control system. Use of redundant sensors to ensure accurate feedback in case of sensor failure. Immediate replacement of any malfunctioning sensors.
2.1.11	**Governor System**	**Governor**	Control System and Sensors: Control System Software Malfunction	A malfunction in the control system software can lead to incorrect operation of the hydraulic governor, causing turbine speed fluctuations.	2	4	8	Regular updates and testing of control system software to ensure reliability. Installation of backup control systems or manual overrides. Continuous monitoring of control system performance with alarms for anomalies.

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2.1.12	**Governor System**	**Governor**	Control System and Sensors: Electrical Power Loss to Control System	Loss of electrical power to the control system can disable the hydraulic governor, leading to uncontrolled turbine operation.	2	5	10	Installation of uninterruptible power supplies (UPS) to maintain power to the control system. Regular testing and maintenance of backup power systems. Implementation of emergency shutdown procedures in the event of power loss.
2.1.13	**Governor System**	**Governor**	Safety and Environmental Impact: Hydraulic Fluid Spill Leading to Environmental Contamination	A significant spill of hydraulic fluid can lead to environmental contamination, particularly if the fluid enters nearby water sources.	2	4	8	Regular inspection of hydraulic lines and fittings to prevent leaks. Use of environmentally friendly hydraulic fluids where possible. Installation of spill containment systems and immediate response plans for spills.
2.1.14	**Governor System**	**Governor**	Safety and Environmental Impact: Uncontrolled Turbine Speed Due to Governor Failure	A complete failure of the hydraulic governor can lead to uncontrolled turbine speed, potentially causing damage to the turbine and other equipment, as well as safety hazards.	2	5	10	Regular testing and maintenance of the governor to ensure reliable operation. Installation of emergency shutdown systems to prevent uncontrolled speed. Training of operational staff to respond quickly to governor failures.
3.1.1	**Batteries and Blackout recovery**	**Batteries**	Battery Performance: Battery Capacity Degradation	Over time, batteries naturally degrade, losing capacity and reducing their ability to provide adequate backup power during outages.	4	3	12	Regular testing of battery capacity and performance. Scheduled replacement of batteries based on their expected lifespan. Implementation of a battery monitoring system to track capacity degradation in real-time.
3.1.2	**Batteries and Blackout recovery**	**Batteries**	Battery Performance: Inadequate Charging	Insufficient charging due to charger malfunction or poor maintenance can result in batteries not being fully charged when needed, reducing their effectiveness.	3	4	12	Regular maintenance and testing of battery chargers to ensure proper operation. Installation of a charge monitoring system to ensure batteries are charged correctly. Use of automatic battery management systems to optimize charging cycles.
3.1.3	**Batteries and Blackout recovery**	**Batteries**	Battery Performance: Overcharging or Undercharging	Overcharging can lead to overheating and damage to the batteries, while undercharging can shorten battery life and reduce capacity.	3	4	12	Use of smart chargers that prevent overcharging and ensure proper charging cycles. Regular inspection and calibration of charging systems. Implementation of a battery management system to monitor and control charging parameters.
3.1.4	**Batteries and Blackout recovery**	**Batteries**	Mechanical Integrity and Safety: Battery Leakage	Leakage of battery electrolyte can lead to corrosion of terminals, potential short circuits, and safety hazards, including the risk of chemical burns.	2	4	8	Regular inspection of batteries for signs of leakage or damage. Use of sealed, maintenance-free batteries to minimize the risk of leaks. Immediate replacement of any leaking batteries and proper disposal of hazardous materials.
3.1.5	**Batteries and Blackout recovery**	**Batteries**	Mechanical Integrity and Safety: Terminal Corrosion	Corrosion of battery terminals can lead to poor electrical connections, reducing the efficiency and reliability of the power supply.	3	3	9	Regular cleaning and inspection of battery terminals to prevent corrosion. Application of anti-corrosion coatings or protective grease on terminals. Ensuring proper ventilation in battery storage areas to reduce moisture buildup.
3.1.6	**Batteries and Blackout recovery**	**Batteries**	Mechanical Integrity and Safety: Physical Damage to Batteries	Physical damage to batteries due to mishandling or external impacts can cause short circuits, leaks, or even fires.	2	5	10	Proper storage and handling procedures to prevent physical damage. Installation of protective barriers or enclosures around battery banks. Regular training of personnel on safe battery handling practices.
3.1.7	**Batteries and Blackout recovery**	**Batteries**	Electrical Performance and Safety: Short Circuit	A short circuit within the battery system can cause overheating, fires, and potentially damaging other connected systems.	2	5	10	Installation of circuit protection devices, such as fuses or breakers, to prevent short circuits. Regular inspection and maintenance of battery connections and wiring. Use of batteries with internal short circuit protection.
3.1.8	**Batteries and Blackout recovery**	**Batteries**	Electrical Performance and Safety: Loss of Connection or Open Circuit	A loose or disconnected terminal can create an open circuit, preventing the battery from delivering power when needed.	3	4	12	Regular inspection and tightening of all battery connections. Use of locking connectors or terminal covers to ensure secure connections. Implementation of a monitoring system to detect and alert for open circuits.
3.1.9	**Batteries and Blackout recovery**	**Batteries**	Electrical Performance and Safety: Battery Explosion Due to Overheating	Overheating, often caused by overcharging or internal faults, can lead to battery explosions, presenting severe safety hazards.	2	5	10	Installation of temperature monitoring systems with alarms to detect overheating. Use of thermal management systems to regulate battery temperature. Regular testing of safety features such as pressure relief vents.
3.1.10	**Batteries and Blackout recovery**	**Batteries**	Environmental Impact: Improper Disposal of Batteries	Improper disposal of used batteries can lead to environmental contamination, particularly if they contain hazardous materials like lead or cadmium.	3	4	12	Implementing proper disposal and recycling procedures for used batteries. Regular training of personnel on environmental regulations and disposal practices. Use of environmentally friendly batteries, such as those with low toxicity or recyclable materials.
3.1.11	**Batteries and Blackout recovery**	**Batteries**	Environmental Impact: Environmental Contamination Due to Leaks	Leakage from batteries can release harmful chemicals into the environment, potentially contaminating soil and water sources.	2	4	8	Regular inspection and maintenance to detect and prevent leaks. Installation of containment systems to capture and neutralize any leaks. Use of batteries with non-toxic or low-impact electrolytes.
3.1.12	**Batteries and Blackout recovery**	**Batteries**	Environmental Impact: Fire Risk from Battery Failure	A catastrophic battery failure can lead to fires, which can spread and cause significant environmental damage.	2	5	10	Installation of fire suppression systems in battery storage areas. Regular fire safety inspections and drills. Use of fire-resistant battery enclosures and materials.
4.1.1	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Operational Performance: Difficulty in Manual Operation	The manual operation of the butterfly valve may become difficult due to wear, debris buildup, or mechanical issues, making it hard to open or close the valve effectively.	3	4	12	Regular maintenance and lubrication of the valve mechanism to ensure smooth operation. Inspection for and removal of debris or sediment that could obstruct valve movement. Training personnel on proper manual operation techniques and procedures.
4.1.2	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Operational Performance: Valve Sticking or Jamming	The intake butterfly valve may stick or jam due to corrosion, debris, or mechanical wear, preventing proper operation and potentially leading to uncontrolled water flow.	3	4	12	Regular inspection and cleaning of the valve to prevent debris buildup and corrosion. Application of anti-corrosion coatings to reduce the risk of sticking. Regular testing of the valve's operation to detect early signs of sticking or jamming.
4.1.3	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Operational Performance: Inability to Respond Quickly in an Emergency	The lack of remote control or electrical operation means the valve cannot be quickly closed in case of an emergency, such as a sudden surge in water flow or a downstream failure.	3	5	15	Develop and practice manual emergency procedures to ensure rapid response. Consider retrofitting the valve with remote or automated emergency operation capabilities. Ensure that personnel are always available on-site or nearby to operate the valve manually.

4.1.4	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Mechanical Integrity: Corrosion of Valve Components	The valve, particularly if exposed to water with high salinity or other corrosive elements, may experience corrosion that can weaken its structural integrity and lead to failure.	3	4	12	Regular inspection for signs of corrosion, particularly in components exposed to water. Application of anti-corrosion coatings and use of corrosion-resistant materials. Monitoring water chemistry and implementing treatment if necessary to reduce corrosive elements.
4.1.5	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Mechanical Integrity: Mechanical Failure Due to Wear and Tear	Continuous use of the valve can lead to wear and tear on its components, including the disc, seals, and operating mechanism, potentially causing failure.	4	3	12	Regular maintenance and replacement of worn components based on their condition. Use of high-quality, wear-resistant materials for critical parts. Scheduled inspections and overhauls to assess and address wear.
4.1.6	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Mechanical Integrity: Seal Degradation	The seals around the valve may degrade over time, leading to leakage and reduced control over water flow.	3	3	9	Regular inspection and replacement of valve seals to ensure they remain effective. Use of durable, high-quality seal materials that resist degradation. Monitoring for signs of leakage and prompt repair if necessary.
4.1.7	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Environmental Impact: Uncontrolled Water Flow Due to Valve Failure	A failure of the intake butterfly valve, whether due to mechanical issues or inability to operate it manually in time, could lead to uncontrolled water flow, potentially causing downstream flooding and environmental damage.	2	5	10	Regular inspection and maintenance to ensure the valve's reliability. Development of contingency plans for rapid response in case of valve failure. Consideration of upgrading to an automated or remotely operable valve to enhance control.
4.1.8	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Environmental Impact: Leakage Through Valve	Leakage through the valve due to inadequate sealing or mechanical failure can result in water loss, potentially stressing local water resources and ecosystems.	3	3	9	Regular inspection and maintenance of the valve and seals to prevent leakage. Monitoring of water levels and flows to detect early signs of leakage. Immediate repair of any detected leaks to prevent further water loss.
4.1.9	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Environmental Impact: Impact on Aquatic Life Due to Sudden Valve Operation	The manual operation of the valve, particularly during sudden closures, may have adverse effects on aquatic life by disrupting natural water flow or causing sudden changes in water levels.	3	3	9	Implementation of operational procedures that minimize the impact on aquatic life, such as gradual valve closures. Regular environmental assessments to monitor the impact of valve operations on local ecosystems. Collaboration with environmental agencies to develop best practices for valve operation.
4.1.10	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Safety and Maintenance: Safety Risks During Manual Operation	Manually operating the intake butterfly valve, especially in adverse conditions (e.g., high flow, cold weather), can pose safety risks to personnel, including the risk of injury or entrapment.	3	4	12	Implementation of strict safety protocols for manual valve operation. Training for personnel on safe operation techniques and emergency procedures. Provision of personal protective equipment (PPE) and safety gear for operators.
4.1.11	**Intake Valves, Gates and Pressure Relief valve**	**Intake Butterfly Valve**	Safety and Maintenance: Inadequate Maintenance Leading to Valve Failure	Insufficient maintenance, particularly in checking the condition of the valve and seals, can lead to the eventual failure of the valve.	3	4	12	Implementation of a rigorous maintenance schedule with detailed inspections. Immediate repair or replacement of any detected issues to prevent further degradation. Consideration of scheduled replacements based on condition assessments.
4.2.1	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Operational Performance: Difficulty in Manual Operation	The manual operation of the wooden intake gate may become difficult due to swelling of the wood, debris buildup, or mechanical wear, making it hard to open or close the gate effectively.	4	3	12	Regular maintenance and inspection to ensure smooth operation. Application of waterproof coatings to prevent wood swelling. Training personnel on proper manual operation techniques and maintenance.
4.2.2	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Operational Performance: Gate Jamming or Sticking	The intake gate may become jammed or stuck due to debris, ice, or warping of the wood, preventing proper operation and potentially leading to uncontrolled water flow.	3	4	12	Regular clearing of debris and inspection during winter months to prevent ice buildup. Application of anti-icing treatments if operating in cold climates. Regular inspection and maintenance to address wood warping and ensure proper alignment.
4.2.3	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Operational Performance: Inability to Respond Quickly in an Emergency	The lack of remote or emergency operation means the gate cannot be quickly closed in case of an emergency, such as a sudden surge in water flow or a downstream failure.	3	5	15	Develop and practice manual emergency procedures to ensure rapid response. Consideration of retrofitting the gate with remote or automated emergency operation capabilities. Ensure that personnel are always available on-site or nearby to operate the gate manually.
4.2.4	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Structural Integrity: Wood Rot or Decay	The wooden intake gate is susceptible to rot or decay over time, particularly in a wet environment, which can weaken the structure and lead to failure.	4	4	16	Regular inspection and maintenance to detect early signs of wood rot or decay. Application of wood preservatives and waterproof coatings to extend the life of the gate. Scheduled replacement of the wooden gate based on its condition and lifespan.
4.2.5	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Structural Integrity: Structural Failure Due to Wear and Tear	Continuous exposure to water pressure and environmental conditions can lead to wear and tear, potentially causing the gate to fail structurally.	3	4	12	Regular monitoring of the gate's structural integrity, especially during periods of high water flow. Reinforcement of the gate structure or replacement with more durable materials if wear is detected. Consideration of retrofitting or replacing the wooden gate with a more durable material, such as metal or composite.
4.2.6	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Structural Integrity: Erosion of Gate Seals	The seals around the intake gate may erode or degrade over time, leading to leakage and reduced control over water flow.	3	3	9	Regular inspection and replacement of gate seals to ensure a tight fit. Use of high-quality, durable seal materials that resist erosion. Monitoring for signs of leakage and prompt repair if necessary.
4.2.7	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Environmental Impact: Uncontrolled Water Flow Due to Gate Failure	A failure of the intake gate, whether due to structural issues or inability to operate it manually in time, could lead to uncontrolled water flow, potentially causing downstream flooding and environmental damage.	2	5	10	Regular inspection and maintenance to ensure the gate's reliability. Development of contingency plans for rapid response in case of gate failure. Consideration of upgrading to an automated or remotely operable gate to enhance control.
4.2.8	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Environmental Impact: Impact on Aquatic Life Due to Gate Operation	The manual operation of the gate, particularly during sudden closures, may have adverse effects on aquatic life by disrupting natural water flow or causing sudden changes in water levels.	3	3	9	Implementation of operational procedures that minimize the impact on aquatic life, such as gradual gate closures. Regular environmental assessments to monitor the impact of gate operations on local ecosystems. Collaboration with environmental agencies to develop best practices for gate operation.
4.2.9	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Environmental Impact: Leakage Leading to Water Loss and Environmental Stress	Leakage through the gate due to inadequate sealing or structural issues can result in water loss, potentially stressing local water resources and ecosystems.	3	3	9	Regular inspection and maintenance of the gate and seals to prevent leakage. Monitoring of water levels and flows to detect early signs of leakage. Immediate repair of any detected leaks to prevent further water loss.

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4.2.10	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Safety and Maintenance: Safety Risks During Manual Operation	Manually operating the intake gate, especially in adverse conditions (e.g., high flow, cold weather), can pose safety risks to personnel, including the risk of injury or entrapment.	3	4	12	Implementation of strict safety protocols for manual gate operation. Training for personnel on safe operation techniques and emergency procedures. Provision of personal protective equipment (PPE) and safety gear for operators.
4.2.11	**Intake Valves, Gates and Pressure Relief valve**	**Intake gate at the penstock**	Safety and Maintenance: Inadequate Maintenance Leading to Gate Failure	Insufficient maintenance, particularly in checking the condition of the wood and seals, can lead to the eventual failure of the gate.	3	4	12	Implementation of a rigorous maintenance schedule with detailed inspections. Immediate repair or reinforcement of any detected issues to prevent further degradation. Consideration of scheduled replacements based on condition assessments.
4.3.1	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Operational Performance: Sensor Failure Leading to Incorrect Operation	The pressure sensors that control the valve may fail, leading to incorrect operation of the pressure relief valve, such as not opening during a pressure surge or opening unnecessarily.	3	5	15	Regular testing and calibration of pressure sensors to ensure accurate readings. Use of redundant sensors to provide backup in case of sensor failure. Continuous monitoring of sensor performance and alarm systems for anomalies.
4.3.2	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Operational Performance: Delayed Response Time	The automated system controlling the valve may experience a delay in responding to pressure surges, leading to potential damage to the penstock or other components.	2	5	10	Regular maintenance and testing of the valve's control system to ensure rapid response. Installation of high-speed processors or control systems to minimize response time. Implementing a backup manual operation procedure in case of system delays.
4.3.3	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Operational Performance: Overly Sensitive Operation	The valve may be too sensitive, opening too frequently due to minor fluctuations in pressure, which can lead to unnecessary water release and operational inefficiencies.	3	3	9	Calibration of the pressure sensors to set appropriate thresholds for valve operation. Use of damping algorithms in the control system to prevent unnecessary triggering. Regular monitoring and adjustment of the valve's operational parameters.
4.3.4	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Mechanical Integrity: Valve Sticking or Jamming	The pressure relief valve may stick or jam due to mechanical wear, corrosion, or debris, preventing it from opening or closing properly.	3	5	15	Regular inspection and cleaning of the valve to prevent debris buildup. Application of anti-corrosion coatings to protect against environmental factors. Scheduled lubrication and maintenance of the valve mechanism to prevent sticking.
4.3.5	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Mechanical Integrity: Corrosion of Valve Components	Corrosion, especially in the presence of water with high salinity or other corrosive elements, can weaken the valve's components and lead to failure.	3	4	12	Use of corrosion-resistant materials in the valve's construction. Regular inspection for signs of corrosion and timely replacement of affected components. Application of protective coatings to reduce the risk of corrosion.
4.3.6	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Mechanical Integrity: Seal Degradation	The seals within the valve may degrade over time, leading to leaks or reduced effectiveness in managing pressure surges.	3	3	9	Regular inspection and replacement of seals to maintain valve integrity. Use of high-quality, durable seal materials that resist degradation. Monitoring for signs of leakage and prompt repair if necessary.
4.3.7	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Control System Reliability: Control System Software Malfunction	A malfunction in the control system software can lead to incorrect operation of the pressure relief valve, potentially causing it to fail to operate when needed.	2	5	10	Regular updates and testing of the control system software to ensure reliability. Installation of backup control systems or manual overrides. Continuous monitoring of control system performance with alarms for anomalies.
4.3.8	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Control System Reliability: Electrical Power Loss to Control System	Loss of electrical power to the control system can disable the pressure relief valve, leading to a failure to manage pressure surges.	2	5	10	Installation of uninterruptible power supplies (UPS) to maintain power to the control system. Regular testing and maintenance of backup power systems. Implementation of emergency shutdown procedures in the event of power loss.
4.3.9	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Control System Reliability: Communication Failure Between Sensors and Valve	A failure in communication between the pressure sensors and the valve could prevent the valve from receiving the necessary signals to operate.	3	4	12	Use of reliable, tested communication protocols and hardware. Regular testing of communication links between sensors and the valve. Installation of redundant communication pathways to ensure signal integrity.
4.3.10	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Safety and Environmental Impact: Uncontrolled Water Release Due to Valve Failure	A failure of the pressure relief valve, either by not opening or by opening unnecessarily, can lead to uncontrolled water release, potentially causing downstream flooding or damage.	2	5	10	Regular inspection and maintenance to ensure the valve's reliability. Implementation of fail-safe mechanisms that ensure the valve opens under critical conditions. Development of emergency response plans to manage uncontrolled water release.
4.3.11	**Intake Valves, Gates and Pressure Relief valve**	**Pressure relief valve**	Safety and Environmental Impact: Environmental Impact of Frequent Water Releases	Frequent operation of the pressure relief valve, particularly if overly sensitive, can lead to unnecessary water releases, potentially impacting local ecosystems.	3	3	9	Calibration of the valve's control system to minimize unnecessary releases. Regular environmental assessments to monitor the impact of water releases. Collaboration with environmental agencies to develop guidelines for valve operation.
5.1.1	**Generator**	**Synchronous Generator (524 KVA, 14 Poles, 514 rpm)**	Operational Performance: Voltage Instability or Fluctuations	Voltage instability can occur due to fluctuations in load demand, issues with the excitation system, or problems with the generator's regulation system, leading to potential damage to connected equipment.	3	4	12	Regular testing and calibration of the voltage regulation and excitation system. Installation of automatic voltage regulators (AVRs) with fine-tuning capability. Continuous monitoring of voltage levels and implementation of alarms for instability.
5.1.2	**Generator**	**Synchronous Generator (524 KVA, 14 Poles, 514 rpm)**	Operational Performance: Frequency Deviation	Frequency deviation can occur if the generator's rotational speed fluctuates due to variations in mechanical input power or load changes, leading to potential grid instability.	3	5	15	Regular maintenance and monitoring of the prime mover to ensure consistent rotational speed. Use of a governor system that is regularly tested and calibrated for precise control of speed. Implementation of frequency monitoring systems with alarms to detect and correct deviations immediately.
5.1.3	**Generator**	**Synchronous Generator (524 KVA, 14 Poles, 514 rpm)**	Operational Performance: Loss of Synchronism	The generator may lose synchronism with the grid due to sudden changes in load, mechanical failures, or electrical faults, leading to potential damage to the generator and connected systems.	2	5	10	Installation of protective relays to detect and respond to loss of synchronism. Regular testing of synchronizing equipment and procedures. Implementation of automatic re-synchronization systems or manual procedures to quickly restore synchronism.
5.1.4	**Generator**	**Synchronous Generator (524 KVA, 14 Poles, 514 rpm)**	Operational Performance: Load Imbalance	An imbalance in the electrical load across the phases can lead to uneven stress on the generator, causing overheating, vibration, and potential damage to the windings and bearings.	3	4	12	Continuous monitoring of load distribution across all phases. Use of phase balance correction systems or load management strategies to ensure even distribution. Regular inspection of electrical connections and load points to detect and correct imbalances.

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5.1.5	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Operational Performance: Overloading	Operating the generator above its rated capacity can cause overheating, reduced efficiency, and accelerated wear of electrical and mechanical components.	2	5	10	Installation of overload protection relays and alarms to prevent overloading. Continuous monitoring of load conditions and generator output to ensure operation within safe limits. Implementing operational procedures to manage load demand and avoid overloading.
5.1.6	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Mechanical Integrity: Rotor Imbalance	Imbalance in the rotor can occur due to uneven wear, deposits, or damage, leading to excessive vibration, bearing wear, and potential catastrophic failure.	3	5	15	Regular dynamic balancing of the rotor during maintenance. Vibration monitoring systems to detect early signs of imbalance. Immediate corrective actions, such as rotor cleaning or repair, if imbalance is detected.
5.1.7	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Mechanical Integrity: Bearing Failure	Bearings are critical for the smooth operation of the generator, and failure due to wear, insufficient lubrication, or contamination can lead to increased friction, overheating, and eventual breakdown.	3	5	15	Regular inspection and maintenance of bearings, including lubrication checks and replacement if necessary. Installation of temperature and vibration monitoring sensors on the bearings to detect early signs of failure. Use of high-quality bearings and adherence to proper installation procedures during refurbishment or replacement.
5.1.8	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Mechanical Integrity: Shaft Misalignment	Misalignment of the generator shaft can lead to uneven loading on bearings and other components, causing increased wear and potential failure.	2	4	8	Precision alignment of the shaft during installation and after any major maintenance. Regular monitoring of alignment using laser alignment tools or other precision instruments. Immediate realignment if misalignment is detected.
5.1.9	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Mechanical Integrity: Fatigue Cracks in Rotor or Stator Core	Repeated cyclic loading can cause fatigue cracks in the rotor or stator core, leading to reduced structural integrity and potential catastrophic failure.	2	5	10	Regular non-destructive testing (NDT) such as ultrasonic or eddy current testing to detect early signs of fatigue. Stress analysis to identify high-risk areas and reinforce them if necessary. Implementing operational procedures to minimize cyclic stress on the generator.
5.1.10	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Mechanical Integrity: Mechanical Wear of Couplings	The couplings between the generator and prime mover can wear over time, leading to misalignment, vibration, and potential failure of the drivetrain.	3	4	12	Regular inspection and maintenance of couplings, including lubrication and alignment checks. Use of high-quality, durable coupling materials that resist wear. Immediate replacement of any worn or damaged couplings to prevent failure.
5.1.11	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Stator Winding Insulation Failure	Insulation failure in the stator windings can occur due to aging, overheating, or mechanical stress, leading to short circuits, arcing, or complete generator failure.	3	5	15	Regular insulation resistance testing (e.g., using a megger) to monitor the condition of the windings. Use of high-quality, thermally stable insulation materials during refurbishment. Installation of temperature monitoring systems to prevent overheating.
5.1.12	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Rotor Winding Faults	Rotor winding faults, such as open circuits or short circuits, can lead to loss of excitation, reduced generator efficiency, and potential damage to the rotor.	3	4	12	Regular inspection and testing of rotor windings, including resistance measurements and visual inspections. Installation of protective relays to detect and isolate rotor winding faults. Use of high-quality materials and precise winding techniques during refurbishment to minimize the risk of faults.
5.1.13	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Electrical Arcing or Flashovers	Electrical arcing or flashovers can occur due to insulation breakdown, loose connections, or contamination, leading to damage to the generator and potential safety hazards.	2	5	10	Regular inspection and cleaning of all electrical connections and components. Ensuring that all connections are tight and secure during installation and maintenance. Use of arc suppression devices and proper grounding to minimize the risk of arcing.
5.1.14	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Excitation System Failure	The excitation system is crucial for maintaining the generator's magnetic field, and failure can lead to a loss of voltage control, reduced output, or even complete shutdown.	2	5	10	Regular maintenance and testing of the excitation system components, including brushes, slip rings, and regulators. Installation of redundant excitation systems or backup power supplies to ensure continuous operation. Monitoring excitation current and voltage to detect and address issues before they lead to failure.
5.1.15	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Ground Faults	A ground fault occurs when electrical current flows directly to the ground, potentially causing damage to the generator and posing a safety risk.	2	5	10	Installation of ground fault protection relays to detect and isolate faults quickly. Regular inspection of insulation and grounding systems to prevent faults. Implementation of routine testing for ground fault vulnerabilities.
5.1.16	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Overvoltage Conditions	Overvoltage conditions can occur due to load shedding, lightning strikes, or faults in the excitation system, leading to insulation breakdown and damage to the generator.	2	5	10	Installation of overvoltage protection devices, such as surge arresters and voltage relays. Regular maintenance of the excitation system to prevent uncontrolled voltage increases. Continuous monitoring of voltage levels with automatic shutdown in case of overvoltage.
5.1.17	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Harmonic Distortion	Harmonic distortion in the electrical system, caused by non-linear loads, can lead to overheating, increased losses, and potential damage to the generator windings.	3	4	12	Installation of harmonic filters to reduce distortion in the electrical supply. Regular monitoring of harmonic levels and analysis of the electrical system. Use of power quality meters to detect and address harmonic issues early.
5.1.18	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Electrical Integrity: Open Phase Conditions	An open phase condition occurs when one of the generator's phases becomes disconnected, leading to unbalanced loads, overheating, and potential damage to the windings.	2	5	10	Installation of open phase detection relays to identify and isolate the affected phase. Regular inspection of electrical connections and phase continuity. Immediate corrective action if an open phase is detected.
5.1.19	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Cooling and Ventilation: Cooling System Failure	Failure of the generator's cooling system can lead to overheating of the windings and other components, reducing efficiency and potentially causing permanent damage.	3	5	15	Installation of temperature sensors and alarms to detect overheating. Guarantee the cleaniness of the generator and its sourrondings. Less dirt, less possibility to overheat, due to the fact that the generator uses the movement of the air by the rotor to cool down itself

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5.1.20	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Cooling and Ventilation : Blocked Ventilation Paths	Blockages in ventilation paths, such as due to debris or dust accumulation, can lead to inadequate cooling and overheating of the generator.	3	4	12	Regular inspection and cleaning of ventilation paths to ensure they remain clear. Installation of filters or screens to prevent debris from entering the ventilation system. Monitoring of airflow and temperature within the generator housing to detect blockages early.
5.1.21	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Cooling and Ventilation : Insufficient Cooling Capacity	The cooling system may become insufficient if the generator operates at higher loads than anticipated, leading to gradual overheating and degradation of the generator components.	2	4	8	Proper sizing of the cooling system during design and refurbishment to match the generator's operational profile. Regular performance checks of the cooling system under various load conditions. Implementation of load management strategies to avoid operating the generator beyond its cooling capacity.
5.1.22	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Cooling and Ventilation: Loss of Coolant	Loss of coolant, whether due to leaks or inadequate replenishment, can lead to a failure in the cooling system, causing overheating and damage to the generator.	2	5	10	Regular inspection and maintenance of coolant levels and detection of leaks. Installation of leak detection systems and automatic coolant replenishment systems. Immediate shutdown of the generator if a significant loss of coolant is detected.
5.1.23	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Inadequate Maintenance Practices	Inadequate or infrequent maintenance can lead to undetected wear, insulation degradation, or mechanical failures, increasing the risk of generator failure.	3	5	15	Implementation of a comprehensive maintenance schedule based on the manufacturer's recommendations and industry best practices. Use of predictive maintenance tools, such as vibration analysis and thermography, to detect early signs of issues. Regular training of maintenance personnel to ensure they are aware of the latest techniques and safety protocols.
5.1.24	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Safety Hazards During Maintenance	Maintenance activities, especially those involving electrical or mechanical components, can pose significant safety hazards, including electric shock, entrapment, or burns.	2	5	10	Implementation of strict safety protocols, including lockout/tagout (LOTO) procedures, during maintenance. Use of personal protective equipment (PPE) such as insulated gloves, face shields, and protective clothing. Regular safety training and drills for maintenance personnel to prepare them for potential hazards.
5.1.25	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Improper Refurbishment or Repairs	Improper refurbishment or repairs can lead to undetected faults, incorrect assembly, or use of substandard materials, increasing the risk of generator malfunction.	3	5	15	Ensure that all refurbishment and repairs are conducted by qualified personnel following strict quality control procedures. Use only certified and high-quality materials and components during refurbishment. Conduct thorough testing and inspection after any major repairs or refurbishment before returning the generator to service.
5.1.26	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Incorrect Calibration of Protection Relays	Incorrect calibration of protection relays can lead to either nuisance tripping or failure to trip in an actual fault condition, resulting in potential damage to the generator or unsafe conditions.	2	5	10	Regular testing and calibration of protection relays according to manufacturer specifications. Verification of relay settings after any system modifications or repairs. Use of advanced relay testing equipment to ensure accurate calibration.
5.1.27	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Maintenance-Induced Failures	Maintenance activities themselves can introduce new failures, such as incorrect component installation, improper lubrication, or accidental damage to sensitive parts.	3	4	12	Implementing detailed maintenance procedures that include step-by-step instructions and quality checks. Providing comprehensive training to maintenance personnel on specific generator components and systems. Conducting post-maintenance inspections and tests to verify the integrity of the generator before returning it to service.
5.1.28	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Delayed Maintenance or Inspections	Delays in scheduled maintenance or inspections can lead to the deterioration of critical components, increasing the likelihood of unexpected failures.	3	5	15	Strict adherence to a maintenance schedule with clear timelines for each task. Implementation of a maintenance management system to track and remind about upcoming maintenance activities. Prioritization of critical maintenance tasks to ensure they are completed on time.
5.1.29	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Inadequate Documentation and Record Keeping	Inadequate documentation of maintenance activities, repairs, and inspections can lead to incomplete maintenance history, making it difficult to identify trends or predict failures.	3	4	12	Implementing a comprehensive maintenance record-keeping system, including digital documentation. Ensuring all maintenance activities, inspections, and repairs are thoroughly documented and reviewed. Regular audits of maintenance records to ensure accuracy and completeness.
5.1.30	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Contaminant Intrusion During Maintenance	Contaminants such as dust, moisture, or oil can enter the generator during maintenance activities, leading to potential insulation breakdown, corrosion, or mechanical wear.	2	4	8	Use of clean and controlled environments for maintenance activities, particularly when working on sensitive components. Sealing or covering open components during maintenance to prevent contaminant intrusion. Thorough cleaning and inspection after maintenance before reassembly and operation.
5.1.31	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Maintenance and Safety: Human Error During Maintenance	Human error during maintenance, such as incorrect wiring, improper torque application, or misalignment, can result in generator damage or unsafe operating conditions.	3	4	12	Implementation of checklists and double-check procedures to minimize the risk of human error. Comprehensive training for maintenance personnel, including simulations and practical exercises. Conducting peer reviews and supervision during critical maintenance tasks.
5.1.32	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Environmental and External Factors: Lightning Strikes or Surge Events	Lightning strikes or surge events can cause significant overvoltage conditions, leading to damage to the generator's insulation and electrical systems.	2	5	10	Installation of surge protection devices, such as lightning arresters, on the generator and associated systems. Regular inspection and maintenance of grounding systems to ensure proper dissipation of surges. Conducting regular risk assessments for surge events and updating protection measures as needed.
5.1.33	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Environmental and External Factors: Flooding or Water Ingress	Flooding or water ingress due to natural disasters or leaks can cause short circuits, corrosion, or damage to the generator's electrical and mechanical components.	2	2	4	Installation of waterproof enclosures or barriers around the generator. Regular inspection of seals and drainage systems to prevent water ingress. Implementation of emergency response plans for flooding events, including generator shutdown and isolation procedures.

5.1.34	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Environmental and External Factors: Extreme Temperature Conditions	Extreme temperatures, whether high or low, can affect the performance of the generator's insulation, lubrication, and cooling systems, leading to potential failures.	3	4	12	Regular monitoring of ambient and operating temperatures with alarms for deviations. Use of temperature-resistant materials and lubricants suited to the operational environment. Implementation of climate control measures, such as heating or cooling systems, to maintain optimal operating conditions.
5.1.35	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Environmental and External Factors: Vibration and Seismic Events	Excessive vibration due to seismic events or external mechanical disturbances can lead to misalignment, bearing wear, or structural damage to the generator.	2	5	10	Installation of vibration dampers or isolators to minimize the impact of external vibrations. Regular monitoring of vibration levels and analysis to detect abnormal conditions. Implementation of seismic protection measures, such as reinforced foundations or flexible connections.
5.1.36	Generator	Synchronous Generator (524 KVA, 14 Poles, 514 rpm)	Environmental and External Factors: Rodent or Pest Infestation	Rodents or pests can damage electrical insulation, wiring, or cooling systems, leading to short circuits, fires, or operational failures.	2	3	6	Regular inspection and sealing of entry points to prevent pest access. Use of rodent-proof materials and wiring conduits where possible. Implementation of pest control measures, including traps or repellents, in and around the generator housing.
6.1.1	Crane	Chain Hoist	Operational Performance: Manual Operation Fatigue	Since the crane is manually operated, there is a risk of operator fatigue during prolonged use, which could lead to mistakes or accidents.	3	3	9	Ensure that operations are conducted by trained personnel who are aware of the risks of fatigue. Implement work/rest cycles to prevent operator fatigue. Provide regular breaks and rotate operators during extended lifting operations.
6.1.2	Crane	Chain Hoist	Operational Performance: Difficulty in Operation Due to Load Weight	The chain hoist may become difficult to operate if the load is near the maximum capacity, leading to slow or erratic lifting and increased physical strain on the operator.	3	4	12	Clearly label the maximum load capacity and ensure operators are trained not to exceed it. Use appropriate rigging techniques to distribute the load evenly. Conduct regular training on safe lifting practices and load management.
6.1.3	Crane	Chain Hoist	Operational Performance: Load Slippage	There is a risk of the load slipping from the hook or rigging if it is not properly secured, which could lead to damage or injury.	3	5	15	Regular inspection of the chain, hook, and rigging components for wear or damage. Ensure that all loads are properly secured before lifting. Provide operators with training on proper rigging techniques.
6.1.4	Crane	Chain Hoist	Mechanical Integrity: Chain Wear and Tear	Continuous use of the chain hoist can lead to wear and tear on the chain, which may eventually weaken and cause the chain to fail under load.	4	4	16	Regular inspection of the chain for signs of wear, such as elongation, rust, or damaged links. Replace the chain at the first sign of significant wear or according to the manufacturer's recommended schedule. Lubricate the chain regularly to prevent corrosion and reduce friction.
6.1.5	Crane	Chain Hoist	Mechanical Integrity: Hook Deformation or Breakage	The hook used to attach the load may deform or break if it is overloaded or damaged, leading to a potential drop of the load.	3	5	15	Regular inspection of the hook for signs of deformation, cracks, or wear. Ensure that the hook is used within its rated capacity. Replace the hook immediately if any signs of damage are detected.
6.1.6	Crane	Chain Hoist	Mechanical Integrity: Mechanical Failure of Gears or Brakes	The internal gears or brakes of the chain hoist may fail due to wear, leading to uncontrolled lowering of the load or inability to lift.	3	4	12	Regular maintenance and inspection of the hoist's internal mechanisms. Lubricate gears and check brake function regularly to ensure reliable operation. Replace worn or damaged parts as per the manufacturer's guidelines.
6.1.7	Crane	Chain Hoist	Safety and Maintenance: Operator Injury During Operation	The manual nature of the chain hoist operation may pose a risk of injury to the operator, particularly in the event of a sudden movement or if the load shifts unexpectedly.	3	4	12	Provide operators with proper training on safe use of the chain hoist. Ensure that operators use personal protective equipment (PPE) such as gloves and safety shoes. Implement safety protocols that include clear communication and load handling procedures.
6.1.8	Crane	Chain Hoist	Safety and Maintenance: Inadequate Maintenance Leading to Equipment Failure	Insufficient or irregular maintenance of the chain hoist can lead to equipment failure during operation, posing a risk to both personnel and equipment.	3	4	12	Implement a regular maintenance schedule, including detailed inspections. Document all maintenance activities and inspections to ensure compliance with safety standards. Replace any worn or damaged components immediately to prevent failure during use.
6.1.9	Crane	Chain Hoist	Safety and Maintenance: Load Falling Due to Operator Error	Improper use of the chain hoist, such as sudden movements or incorrect rigging, may result in the load falling, posing a significant risk of injury or damage.	3	5	15	Provide thorough training for all operators on proper hoist use and load securing techniques. Ensure clear communication and signaling protocols during lifting operations. Implement a system of checks and verifications before commencing lifting operations.
6.1.10	Crane	Chain Hoist	Environmental Impact: Environmental Contamination Due to Lubricant Spills	Lubricants used on the chain and gears may spill or leak, leading to contamination of the surrounding environment.	2	3	6	Use environmentally friendly lubricants where possible. Implement spill containment measures during maintenance. Regularly check and maintain seals and reservoirs to prevent leaks.
6.1.11	Crane	Chain Hoist	Environmental Impact: Noise Pollution During Operation	The operation of the manual chain hoist, particularly when lifting heavy loads, may generate noise that could impact the surrounding environment.	2	2	4	Implement noise-reducing techniques such as lubrication and maintenance of moving parts. Limit hoist operation during times when noise could be disruptive. Provide ear protection for operators if necessary.