City Council Memorandum

To: Mayor Fasbender & City Council Members
From: Ryan Stempski, P.E. – Public Works Director
Date: January 5, 2026
Item: Authorize Signature of Letter of Intent and Consider Resolution Regarding Disposal and Sale of the Hydroelectric Plant

COUNCIL ACTION REQUESTED

Council has been requested to authorize signature of the attached Letter of Intent with J.F. Brennan Company, Inc. regarding the terms of sale of the Hydroelectric Plant. Additionally, the Council has been requested to consider adopting the enclosed resolution regarding the disposal and sale of the Hydroelectric Plant to comply with Section 7.04 of the City Charter.

BACKGROUND

The Hydroelectric Plant is an aging facility and cost projections to continue to own and maintain the facility are not fiscally responsible to the taxpayers in Hastings.

Several meetings over the past two years have been held regarding this subject to provide information and obtain directions including Utilities Committee Meetings, City Council Workshops, and City Council Meetings.

A Public Hearing was conducted at the December 15th City Council Meeting, and no public comments were received.

NEXT STEPS

J.F. Brennan Company, Inc. is a marine construction firm specializing in environmental remediation, dam construction, commercial diving, harbor management and submarine cable services. They have provided a Letter of Intent that outlines the terms of sale, which has been reviewed by the City Attorney:

- Purchase price is $1 for Brennan to take over ownership and maintenance of the Hydroelectric Plant
- Includes the transfer of the FERC License, USACE Agreement, and Xcel Agreement from the City to Brennan
- As-Is Sale as to the physical conditions of the assets comprising the Plant
- For a period of one year after closing, the City shall provide ongoing assistance with administration, compliance, and submittals to transition requirements and regulations of licensure and agreements of the Plant
- Brennan has a due diligence period of 60 days after execution of the Letter of Intent prior to closing
- If Brennan sells to an unrelated third party within 5 years of closing, Brennan shall pay the City 80% of net sale proceeds if within year 1, 60% of net sale proceeds if within year 2, 40% of net sale proceeds if within year 3, and 20% of net sale if within year 4

Also attached is the Resolution Regarding the Disposal and Sale of the Hydroelectric Plant that recognizes the negative cash flow projections of over $14M over the next 25 years and complies with Section 7.04 of the City Charter for disposal of property.

COUNCIL ACTION REQUESTED

X-A-01 (a,b)

Council is requested to authorize signature of the attached Letter of Intent with J.F. Brennan Company, Inc. and to consider adopting the enclosed resolution regarding the disposal and sale of the Hydroelectric Plant.

ATTACHMENTS

- Letter of Intent from J.F. Brennan Company, Inc.
- Resolution Regarding the Disposal and Sale of the Hydroelectric Plant
- Hastings Hydro Maintenance Optimization Report prepared by Barr Engineering, dated October 2023

J.F. Brennan Company, Inc.
818 Bainbridge Street I La Crosse, WI 54603

December 11, 2025

City of Hastings, Minnesota
101 4th Street East
Hastings, Minnesota 55033
Attn: Mr. Joe Spagnoletti

RE: NONBINDING LETTER OF INTENT ("LOI" OR "LETTER") — HASTINGS HYDROELECTRIC PROJECT (FERC # P-4306)

Dear Mr. Spagnoletti:

This Letter is intended to summarize the principal elements of a proposal being considered by J.F. Brennan Company, Inc., a Wisconsin corporation ("Brennan"), regarding the possible acquisition by one of its affiliates ("Buyer"), for an expected purchase price in good faith of **One and 00/100 Dollars ($1.00)**, of the above-referenced hydroelectric project with plant capacity of 4400 kW, located at or upon Mississippi River Locks and Dam No. 2 (the assets and interests comprising the foregoing being referred to hereafter as the "Plant") and owned by the City of Hastings, Minnesota (the "City"). The possible acquisition of the Plant by Buyer is referred to as the "Transaction." For the avoidance of doubt, except for the provisions contained in Part Two below, this Letter is part of a partial proposal and does not and will not establish a binding obligation of the Buyer or the Seller (each sometimes referred to hereafter as a "Party" and collectively as the "Parties"), it being understood that the Parties will be legally bound to complete the Transaction **only** upon the execution of a mutually agreed upon definitive written purchase and sale agreement (the "Definitive Agreement").

Part One - Nonbinding

As soon as reasonably practicable after execution of this Letter, the Parties shall commence to negotiate the Definitive Agreement relating to Buyer's acquisition of the Plant. The Parties presently contemplate executing the Definitive Agreement and closing the Transaction on or before June 1, 2026, which will be subject in all respects to (1) satisfactory completion of the Buyer's due diligence review of the Plant as hereinafter set forth, (2) prior approval by the Board of Directors or Managers, as applicable, of the Buyer, and (3) satisfaction of all conditions applicable to assignment of the Permits (as defined below). The following represent the principal elements of the proposed Transaction:

1. Acquisition of Purchased Assets. Subject to satisfaction of the conditions described in this Letter and in those contained in the Definitive Agreement, at the closing of the Transaction, the Buyer would acquire substantially all the assets, and no liabilities or obligations of any kind or character, comprising the Plant and/or necessary or appropriate for the ownership and operation of the Plant, free and clear of all encumbrances. Buyer assumes maintenance obligations and liabilities of the Plant assets as of the date of closing, such assets being sold in "as-is" condition as more fully described in Paragraph 4. By way of reference only, and not as a limitation, the assets comprising the Plant and/or necessary or appropriate for the ownership, operation and maintenance of the Plant shall include the following:

(a) Real Property. All real property owned or occupied by the City and used in the operation of or in any way associated with the Plant, including without limitation leasehold interests, rights of access, licenses for access and/or occupancy (including any and all agreements between the City and the United States Army Corps of Engineers (collectively, "USACE Agreements"), and servitudes.

(b) Personal Property. All personal property owned, leased or otherwise held by the City under contract and used in the operation of or in any way associated with the Plant, including without limitation water diversion equipment, water conveyance equipment, power generation equipment, electric interconnection and related facilities, spare and replacement parts, inventory, tools, equipment leases, occupancy or access agreements and licenses (including the USACE Agreements), power purchase agreements (including any and all agreements between the City and Northern States Power/Xcel Energy (collectively, "Xcel Agreements")), Federal Energy Regulatory Commission (FERC) license(s), other federal or state licenses, permits and operating orders or decrees, supplies, books, and records (both electronic and physical).

2. Assignment of Licenses, Permits, Etc. The City shall initiate the process to assign or transfer to the Buyer in accordance with relevant federal and state law all licenses (including FERC license(s)), permits and operating orders or decrees issued by federal or state authorities and necessary or appropriate for ownership, operation and maintenance of the Plant (collectively, the "Permits"), subject to the Buyer's commercially reasonable approval of the same. The City will coordinate with the Buyer on such assignment and transfer process, including providing copies of all material communications and filings with applicable governmental authorities prior to any submissions with a reasonable time to review and approve the same. The Buyer will work with the City to effect an orderly and timely assignment and transfer of all such Permits and will cooperate with the City in providing any and all information or documentation necessary to effectuate the assignment and transfer of all such Permits.

3. Assumed Liabilities. The Buyer shall not, by virtue of the Transaction, be deemed to have assumed, and is not assuming, any liability or obligation of any kind, character or description whatsoever of the City or the Plant, or otherwise applicable to ownership or operation of the Plant prior to the date of closing for the Transaction. The Buyer will accept assignment of contracts, agreements, licenses and permits, and the obligation to perform in accordance with the foregoing, from and after the date of closing for the Transaction.

4. "As Is" Sale. The terms of the Transaction shall be "As Is, Where Is" as to the physical condition of the assets comprising the Plant. The City shall nonetheless provide customary and limited representations, warranties and indemnities to the Buyer.

5. Post-Closing Cooperation/Consultation. For a period of one year after the date of closing for the Transaction, the City shall provide ongoing assistance to the Buyer with applicable administration, compliance and submittals to and with FERC, the United States Army Corps of Engineers, Northern States Power/Xcel Energy and other applicable regulatory bodies and contract counterparties, as reasonably necessary and appropriate to transition operational history and experience from the City to the Buyer. At the request of either Party, the Parties shall execute at closing a mutually acceptable consulting services agreement documenting such assistance services.

6. Reserved.

Part Two - Binding

Upon execution of this Letter, the following paragraphs 7 through 11 of this Letter are legally binding and enforceable agreements of the Parties (collectively, the "Binding Provisions").

7. Due Diligence. Brennan has based current due diligence regarding the Plant, its constituent assets, and their current condition and operating history on information that is publicly available, information provided by the City, and a site visit conducted at the Plant on October 21, 2025. For a period of sixty (60) days after full execution of this Letter, or for such longer period as may be later agreed upon by the Parties in writing (the "Due Diligence Period"), the City will afford Brennan, the Buyer and their respective representatives reasonable access to all assets and facilities comprising the Plant, and all data, drawings, specifications, operating manuals, books and records (including those of its advisors, accountants, attorneys and other representatives) relating to the Plant for the purpose of permitting Brennan, the Buyer and their respective representatives, at their sole cost and expense, to conduct a thorough due diligence investigation of the legal, operational and financial condition of the Plant (the "Due Diligence Investigation"). Brennan, the Buyer and/or their respective representatives will conduct the Due Diligence Investigation in such a manner so as not to unreasonably interfere with the normal conduct of operations at the Plant. Nonpublic information regarding the Plant obtained from the City in the course of the Due Diligence Investigation will be subject to the terms and conditions of a mutually acceptable Confidentiality Agreement between the City and Brennan or the Buyer, as applicable.

8. Exclusive Dealing. In consideration of the expenses the Buyer has incurred and will incur in connection with the proposed Transaction, the City acknowledges and agrees that concurrent with the Due Diligence Period, neither the City nor any of its representatives, officers, employees, managers, supervisors, or agents shall initiate, solicit, entertain, negotiate, accept or discuss, directly or indirectly, any proposal or offer from any person or group of persons other than Brennan, the Buyer or their respective affiliates (an "Acquisition Proposal") to acquire all or any significant portion of the assets and properties comprising the Plant, or provide any non-public information to any third party in connection with an Acquisition Proposal, or enter into any agreement, arrangement or understanding requiring the City to abandon, terminate or fail to consummate the Transaction.

9. Disclosure. Except as and to the extent required by law or regulation or except as to their respective representatives that will perform work with respect to the proposed Transaction, absent the prior written consent of the other Party, the Parties hereto will not, and will direct their respective representatives not to, make, directly or indirectly, any public comment, statement or communication with respect to, or otherwise disclose or permit the disclosure of the existence of discussions regarding a possible transaction among the Parties or any of the terms, conditions or other aspects of the proposed Transaction. If any Party is required by law or regulation to make any such disclosure, such Party will first provide to the other Party the content of the proposed disclosure, the reasons that such disclosure is so required, and the time and place that the disclosure will be made. Notwithstanding the foregoing, Brennan or Buyer agrees and acknowledges that the City is a political subdivision of the State of Minnesota and is subject the Open Meeting Law (Minn. Stat. ch. 13D) and the Minnesota Government Data Practices Act (Minn. Stat. ch. 13). Accordingly, this LOI must be authorized by the City Council of the City during a public

meeting and this LOI and the Transaction will be public data, as defined by Minnesota law. The City will use commercially reasonable efforts, but at all times subject to applicable law, to notify Brennan or Buyer of the request for disclosure of trade secrets, or non-public or confidential information provided by Brennan or Buyer to the City.

10. Expenses. The Parties will each pay their own transaction expenses, including, but not limited to, the fees and expenses of accountants, attorneys, consultants, and other advisors, incurred in connection with the proposed Transaction.

11. Sale of Plant. If Brennan or the Buyer sells to an unrelated third party a controlling interest in the Plant, whether as an asset transaction or through an equity transfer, within five years of Closing (as defined in the Definitive Agreement), Brennan or Buyer shall be obligated to pay City the percentage of the net sale proceeds as outlined below:

    within Year 1 - 80% of net sale proceeds to the City.
    within Year 2 - 60% of net sale proceeds to the City.
    within Year 3 - 40% of net sale proceeds to the City.
    within Year 4 - 20% of net sale proceeds to the City.
    After Year 4 - No sale proceeds to the City.

    For purposes of clarification, "net sale proceeds" shall be equal to the total sale price, less the applicable costs of the sale transaction incurred by Brennan or the Buyer, less the then unamortized cost of all improvements to the Plant made by Brennan or the Buyer after Closing and on or prior to the date of such third-party sale transaction. This provision shall survive the Closing of the Transaction.

Termination. Following full execution hereof, this Letter will terminate upon the first to occur of: (a) the mutual written agreement of the Buyer and the City; (b) the execution of the Definitive Agreement(s); or (c) unless otherwise extended by the Parties in writing, September 30, 2026. Upon termination of this Letter, the Parties shall have no further obligations hereunder except that of the provisions of Part Two hereof, and the obligations of the Parties thereunder shall survive any such termination.
If this Letter meets your approval, please confirm the same by executing the acknowledgment below and return it via email to markbinsfeld@jfbrennan.com. If you have any questions, please contact Mark Binsfeld at (608) 406-5385.

Sincerely,

J.F. Brennan Company, Inc.

By: _____
Name: Mark Binsfeld
Title: Vice President of Business Development/ Principal

The foregoing Letter of Intent is hereby accepted as of the ____ day of _____, 202_.

City of Hastings, Minnesota

By: _____

Name: _____

Title: _____

By: _____

Name: _____

Title: _____

RESOLUTION NO. _____ X-A-01 (a,b)

CITY OF HASTINGS
DAKOTA COUNTY, MINNESOTA

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF HASTINGS REGARDING THE DISPOSAL AND SALE OF THE HYDROELECTRIC PLANT

WHEREAS, the City of Hastings owns the Hastings Hydroelectric Plant located at and upon the Mississippi River Lock and Dam No. 2 ("Plant") upon Parcel Identification No. 190210060010; and

WHEREAS, the City authorized the preparation of the "Hastings Hydro Maintenance Optimization Report," prepared by Barr Engineering, dated October 2023, which was included in the council packet (the "Report"); and

WHEREAS, the Report concluded estimated operations and maintenance costs of the Plant that was included in the City's financial outlook over the next 25 years, which resulted in a negative cash flow amount of over $14 Million; and

WHEREAS, Section 7.04 of the City Charter states that no real property shall be disposed of unless the City Council passes a resolution containing specific findings that the public interest requires the Plant be disposed of after a notice and public hearing; and

WHEREAS, the City Council held a public hearing on December 15, 2025, and published notice of the same in the Hastings Journal, at which time the public was afforded the opportunity to provide comments on the disposal and sale of the Plant; and

WHEREAS, given the Report conclusions and the public comments, the City Council finds that it is not fiscally responsible to the citizens of Hastings to continue owning the Plant and desires to sell the Plant to a suitable buyer, who will continue operations; and

NOW THEREFORE BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF HASTINGS AS FOLLOWS:

1. The City has satisfied the notice and hearing requirements of Section 7.04 of the City Charter.

2. The public interest requires the Plant be disposed of and sold.

3. The Mayor and any other necessary staff are authorized to execute the necessary documents on behalf of the City to complete the sale of the Plant to J.F. Brennan Company, Inc. consistent with the terms of the December 11, 2025, Letter of Intent.

Council member_____ moved a second to this resolution and upon being put to a vote it was adopted by the Council Members present.

Adopted by the Hastings City Council on_____, 2026, by the following vote:

Ayes:
Nays:
Absent:

Mary Fasbender, Mayor

ATTEST:

Kelly Murtaugh, City Clerk

X-A-01 (a,b)

BARR

Hastings Hydro Maintenance Optimization Report

Prepared for
L&S Electric / City of Hastings

October 2023

3128 14th Avenue East
Hibbing, MN 55746
218.262.8600
www.barr.com

Certification

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota.

Kurt L. Sobczynski
PE #: 41973

October 4, 2023
Date

Hastings Hydro Maintenance Optimization Report

October 2023

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1 Abstract

The purpose of this study is to determine the preventative maintenance activities that are required to preserve the functional capabilities of the hydroelectric power plant owned by the City of Hastings. The process used to determine the maintenance activities is Reliability Centered Maintenance (RCM). The RCM methodology focuses on preserving the core functions of a system by identifying and controlling failure modes. The team members who performed the RCM analysis can be listed as follows:

- Joe Spagnoletti, City of Hastings Public Works Superintendent
- Ryan Stempski PE, City of Hastings Public Works Director/City Engineer
- Troy Ellison, L&S Electric, Territory Manager
- Doug Junion, L&S Electric, General Manager
- Kurt L. Sobczynski PE, Mechanical Engineer, Barr

The RCM process consists of four elements. These elements were accomplished in a series of seven steps. The elements and steps can be listed as follows:

- **Element 1:** Identifying System Boundary and Functions
    - Step 1: System Selection and Information Collection
    - Step 2: System Boundary Definition
    - Step 3: System Description/Functional Block Diagram (Appendix B, Figure 1)
    - Step 4: System Functions and Functional Failures
- Element 2: Identify Specific Failure Modes that Could Potentially Produce Functional Failures
    - Step 5: Failure Mode and Effects Analysis
- Element: 3: Prioritize Failure Modes
    - Step 6: Logic Tree Analysis
- Element: 4: Task Selection and Evaluation
    - Step 7: Task Selection and Evaluation

A maintenance plan was developed because of this exercise. The maintenance plan includes turbine and generator major and minor inspections as well as electrical and vibration testing and monitoring. An economic analysis was performed to determine the present value of the estimated operating and maintenance (O&M) costs, and to compare these costs to the present value of the revenue for power generation over the next 25 years. The results of the economic analysis can be listed as follows:

Projected power production revenue:	$10,100,000
Estimated O&M costs:	$12,400,000
Net cash (revenue – O&M):	-$2,300,000
O&M % of revenue:	122%

The details of the economic analysis and associated assumptions can be found later in this document.

2 Element 1: Identify System Boundaries and Functions

The first element identifies the system boundary and functions. Identification of the system boundary includes listing the equipment that will be covered in this study and identifying the functions of the entire system collectively as well as the individual system components. The sources for the data that was used in this element of the process include:

- Equipment list
- Operating and maintenance manual from Voith Hydro Services (turbine generator OEM)

2.1 Step 1: System Selection and Information Collection

The purpose of this step is to select the systems that are going to be analyzed and to determine the level of assembly on which the analysis will be performed.

This step was performed as a group during a Team's meeting. The group consisted of Kurt Sobczynski, as facilitator and engineer; Joe Spagnoletti, as owner & operator; Doug Junion, mechanical and electrical maintenance technician; and Troy Ellison, as facilitator.

The hydroelectric plant was divided into three sub-systems for the purposes of this study. These three sub-systems contain all the equipment needed for the operation of the plant.

The sub-systems selected for study are:

1. Sub-system 1 Hydro Turbine Generator #1
2. Sub-system 2 Hydro Turbine Generator #2
3. Sub-system 3 General Plant

The level of assembly refers to the amount of detail that each component of each system and sub-system are analyzed. It was decided that for this study the level of assembly would refer to the following:

1. Single large or unique assets or components for the mechanical system.
2. Hydraulic and electronic controls, switches and transformers will be treated and analyzed as "black box' systems.

2.2 Step 2: System Boundary Definition

The purpose of this step was to identify the boundaries of the three sub-systems and to list the components of each system. This step was also performed as a team during a meeting.

The turbine generator boundaries were selected to begin at the intake flumes and stop at the draft tubes for each machine. Included with the turbine generators were all the electrical equipment associated with the generators. The general plant system boundaries were selected to include all the auxiliary equipment not included with the turbine generators. The systems, sub-systems, and equipment contained in the boundaries can be listed as follows:

System Hydroelectric Plant City of Hastings

Sub-system 1: Hydro Turbine/Generator #1

1. Gate case, control servo, linkage, and HPU
2. Runner hub and pitch control servo and linkage
3. Turbine casing
4. Turbine and generator thrust and guide bearings.
5. Speed changer
6. Generator field, stator
7. Oil system
8. Cooling water system
9. Seal water system
10. Electronic speed governors and turbine controls
11. Static excitation and voltage controls
12. Switchgear and protective relays

Sub-system 2: Hydro Turbine/Generator #2

1. Gate case, control servo, linkage, and HPU
2. Runner hub and pitch control servo and linkage
3. Turbine casing
4. Turbine and generator thrust and guide bearings.
5. Speed changer
6. Generator field, stator
7. Oil system

8. Cooling water system
9. Seal water system
10. Electronic speed governors and turbine controls
11. Static excitation and voltage controls
12. Switchgear and protective relays

Sub-system 3: General Plant

1. Trash rack & gates
    a. Flume gate
    b. Lifting equipment
    c. Trash rack cleaner
2. Intake flume & draft tube
3. Station transformer
4. HVAC equipment
5. Miscellaneous equipment
    a. Sump pumps
    b. Air compressors

2.3 Step 3: System Description/Functional Block Diagram

The purpose of this step was to define the system functions, determine if there are any redundancy features and key control parameters that will affect maintenance decisions.

A functional block diagram (Figure 1) of the sub-systems #1 and #2 was developed. The input and output of these sub-systems was also listed. sub-systems #1 and #2 were broken down further and the individual components of each sub-system were assigned asset numbers and listed under each sub-system. The systems, sub-systems, and asset numbers are listed in Table A-2 in Appendix A.

A group review of the functional block diagram (Figure 1) and the system and asset list was conducted. The following observations were made:

1. Sub-system #1 And sub-system #2, the turbine generators, are identical units and therefore the hydroelectric plant has double redundancy. This is in effect when the flow rate through the plant does not exceed the capacity of one turbine. It was pointed out that this occurs mostly in the winter season, approximately 80% of the time.

2. The flow rate through the plant "CFS" is dictated solely the Army Corps of Engineers. The primary purpose of the dam is navigation. Electric power generation is secondary. Therefore, during the summer months power generation is limited to maintain water for the locks and in the winter a minimum flow must be passed though the spillway for environmental purposes also limiting power production.

3. Protection features such alarms, interlocks, and trips for vibration, temperatures, and load rejection are included in the control logic for the hydro turbine governors.

The sole purpose of the hydroelectric power plant is to convert the energy from the river into electric power. The electric power is sold to the local utility. The main season for generating hydropower is in the winter since the river traffic is stopped and the water flow is passed for environmental purposes and hydropower generation.

2.4 Step 4: System Functions and Functional Failures

The purpose of this step was to define the functions of the components for each of the sub-systems and to describe the functional failure(s) of this component.

The list of assets was reviewed, and the functions and functional failures was determined. The emphasis was on the loss of function and not the failure of the component.

During this analysis it became apparent that the functions of sub-system's #1 and #2, the turbine generators, are identical so the analysis was performed on one unit only and copied to the other machine. It was also realized that the potential preventative maintenance activities for the electrical power transmission equipment were identical and that the individual functions of each electrical cabinet were not relevant. Therefore, the electrical power transmission components were grouped into a common sub-system and treated as a "black box" and given a common function and failure mode.

The functional block diagram (Figure 1), the asset list, and the system functions and failures are presented in Table A-1.

3 Element 2: Identify Specific Failure Modes that Could Potentially Produce Functional Failures

The second element identifies the specific failure modes that could hinder the system and equipment functions. A Failure Mode and Effects Analysis (FMEA) was performed to identify the failure modes that could defeat the functions. An initial prioritization of the functions and failure modes was also conducted. The FMEA and the prioritization are presented in chart form in a spreadsheet located in the Table A-3.

3.1 Step 5: Failure Mode and Effects Analysis (FMEA)

The purpose of this step was to connect the system functions and the system components by directly identifying specific hardware failure modes that could produce the unwanted functional failures.

The System Functions and Functional Failure list developed in Step #4 was reviewed. Failure Modes were assigned to each functional failure as described below:

- The failure mode is the reason or cause for the component failing to perform.
- A failure cause is the effect that caused the failure mode.

For example, the first asset analyzed, Asset #100 Kaplan Runner, the failure mode was cavitation and wear on the runner. Cavitation is the spalling and uneven wear on the downstream side of the runner blades. The potential causes (failure causes) of cavitation and wear are the improper adjustment of the blade pitch and impact from foreign objects. The effects of the failures were also evaluated on the local sub-system, the system, and the entire plant. The failure modes that affect both turbines, and thus the plant, were determined to require further analysis to determine if preventative maintenance activities are applicable. It was also determined that the failure modes that effect only one of the turbines would still require further analysis since the costs of repair of the turbine due to failure outweigh the costs of the preventative maintenance. The only failure modes that qualified for run to failure status were connected to the HVAC equipment in the plant.

4 Element 3: Prioritize Failure Modes

The third element prioritizes the functions and failure modes uncovered during the FMEA utilizing a Logic Tree Analysis (LTA) approach. LTA is an analytical method that uses deductive logic to guide though a process used to draw correct conclusions. The results of the LTA are presented in chart form in a spreadsheet located in Table A-4.

4.1 Step 6: Logic Tree Analysis (LTA)

The purpose of this step is to evaluate and categorize the failure modes to determine if preventative maintenance activities are warranted.

Each of the Failure Modes from Step #5 that required analysis, was subjected to the following questions. The first question was that under normal conditions will the operator be aware that the failure mode has occurred. If the answer to that question is yes, then the failure is deemed evident. The second question asks whether the failure mode causes a safety problem, and the final question is does the failure mode cause an outage for the system. Categories based upon these answers are assigned to each of the failure modes as follows:

Safety = A
Outage = B
Minor = C
Hidden = D

Categories A or D/A, B or D/B are candidates for preventative maintenance activities while category C and D/C are candidates for run to failure (RTF).

Only three failure modes were Category C and deemed run to failure, the remainder of the failure modes were carried onto Step #7.

5 Element 4: Task Selection and Evaluation

The fourth element is the identification of preventative maintenance activities to address the failure modes selected in Step #6.

5.1 Step 7: Task Selection

The purpose of this step is to select preventative maintenance tasks (PM's) for each of the failure causes. Each failure cause identified in Step #6 was reviewed based on the following seven question criteria:

- Q1: Is the age reliability relationship for this failure known?
- Q2: Are there any applicable time dependent (td) tasks?
- Q3: Are there any applicable condition dependent (cd) tasks?
- Q4: Is this a category "d" failure mode?
- Q5: Are there any applicable failure finding (ff) tasks?
- Q6: Are any of these tasks effective?
- Q7: Can a design modification eliminate the failure mode or effects?

Based upon the results of these questions, candidate PM tasks and the frequency of these tasks were selected. In Question #1, the age reliability relationship refers to the wear rate of a component. This question asks based on operating time or cycles is the wear or degradation of the component known and constant so that a failure time can be predicted. Question #2 follows on Question #1 by asking if there are any applicable time or life cycle dependent tasks or PM's that can be performed. Question #3 asks if there are any PM's that can be performed that will be able to detect the onset of failure, Question #4 asks if the failure mode is a category "D" or hidden failure. A hidden failure is unknown to an operator and may also not be time dependent. Question #5 asks if there are any tasks that can be used to discover the failure such as internal inspections. Question #6 asks if any of the PM's suggested are effective. For this exercise we recommended PM's that L&S currently use in hydroelectric industry. The final question asks whether a design modification of the component could eliminate the failure mode. The results of the task election process can be seen in Table A-5.

The list of recommended preventative maintenance activities is presented in chart form in Table A-6. This list includes the following:

1. Covered Equipment
2. Scope of work
3. Recommended Frequency
4. Cost Estimate

It should be noted that a substantial driver in determining the PM frequency was the FERC Part 12D regulatory requirement for dewatering the turbine forebays and tailraces every 5 years for inspection. Dewatering costs will also consume a substantial amount of the maintenance budget.

5.2 Economic Evaluation of Recommended Maintenance

An economic evaluation was performed by balancing the cost of the recommended maintenance over the next 25 years with the projected revenue produced by power generation.

5.2.1 Assumptions and Clarifications

The following assumptions were made in this evaluation and in the full process described further in this document:

- The annual power generation revenue is estimated to be $716,500. It is based on a budget number for 2024 provided by the City of Hastings. A cost escalation for future power sale price has not been included.
- The historical annual revenue data from 2006 to 2022 was also provided by the City of Hastings. The year 2006 was the first full year of power generation revenue data. The average power production was determined from the historical data to be $888,115. See Table 5-1.
- The rate of return for the power generation and the interest rate on the maintenance costs have been assumed to be constant over the next 25 years at 5%.
- Repair and maintenance cost escalation has not been included in the maintenance costs estimates.
- Repair and maintenance cost estimates were provided by L&S Electric.
- The maintenance intervals are based on typical industry requirements. Sit specific usage, wear, and damage may affect the typical maintenance timing. It should be noted that the recommended maintenance program is cyclical and begins again in 25 years.
- The equipment lists, and subsequent recommended preventative maintenance tasks were developed in conjunction with L&S Electric and the City of Hastings. Barr did not visit the site to assess or document the equipment and is not responsible for any omitted components or equipment.
- An annual miscellaneous maintenance cost of $25,000 was added to account for small repairs not included in specific line items. This is in addition to $44,000 in line item 6354 Repairs & Maintenance Equipment from the budget supplied by the City of Hastings. The miscellaneous maintenance cost is included in the overall maintenance costs and line item 6354 is included in the operating costs.

- It was assumed for this study that the current condition of both turbine/generators was such that a 25-yr major inspection and generator rewind is required for both units. It should be noted that this is a conservative scenario. It is possible that the units are in better condition and that a 10-yr minor inspection could be performed to determine the condition of the units. However, it would be prudent to anticipate the more conservative requirement.
- The estimated annual operating costs for the hydroelectric plant are $450,000 and were provided by the City of Hastings.

Table 5-1 History of Revenues -Electricity (provided by the City of Hasting)

Year	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov.	Dec.	Total
2003	$-	$-	$-	$-	$-	$-	$-	$-	$-	$69,997	$70,636	$78,533	$219,165
2004	$59,845	$59,270	$87,281	$82,234	$58,661	$74,626	$-	$136,612	$67,629	$-	$-	$-	$626,159
2004	$-	$-	$-	$-	$-	$-	$-	$-	$-	$68,215	$-	$143,703	$211,918
2005	$98,169	$93,577	$103,093	$56,733	$72,122	$64,149	$94,054	$116,055	$111,246	$-	$-	$-	$809,198
2005	$-	$-	$-	$-	$-	$-	$-	$-	$-	$67,860	$192,071	$98,993	$358,924
2006	$115,810	$88,425	$81,643	$54,453	$61,444	$89,607	$101,410	$89,986	$54,072	$59,338	$63,983	$98,041	$958,213
2007	$110,881	$81,426	$85,063	$51,955	$79,694	$104,207	$103,659	$96,780	$100,568	$90,086	$102,555	$113,879	$1,120,754
2008	$92,761	$80,057	$100,020	$83,849	$68,585	$75,184	$116,089	$108,934	$93,398	$117,983	$114,113	$99,507	$1,150,481
2009	$98,703	$105,942	$98,267	$65,992	$78,700	$94,305	$95,391	$94,269	$74,420	$95,788	$90,087	$97,725	$1,089,590
2010	$97,858	$67,912	$54,367	$48,452	$62,399	$71,269	$77,911	$86,717	$84,807	$69,968	$92,628	$116,057	$930,344
2011	$94,394	$87,998	$75,284	$41,170	$41,239	$46,755	$26,118	$70,903	$98,593	$141,031	$76,910	$110,949	$911,343
2012	$80,232	$82,411	$102,229	$99,056	$61,221	$49,437	$79,551	$108,935	$76,780	$66,975	$88,598	$86,393	$981,820
2013	$74,176	$105,269	$71,815	$78,610	$45,737	$52,769	$70,257	$111,500	$82,605	$72,223	$87,926	$94,735	$947,624
2014	$96,570	$92,189	$100,788	$56,525	$38,823	$36,885	$49,265	$106,662	$74,476	$101,848	$80,138	$75,659	$909,827
2015	$94,954	$94,509	$95,361	$91,765	$66,536	$67,652	$86,252	$93,660	$84,228	$83,028	$69,227	$72,651	$999,822
2016	$178,497	$82,075	$138,546	$64,681	$64,121	$70,655	$44,309	$66,429	$48,225	$52,825	$61,060	$61,479	$932,900
2017	$75,917	$61,144	$67,031	$56,971	$32,001	$64,823	$87,620	$83,100	$76,406	$46,538	$66,607	$59,436	$777,594
2018	$62,236	$59,790	$60,370	$47,253	$37,746	$47,604	$43,536	$83,912	$64,685	$48,332	$64,646	$71,909	$692,018
2019	$85,517	$84,643	$66,194	$36,360	$34,599	$42,538	$44,479	$68,448	$55,768	$35,741	$49,230	$58,631	$662,148
2020	$57,480	$49,876	$42,468	$38,277	$39,491	$35,364	$33,031	$58,320	$55,615	$54,870	$53,299	$58,875	$576,967
2021	$69,787	$60,904	$52,539	$50,646	$59,280	$69,093	$61,350	$54,769	$61,320	$73,592	$55,610	$61,200	$730,088
2022	$66,760	$57,323	$58,199	$47,038	$30,286	$43,092	$82,676	$82,797	$73,638	$55,522	$65,009	$64,099	$726,439
2023	$78,589	$65,655	$82,107	$43,451	$-	$-	$-	$-	$-	$-	$-	$-	$-
Total	**$1,789,136**	**$1,560,395**	**$1,622,666**	**$1,195,472**	**$1,032,684**	**$1,200,014**	**$1,296,956**	**$1,718,787**	**$1,438,480**	**$1,471,760**	**$1,544,330**	**$1,722,455**	**$17,323,333**

5.2.2 Economic Analysis Approach

The analysis was performed by calculating the present value of the projected power production revenue and subtracting the estimated present value of the operating and maintenance (O&M) costs over the next 25 years. The present value analysis calculates the current value of a future cash flow or investment that will be paid or disbursed at a future date, discounted back to the present at a given interest rate.

The purpose of the following calculations is to determine the current value of the cash flows and investments of the Hastings Hydroelectric Plant to make an accurate assessment of the financial viability of the investment.

5.2.2.1 Present Value Given Future Investment/Cash Flow

The present value formula calculates the current worth of a future cash flow or investment that will be received or paid at a future date, discounted back to the present at a given interest rate.

Present Worth (P/F, i, n)

Operational cycle (n)	25	years
Interest rate (i)	5	%
Present value (P)		
Future value (F)		

$$P = F(1+i)^{-n}$$

or the Factor (P/F) for i=5%, n=25 can be looked up in a table in which case:

$$P = \left({}^{P}/_{F}\right)F$$

5.2.2.2 Present Value Given Annual Investment/Cash Flow

The series present worth formula calculates the equivalent present value of equal cash flows received or disbursed at regular intervals over a specific period of time at a given interest rate.

Series Present Worth (P/A, i, n)

Operational cycle (n)	25	years
Interest rate (i)	5	%
Present value (P)		
Annual worth or costs (A)		

$$P = \frac{(1+i)^n - 1}{i(1+i)^n}$$

or the Factor (P/A) for i=5%, n=25 can be looked up in a table in which case:

$$P = \left(P/_A\right)A$$

5.3 Economic Analysis Results

The present value of the projected revenue of the hydroelectric plant was determined to be $10,100,000. The present value of the O&M costs were determined to be $12,400,000. The present value of the net cash flow is a negative $2,300,000. In this case the O&M costs are 122% of the projected power revenue.

According to the US Energy Information Administration (EIA) in the Annual Energy Outlook for 2022, the average O&M costs for a conventional hydroelectric power plant were $43.78 per KW. The hydro turbines at the City of Hasting facility are rated at 2200 KW for each unit. The annual combined O&M costs for both units based on the EIA 2022 average should then be approximately $193,000. The present value for the O&M costs for the next 25 years based on this average are $2,700,000. These O&M costs are approximately 27% of the present value of the projected power revenue.

The present values from the current projection and from a projection based on the O&M costs from the IEA 2022 average are listed in the Table 5-2. The projected annual cash flow can be seen in Table 5-3. The present value calculations can be seen in Appendix C.

Table 5-2 Present Value Analysis Results

Revenue	Current Projection	Projection based on EIA 2022
Projected Power Revenue	$10,100,000	$10,100,000
O&M Costs	$12,400,000	$2,700,000
Net Cash (Revenue -O&M)	-$2,300,000	$7,400,000
O&M % of Revenue	122 %	27 %

Table 5-3 Projected Cash Flow

Year	Projected Revenue	Operating Costs	Maintenance Costs						O&M Total	Cash Flow
			Annual	3 Year	5year	10 Year	25 Year	Total		
0	$716,500	$450,000	$60,000	-	-	-	3,050,000	$3,110,000	$3,560,000	$2,843,500
1	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
2	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
3	$716,500	$450,000	$60,000	$45,000	-	-	-	$105,000	$555,000	$161,500
4	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
5	$716,500	$450,000	$60,000	-	$714,000	-	-	$774,000	$1,224,000	$507,500
6	$716,500	$450,000	$60,000	$45,000	-	-	-	$105,000	$555,000	$161,500
7	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
8	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
9	$716,500	$450,000	$60,000	$45,000	-	-	-	$105,000	$555,000	$161,500
10	$716,500	$450,000	$60,000	-	-	$1,020,000	-	$1,080,000	$1,530,000	$813,500
11	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
12	$716,500	$450,000	$60,000	$45,000	-	-	-	$105,000	$555,000	$161,500
13	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
14	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
15	$716,500	$450,000	$60,000	$45,000	$714,000	-	-	$819,000	$1,269,000	$552,500
16	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
17	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
18	$716,500	$450,000	$60,000	$45,000	-	-	-	$105,000	$555,000	$161,500
19	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
20	$716,500	$450,000	$60,000	-	-	$1,020,000	-	$1,080,000	$1,530,000	$813,500

Year	Projected Revenue	Operating Costs	Maintenance Costs						O&M Total	Cash Flow
			Annual	3 Year	5year	10 Year	25 Year	Total		
21	$716,500	$450,000	$60,000	$45,000	-	-	-	$105,000	$555,000	$161,500
22	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
23	$716,500	$450,000	$60,000	-	-	-	-	$60,000	$510,000	$206,500
24	$716,500	$450,000	$60,000	$45,000	-	-	-	$105,000	$555,000	$161,500
25	$716,500	$450,000	$60,000	-	-	-	3,050,000	$3,110,000	$3,560,000	$2,843,500

The O&M costs for the City of Hastings hydroelectric plant are more than four times greater than the average as reported by the EIA. Some potential causes for the higher-than-average costs are:

- Economy of scale – The O&M costs for smaller projects tend to higher than the larger projects. Much of the regulatory inspection, operating staff, and maintenance are performed and needed on both small and large projects, however the larger projects have more income to offset these costs.
- Accessibility - The difficultly in accessing and in dewatering the facility greatly increase the costs of inspection and maintenance.
- Power Production – The primary purpose of the Lock and Dam is for navigation of the river and not for power generation. Power production is limited due to the need to keep water available for navigation purposes.
- Complexity of the Turbine/Generators - The turbines installed in this facility are Kaplan style turbines with speed changers that are coupled to synchronous generators. This style of turbine was chosen to accommodate the variable heads and high water flows indicative of a facility that is integrated with a navigable Lock and Dam. While this type of turbine is efficient in this application, it is by its nature complex and, therefore, requires more maintenance and upkeep than a Francis or propeller style turbine.
- Power costs – The power produced by the facility is purchased by the local utility. The rate for this power is a function of the avoided variable costs for one of the Utilities existing power generating plants and an accredited capability based on the current generation in either the summer or winter season. It is possible that a higher rate could be negotiated that will lower the effect of the O&M costs.

Appendices

Appendix A

Tables

Table A-1
System Functions and Functional Failures

Sub-System:	Asset #	Description	Function #	Functional Failure #	Function/Functional Failure Description
Turbine	100	Kaplan Runner	1.0		Convert Hydraulic Energy of Water into Torque
				1.1	Inefficient Conversion of Hydraulic Energy to Torque (80%)
				1.2	Complete Failure to Convert Hydraulic Energy to Torque
	101	Trunnion Seal	2.0		Seal Turbine Blade & Separate Governor Oil in Hub from River Water
				2.1	Loss Of Oil into River
				2.2	Water Contamination in Oil System
	102	Mechanical shaft seal	3.0		Seal Runner and Turbine Shaft
				3.1	River Water Leaks into Power Plant
				3.2	Water Contamination in Oil System of River Side Guide Bearing
	103	Pitch control Servo	4.0		Adjust Pitch of Kaplan Blade to Improve Turbine Efficiency
				4.1	Pitch Control Will Not Move
				4.2	Pitch Controls Out of Adjustment
	104	Runner side guide bearing	5.0		Position, Align, And Compensate for Radial Forces from Turbine Shaft
				5.1	Misaligned (Radial) Turbine Shaft
				5.2	Catastrophic Bearing Failure
	105	Thrust bearing	6.0		Position, Align, And Compensate for Axial Forces from Turbine Shaft
				6.1	Misaligned (Radial) Turbine Shaft
				6.2	Misaligned (Axial) Turbine Shaft
				6.3	Catastrophic Bearing Failure
	106	Wicket gates & controls	7.0		Adjust Position of Wicket Gate to Increase and Decrease Water Flow Through the Turbine
				7.1	Unable to Increase or Decrease Water Flow Though Turbine
				7.2	Unable to Shut Off Water Flow Through Turbine
	107	Brake system	8.0		Stop Turbine from Rotating When Speed is Lower Than 96 RPM
				8.1	Will Not Stop Turbine from Rotating
				8.2	Will Not Allow Turbine to Rotate
Reducer	108	Gearbox Speed Reducer	9.0		Increase Turbine Shaft Speed to Synchronous Generator Speed. Transmit Power from Turbine to Generator
				9.1	Unable To Transmit Power from Turbine to Generator
Generator	109	Rotating Electric Generator	10.0		Convert Torque from Turbine into Electricity
				10.1	Loss Of Electrical Power
Generator Exciter	110	Generator Electronic Exciter #1	11.0		Energize Generator Field
				11.1	Cannot Energize Field or Start Up Unit
			12.0		Provide Voltage Control
				12.1	Unable to Control Voltage or Frequency
Governor	111	HPU	13.0		Provides Hydraulic Power to Wicket and Blade Pitch Control & Brakes
				13.1	Cannot Open Wicket Gates or Control Pitch of Blades or Release Brakes
	112	Accumulator	14.0		Stores Hydraulic Power to Balance Operation of Hydraulic Pumps and Motors
				14.1	Cannot Open Wicket Gates or Control Pitch of Blades
			15.0		Stores Hydraulic Power to Allow a Final Closing of Wicket Gates in the Event of Loss of Station Power
				15.1	Cannot Stop Rotation of Turbine (Runaway)
	113	Governor Oil Tank	16.0		Store Control Oil for Both Wicket and Kaplan Control Governors
				16.1	Integrity, Loss of Oil into River
				16.2	No Control Oil for Governor, Cannot Control Wicket Gates or Blade Pitch
	114	LP1 Controls Hydraulic Main Floor	17.0		Hydraulic Switches & Controls to Regulate Wicket Gate and Kaplan Servo's
				17.1	Cannot Open Wicket Gates or Control Pitch of Blades
	115	HPU Motor #1	18.0		Provide Hydraulic Pressure For HPU
				18.1	No Pressure, Cannot Open Wicket Gates or Control Pitch of Blades
	116	HPU Motor #2	19.0		Provide Hydraulic Pressure For HPU
				19.1	No Pressure, Cannot Open Wicket Gates or Control Pitch of Blades

Sub-System:	Asset #	Description	Function #	Functional Failure #	Function/Functional Failure Description
Governor (Cntd)	117	Accumulator Motor Fluid Trans	20.0		Moves Control Oil from Accumulator to Oil Cooler Heat Exchanger
				20.1	Control Oil Will Overheat, Cannot Control Wicket Gates of Control Pitch of Blades
Lube Oil System	118	Filtration Assembly	21.0		Removes Contaminants from Lube Oil
				21.1	Contaminated Lube Oil, Decreased Bearing Life
				21.2	Plugged Filter, No Lube Oil Flow, Bearing Failure
	119	Filtration System Motor	22.0		Circulates Lube Oil Through Filters
				22.1	Insufficient Lube Oil Pressure
	120	Lube Oil Motor	23.0		Drives Lube Oil Pump
				23.1	No Lube Oil Pressure
	121	Lube Oil Pump	24.0		Pumps Lube Oil Through System, Minimum Pressure
				24.1	Insufficient Lube Oil Pressure
				24.2	No Lube Oil Pressure
	122	Heat Exchanger Cooling Fan Motor	25.0		Cools Lube Oil Maximum Allowed Lube Oil Temp
				25.1	Lube Oil Temp Above Maximum
	123	Heat exchanger	26.0		Cools Lube Oil Maximum Allowed Lube Oil Temp
				26.1	Lube Oil Temp Above Maximum
				26.2	Lube Oil Temp Below Minimum
				26.3	Integrity Of Heat Exchanger, Loss of Lube Oil
	124	Lube Oil Tank #1	27.0		Stores Lube Oil & Governor Control Oil
				27.1	Loss Of Oil into River
				27.2	No Lube Oil for Turbine
Electrical Switchgear	-	Electrical Switchgear “Black Box”	28.0		Transfer electrical power, signals, and control for operation of Turbine generator
	125	Cabinet S4 for Generator #1		28.1	Electrical failure results in the shutdown of the turbine and the inability to generate power
	126	Ground Fault Relay			
	127	Gen Differential Relay			
	128	Gen Protection System			
	129	ITE Breaker 4.76KV			
	130	Cabinet S5 for Generator #1			
	131	Misc. gauges and indicator readouts			
VFD cabinet Unit #1	132	Unit #1 HPU	29.0		Provides power to HPU
				29.1	control logic keeps turbine offline
	133	Unit #1 LOP	30.0		Provides power to lube oil pump
				30.1	control logic keeps turbine offline
	134	Prime Sump Pump	31.0		Provides power to HPU
				31.1	prime sump pump will not pump
	135	Secondary Sump Pump	32.0		Provides power to HPU
				32.1	secondary sump pump will not pump

Table A-2
System Work Breakdown Structure Step 3-4

Sub-System	Asset #	Description	MFG	Serial #
Unit #1				
Turbine	100	Kaplan Runner	Voith	-
	101	Trunnion Seals	Voith	-
	102	Shaft Mechanical Seal	Voith	-
	103	Pitch Control Servo	Voith	-
	104	Runner Side Guide Bearing	Voith	-
	105	Thrust Bearing	Voith	-
	106	Wicket Gates & Controls	Voith	-
Reducer	108	Gearbox Speed Reducer	Voith	H19631
Generator	109	Rotating Electric Generator	Yaskawa	515386101
Exciter	110	Electronic Exciter #1	Basler DECS-200	-
Governor	111	HPU	Continental	-
	112	Accumulator	Wilkes & McLean	-
	113	Governor Oil Tank	-	-
	114	LP1 Controls Hydraulic Main Floor	-	-
	115	HPU Motor #1	Dayton	VM3558
	116	HPU Motor #2	Baldor	CM3714T
	117	Accumulator Motor Fluid Trans	Baldor	VM3558
Lube Oil System	118	Filtration Assembly	-	-
	119	Filtration System Motor	Baldor	VM3558
	120	Lube Oil Motor	Leeson	170165.6
	121	Lube Oil Pump	-	-
	122	Heat Exchanger Cooling Fan Motor	Baldor	VM3554T
	123	Heat Exchanger	Thermal Trans	Z7611

Sub-System	Asset #	Description	MFG	Serial #
Electrical Switchgear	125	Cabinet 54 for Generator #1	-	-
	126	Ground Fault Relay	Bassler BE1-59N	Mounted on S4
	127	Gen Differential Relay	Bassler BE1-87G	Mounted on S4
	128	Gen Protection System	Bassler BE1-GPS	Mounted on S4
	129	ITE Breaker 4.76KV	-	-
	130	Cabinet 55 for Generator #1	-	-
	131	Misc. Gauges and Indicator Readouts	-	Mounted on S3
	132	VFD Cabinet Unit #1	-	-
	133	Unit #1 LOP	ABB	ACQ550-U1.015A-4
	134	Unit #2 Chiller VFD	Mitsubishi	FRF84000170E3N6
	135	Prime Sump Pump	Mitsubishi	FRF74000380NA
	136	Secondary Sump Pump	ABB	22C-D030N103
Unit #2				
Turbine	200	Kaplan Runner	Voith	-
	201	Trunnion seals	Voith	-
	202	Shaft Mechanical Seal	Voith	-
	203	Pitch control Servo	Voith	-
	204	Runner side guide bearing	-	-
	205	Thrust bearing	-	-
	206	Wicket gates & controls	Voith	-
	207	Brake system	Voith	-
Reducer	208	gearbox speed reducer	Voith	H19632
Generator	209	2000 KW Rotating Electric Generator	Yaskawa	515386102
Exciter	210	Electronic Exciter #1	Basler DECS-200	Mounted on S3
Governor	211	HPU	Continental	-
	212	Accumulator	Wilkes & McLean	-
	213	LP2 Controls Hydraulic Main Floor	-	-
	214	HPU Motor #1	Baldor	36VF71B
	215	HPU Motor #2	Baldor	CM3714T
	216	Accumulator Motor	Baldor	VM3558
	217	Governor oil tank	-	-

Sub-System	Asset #	Description	MFG	Serial #
Lube Oil System	218	Filtration Assembly	-	-
	219	Filtration System Motor	Baldor	VM3558
	220	Lube Oil Motor	Leeson	170165.6
	221	Lube Oil Pump	-	-
	222	Heat exchanger motor	Baldor	VM3554T
	223	Heat exchanger	Thermal Trans	Z7677
	224	Lube oil tank 2	-	-
Electrical Switchgear	225	Cabinet 52 for Generator #2	-	-
	226	Ground Fault Relay	Bassler BE1-59N	Mounted on S2
	227	Gen Differential Relay	Bassler BE1-87G	Mounted on S2
	228	Gen Protection System	Bassler BE1-GPS	Mounted on S2
	229	ITE Breaker 4.76 KV	-	-
	230	Cabinet 55 for Generator #2	-	-
	231	Misc. gauges and indicator readouts	-	Mounted on S3
	232	VFD cabinet Unit #2	-	-
	233	Unit #2 HPU VFD controller	-	AC5550-U1.015A-4
	234	Unit #2 LOP VFD controller	-	22BD012N104
	235	Starter intake fan VFD controller	-	-
	236	Starter exhaust fan VFD controller	-	-

Table A-3
Failure Mode and Effects Analysis (FMEA)

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Local	System	Plant	LTA	Comments
1.1	100 & 200	Kaplan Runner	1.00	Cavitation And Wear on Runner	1.11	Normal Wear on Runner (Age Related)	x	x		x	Even Though Effects Only One Turbine, Both Turbines Are Needed to Pass CFS At Some Conditions, Cost of Failure Too Great (Red).
					1.12	Cavitation Caused by Improper Adjustment of Blade Pitch	x	x		x	
1.2	100 &200	Kaplan Runner	1.20	Catastrophic Failure of Runner	1.21	Impact Damage from Foreign Object	x	x		x	Plant Issue Due to Environmental Contamination
					1.22	Impact Damage from Turbine Gate Component	x	x		x	
2.1	101 & 201	Trunnion Seal	2.10	Worn Seal	2.11	Normal Wear on Seal (Age Related)	x	x	x	x	Plant Issue Affects Both Turbines
					2.12	Mechanical Failure of Seal Keepers	x	x	x	x	
2.2	102 & 202	Trunnion Seal	2.20	Worn Seal	2.21	Normal Wear on Seal (Age Related)	x	x		x	
					2.22	Mechanical Failure of Seal Keepers					
3.1	102& 202	Mechanical Seal	3.10	Worn Seal	3.11	Normal Wear on Seal (Age Related)					
					3.12	Flush Water Lines Plugged Not on Trunnion Not Used on Mechanical					
3.2	102& 202	Mechanical Seal	3.20	Worn Seal	3.11	Normal Wear on Seal (Age Related)					Plant Issue Affects Both Turbines
					3.12	Flush Water Lines Plugged Not on Trunnion Not Used on Mechanical	x	x	x	x	
4.1	102 & 202	Pitch Control Servo	4.10	Servo and Linkages Frozen in Position	4.11	Servo Cylinder Scored or Damaged and Frozen into Cylinder	x	x		x	
					4.12	Linkage or Bushing Bearings Broken or Severed or Frozen in Position	x	x		x	
4.2	102 & 202	Pitch Control Servo	4.20	Servo and Linkages Out of Adjustment	4.21	Linkage or Connecting Bushings Loose (Primary Control Electronic)	x	x		x	
					4.22	Leaking Fittings and Servo					
5.1	103 & 203	Runner Side Guide Bearing	5.10	Guide Bearing Wear	5.11	Normal Bearing Wear (Age Related)	x	x		x	
					5.12	Contaminated Lube Oil (Premature Wear)	x	x		x	
					5.13	Shaft Misalignment (Uneven Wear)	x	x		x	
5.2	104 & 203	Runner Side Guide Bearing	5.20	Guide Bearing Liner Failure	5.21	Contaminated Lube Oil (Premature Wear) Mechanical Seal Failure Water Contamination	x	x		x	
					5.22	Shaft Misalignment (Uneven Wear)	x	x		x	
					5.23	Excessive Radial Clearance	x	x		x	
6.1	104 & 204	Thrust Bearing	6.10	Thrust Bearing Liner Wear (Look Up)	6.11	Shaft Misalignment (Uneven Wear)	x	x		x	
6.2	104 & 204	Thrust Bearing	6.20	Thrust Bearing Liner Wear (Look Up)	6.22	Shaft Misalignment (Uneven Wear)	x	x		x	
6.3	104 & 204	Thrust Bearing	6.30	Thrust Bearing Liner Wear (Look Up)	6.31	Shaft Misalignment (Uneven Wear)	x	x		x	
					6.32	Contaminated Lube Oil (Premature Wear)	x	x		x	
					6.33	Excessive Radial Clearance	x	x		x	
7.1	105 & 205	Wicket Gates & Controls	7.10	Stiction in Gates and Controls	7.11	Wear In Bushings	x	x		x	
					7.12	Foreign Object or Debris in Wickets	x	x		x	

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Local	System	Plant	LTA	Comments
7.2	105 & 205	Wicket Gates & Controls	7.20	Frozen Or Broken Gates and Controls	7.21	Wear In Bushings	x	x		x	
					7.22	Foreign Object or Debris in Wickets	x	x		x	
8.1	106 & 206	Brake System	8.10	Worn Brake Shoes	8.11	Normal Wear on Linings (Age Related)	x	x		x	
8.2	106 & 206	Brake System	8.20	Failed Brake Mechanism	8.21	Excessive Stress on Brake Components Caused by Overspeed	x	x		x	
9.1	107 & 207	Gearbox Speed Reducer	9.10	Gearbox Bearing or Gear Failure	9.11	Bearing Failure (Age Related)	x	x		x	
					9.12	Bearing Failure (Lube Related)	x	x		x	
					9.13	Gear Failure (Age Related)	x	x		x	
					9.14	Gear Failure (Lube Related)	x	x		x	
					9.15	Coupling Failure (Turbine /Gearbox)	x	x		x	
					9.16	Coupling Failure (Gearbox Generator)	x	x		x	
					9.17	Gearbox Seal Failure (Age Related)	x	x		x	
10.1	108 & 208	Rotating Electric Generator	10.10	Generator Stator or Field Failure	10.11	Rotor Winding Resistance (Age Related)	x	x		x	
					10.12	Stator Winding Resistance (Age Related)	x	x		x	
					10.13	Stator Wedges or Bar Failures	x	x		x	
					10.14	End Winding Supports and Connections Failure	x	x		x	
					10.15	Air Cooling and Ventilation Failure	x	x		x	
					10.16	Upstream And Downstream Generator Bearing Failures	x	x		x	
					10.17	Diode Failure	x	x		x	
11.1	109 & 209	Electronic Exciter #1	11.1	Electronic Failure	11.11	Electronic Failure	x	x		x	
12.1	109 & 209	Electronic Exciter #1	12.10	Electronic Failure	12.11	Electronic Failure	x	x		x	
13.1	110 & 210	HPU	13.10	No Control Hydraulic Oil Pressure or Flow	13.11	Electronic Failure	x	x		x	
14.11	111 & 211	Accumulator	14.10	Low Pressure in Bladder	14.11	Broken Bladder	x	x		x	
					13.1214.12	Low Nitrogen Charge	x	x		x	
15.1	111 & 211	Accumulator	15.10	Low Pressure in Bladder	15.11	Broken Bladder	x	x		x	
					15.12	Low Nitrogen Charge	x	x		x	
16.1	112 & 212	Governor Oil Tank	16.10	Corroded Oil Tank That Leaks	16.10	Corrosion Due to Age	x	x		x	
16.2	112 & 212	Governor Oil Tank	16.20	Catastrophic Failure of Oil Tank Due to Overpressure	16.22	Cannot Be Overpressure	x	x		x	
17.1	113 & 213	Lp1&2 Controls Hydraulic Main Floor	17.10	Electronic Failure	17.11	Electronic Failure	x	x		x	
18.1	114 & 214	HPU Motor #1	18.10		18.11	Motor Bearing Failure	x	x		x	

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Local	System	Plant	LTA	Comments
				No Control Hydraulic Oil Pressure or Flow	18.12	Electronic Failure	x	x		x	
19.1	115 & 215	HPU Motor #2	19.10	No Control Hydraulic Oil Pressure or Flow	19.11	Motor Bearing Failure	x	x		x	
					19.12	Electronic Failure	x	x		x	
20.1	116 & 216	Accumulator Motor Fluid Trans	20.10	Overheated Lube & Hydraulic Oil	20.11	Motor Bearing Failure	x	x		x	
					20.12	Electronic Failure	x	x		x	
21.1	117 & 217	Filtration Assembly	21.10	Contaminated Filter	21.11	Defective Filter	x	x		x	
21.2	117 & 217	Filtration Assembly	21.20	Plugged Filter	21.12	Plugged Filter (Age or Pressure Drop) Trip Off Turbine	x	x		x	
21.3	118 & 218	Filtration System Motor	21.30	No Oil Pressure	21.13	Motor Bearing Failure	x	x		x	
					21.14	Electronic Failure	x	x		x	
22.1	119 & 219	Lube Oil Motor	22.10	No Oil Pressure	22.11	Motor Bearing Failure	x	x		x	
					22.12	Electronic Failure	x	x		x	
23.1	120 & 220	Lube Oil Pump	23.10	Pump Impeller Worn	23.11	Normal Wear (Age Related)	x	x		x	
23.2	120 & 220	Lube Oil Pump	23.20	Pump Relief Valve Improperly Set or Failed	23.21	Relief Valve Failure Components Frozen or Rusted In Position	x	x		x	
24.1	121 & 221	Heat Exchanger Cooling Fan Motor	24.10	Overheated Lube & Hydraulic Oil	24.11	Motor Bearing Failure	x	x		x	
					24.12	Electronic Failure	x	x		x	
25.1	122 & 222	Heat Exchanger	25.10	Fouled Heat Exchanger	25.12	Build Up on Oil Side of Heat Exchanger or Debris on Air Side (Time Factor)	x	x		x	
25.2	122 & 222	Heat Exchanger	25.20	Thermostat Failure	25.21	Buildup of Insulating Contaminant on Temperature Sensor (Mechanical)	x	x		x	
25.3	122 & 222	Heat Exchanger	25.30	Heat Exchanger Tube Failure	25.31	Tube Rupture Due to Overheating & Corrosion	x	x		x	
26.1	123 & 223	Lube Oil Tank 1 & 2	26.10	Loss Of Integrity of Tank	26.12	Tank Failure Due to Corrosion	x	x		x	
26.2	123 & 223	Lube Oil Tank 1 & 2	26.20	Loss Of Integrity of Tank	26.21	Tank Failure Due to Corrosion	x	x		x	
27.1	Multi	Electrical Switchgear	27.10	Electronic Failure	27.12	Electronic Failure	x	x		x	
28.1	134	Unit #1 &#2 HPU VFD	28.10	Electronic Failure	28.12	Electronic Failure	x	x		x	
29.1	135	Unit #1 &#2 LOP VFD	29.10	Electronic Failure	29.12	Electronic Failure	x	x		x	

Table A-4
Logic (Decision) Tree Analysis (LTA)

Functional Failure	Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Evident	Safety	Outage	Cat	Comments
-	1.1	100 & 200	Kaplan Runner	1.00	Cavitation And Wear on Runner	N	N	Y	D/B	
-	1.2	100 & 200	Kaplan Runner	1.20	Catastrophic Failure of Runner	Y	Y	Y	B	
-	2.1	101 & 201	Trunnion Seal	2.10	Worn Seal	Y	N	Y	B	
-	2.2	102 & 201	Trunnion Seal	2.20	Worn Seal	Y	N	Y	B	
			Mechanical Seal		Worn Seal	Y	N	Y	B	
			Mechanical Seal		Worn Seal	Y	N	Y	B	
-	3.1	102 & 202	Pitch Control Servo	3.10	Servo And Linkages Frozen in Position	Y	N	Y	B	
-	3.2	103 & 202	Pitch Control Servo	3.20	Servo and Linkages Out of Adjustment	Y	N	Y	B	
-	4.1	103 & 203	Runner Side Guide Bearing	4.10	Guide Bearing Wear	N	N	Y	D/B	
-	4.2	104 & 203	Runner Side Guide Bearing	4.20	Guide Bearing Liner Failure	N	N	Y	D/B	
-	5.1	104 & 204	Thrust Bearing	5.10	Thrust Bearing Liner Wear (Look Up)	N	N	Y	D/B	
-	5.2	104 & 204	Thrust Bearing	5.20	Thrust Bearing Liner Wear (Look Up)	N	N	Y	D/B	
-	5.3	104 & 204	Thrust Bearing	5.30	Thrust Bearing Liner Wear (Look Up)	N	N	Y	D/B	
-	6.1	105 & 205	Wicket Gates & Controls	6.10	Stiction In Gates and Controls	Y	N	Y	B	
-	6.2	105 & 205	Wicket Gates & Controls	6.20	Frozen or Broken Gates and Controls	Y	Y	Y	A	
-	7.1	106 & 206	Brake System	7.10	Worn Brake Shoes	N	N	Y	D/B	
-	7.2	106 & 206	Brake System	7.20	Failed Brake Mechanism	Y	Y	Y	A	
-	8.1	107 & 207	Gearbox Speed Reducer	8.10	Gearbox Bearing or Gear Failure	Y	N	Y	B	
-	9.1	108 & 208	Rotating Electric Generator	9.10	Generator Stator or Field Failure	Y	Y	Y	A	
-	10.1	109 & 209	Electronic Exciter #1	10.10	Electronic Failure	Y	N	Y	B	
-	11.1	109 & 209	Electronic Exciter #1	11.10	Electronic Failure	Y	N	Y	B	
-	12.1	110 & 210	HPU	12.10	No Control Hydraulic Oil Pressure or Flow	Y	N	Y	B	
-	13.1	111 & 211	Accumulator	13.10	Low Pressure in Bladder	Y	N	Y	B	
-	14.1	111 & 211	Accumulator	14.10	Low Pressure in Bladder	Y	N	Y	B	
-	15.1	112 & 212	Governor Oil Tank	15.10	Corroded Oil Tank that Leaks	Y	Y	Y	A	
-	15.2	112 & 212	Governor Oil Tank	15.20	Catastrophic Failure of Oil Tank Due to Overpressure	Y	Y	Y	A	
-	16.1	113 & 213	LP1&2 Controls Hydraulic Main Floor	16.10	Electronic Failure	Y	N	Y	B	
-	17.1	114 & 214	HPU Motor #1	17.10	No Control Hydraulic Oil Pressure or Flow	Y	N	Y	B	
-	18.1	115 & 215	HPU Motor #2	18.10	No Control Hydraulic Oil Pressure or Flow	Y	N	Y	B	
-	19.1	116 & 216	Accumulator Motor Fluid Trans	19.10	Overheated Lube & Hydraulic Oil	Y	N	Y	B	
-	20.1	117 & 217	Filtration Assembly	20.10	Contaminated Filter	Y	N	Y	B	
-	20.2	117 & 217	Filtration Assembly	20.20	Plugged Filter	Y	N	Y	B	

Functional Failure	Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Evident	Safety	Outage	Cat	Comments
-	21.1	118 & 218	Filtration System Motor	21.10	No Oil Pressure	Y	N	Y	B	
-	22.1	119 & 219	Lube Oil Motor	22.10	No Oil Pressure	Y	N	Y	B	
-	23.1	120 & 220	Lube Oil Pump	23.10	Pump Impeller Worn	Y	N	Y	D/B	
-	23.2	120 & 220	Lube Oil Pump	23.20	Pump Relief Valve Improperly Set or Failed	N	N	Y	D/B	
-	24.1	121 & 221	Heat Exchanger Cooling Fan Motor	24.10	Overheated Lube & Hydraulic Oil	Y	N	Y	B	
-	25.1	122 & 222	Heat Exchanger	25.10	Fouled Heat Exchanger	N	N	N	C	
-	25.2	122 & 222	Heat Exchanger	25.20	Thermostat Failure	N	N	Y	B	
-	25.3	122 & 222	Heat Exchanger	25.30	Heat Exchanger Tube Failure	N	Y	Y	D/A	River Water Contamination
-	26.1	123 & 223	Lube Oil Tank 1 & 2	26.10	Loss of Integrity of Tank	Y	Y	Y	D/A	River Water Contamination
-	26.2	123 & 223	Lube Oil Tank 1 & 2	26.20	Loss of Integrity of Tank	Y	Y	Y	D/A	River Water Contamination
-	27.1	Multi	Electrical Switchgear	27.10	Electronic Failure	Y	N	Y	B	
-	28.1	134	Unit #1 &#2 HPU VFD	28.10	Electronic Failure	Y	N	Y	B	
-	29.1	135	Unit #1 &#2 LOP VFD	29.10	Electronic Failure	Y	N	Y	B	
Unit #2										
Intake And Discharge Equipment	32.1	300	Trash Rack	32.10	Holes In Trash Rack Allow Debris Through	Y	N	Y	B	
	33.1	301	Trash Rack Cleaner	33.10	Failed Cleaner Mechanism	Y	N	Y	B	
	34.1	302	Intake Flume	34.10	Failed Integrity of Flume	Y	Y	Y	A	
	35.1	303	Draft Tube	35.10	Failed Integrity of Draft Tube	Y	Y	Y	A	
Electrical	36.1	304	Backup Generator	36.10	Failed Generator	Y	Y	N	A	
	37.1	305	Breaker De-Watering Use	37.10	Electronic Failure	N	N	N	C	
	38.1	306	Battery Storage System	38.10	Batteries Discharged; No Power Available	N	Y	Y	D/A	
	39.1	307	Sump Starter/Control	39.10	Electronic Failure	N	Y	Y	A	
	40.1	308	Starter/Relays-Sump Pumps	40.10	Electronic Failure	N	Y	Y	A	
	41.1	309	Trolley & Hoist Controls/Disconnect	41.10	Electronic Failure	N	N	Y	B	Needed to Correct Other Failures
	42.1	Multi	Common Power Elec Tx Equip	42.10	Electronic Failure	N	N	Y	B	
Sump Pumps and Compressors	43.1	Multi	Submersible Sump Pump	43.10	Pump Failure	N	N	Y	B	
	44.1	326	Emergency B/U Pump	44.10	Pump Failure	N	Y	Y	A	
	45.1	234	Emergency B/U Pump Motor	45.10	Electronic Failure	N	Y	Y	A	
HVAC	46.1	Multi	Starter Exhaust Fan VFD	46.10	Electronic Failure	N	N	N	C	

Table A-5
Task Selection

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Question #							Candidate task	Effective Info	Est Freq	Comments
							1	2	3	4	5	6	7				
1.1	100 & 200	Kaplan Runner	1.00	Cavitation And Wear on Runner	1.11	Normal Wear on Runner (Age Related)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
					1.12	Cavitation Caused by Improper Adjustment of Blade Pitch	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
1.2	100 & 200	Kaplan Runner	1.20	Catastrophic Failure of Runner	1.21	Impact Damage from Foreign Object	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
					1.22	Impact Damage from Turbine Gate Component	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
2.1	101 & 201	Trunnion Seal	2.10	Worn Seal	2.11	Normal Wear on Seal (Age Related)	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
					2.12	Mechanical Failure of Seal Keepers	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
2.2	102 & 201	Trunnion Seal	2.20	Worn Seal	2.21	Normal Wear on Seal (Age Related)	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
					2.22	Mechanical Failure of Seal Keepers	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
		Mechanical Seal		Worn Seal		Normal Wear on Seal (Age Related)	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
						Flush Water Lines Plugged	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
		Mechanical Seal		Worn Seal		Normal Wear on Seal (Age Related)	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
						Flush Water Lines Plugged	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
3.1	102 & 202	Pitch Control Servo	3.10	Servo And Linkages Frozen in Position	3.11	Servo Cylinder Scored or Damaged and Frozen into Cylinder	N	N	N	N	Y	Y	N	Turbine Major Inspection 25yr		25yr	
					3.12	Linkage Or Bushing Bearings Broken or Severed or Frozen in Position	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
3.2	103 & 202	Pitch Control Servo	3.20	Servo And Linkages Out of Adjustment	3.21	Linkage Or Connecting Bushings Loose (Primary Control Electronic)	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
						Leaking Fittings and Servo	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Question #							Candidate task	Effective Info	Est Freq	Comments
							1	2	3	4	5	6	7				
4.1	103 & 203	Runner Side Guide Bearing	4.10	Guide Bearing Wear	4.11	Normal Bearing Wear (Age Related)	N	N	N	N	Y	Y	N	Turbine Minor Inspection 10yr/Bearing Replacement		10yr	Condition Based Replacement
					4.12	Contaminated Lube Oil (Premature Wear)	N	N	N	N	Y	Y	N	Oil Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Oil Tests
					4.13	Shaft Misalignment (Uneven Wear)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
4.2	104 & 203	Runner Side Guide Bearing	4.20	Guide Bearing Liner Failure	4.21	Contaminated Lube Oil (Premature Wear) Mechanical Seal Failure Water Contamination	N	N	N	Y	Y	Y	N	Oil Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Oil Tests
					4.22	Shaft Misalignment (Uneven Wear)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
					4.23	Excessive Radial Clearance	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
5.1	104 & 204	Thrust Bearing	5.10	Thrust Bearing Liner Wear (Look Up)	5.11	Shaft Misalignment (Uneven Wear)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
5.2	104 & 204	Thrust Bearing	5.20	Thrust Bearing Liner Wear (Look Up)	5.21	Shaft Misalignment (Uneven Wear)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
5.3	104 & 204	Thrust Bearing	5.30	Thrust Bearing Liner Wear (Look Up)	5.31	Shaft Misalignment (Uneven Wear)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
					5.32	Contaminated Lube Oil (Premature Wear)	N	N	N	N	Y	Y	N	Oil Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Oil Tests
					5.33	Excessive Radial Clearance	N	N	N	N	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
6.1	105 & 205	Wicket Gates & Controls	6.10	Stiction In Gates and Controls	6.11	Wear In Bushings	N	N	N	N	Y	Y	N	Turbine Major Inspection 25yr		25yr	
					6.12	Foreign Object or Debris in Wickets	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
6.2	105 & 205	Wicket Gates & Controls	6.20	Frozen Or Broken Gates and Controls	6.21	Wear In Bushings	N	N	N	N	Y	Y	N	Turbine Major Inspection 25yr		25yr	
					6.22	Foreign Object or Debris in Wickets	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
7.1	106 & 206	Brake System	7.10	Worn Brake Shoes	7.11	Normal Wear on Linings (Age Related)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
7.2	106 & 206	Brake System	7.20	Failed Brake Mechanism	7.21	Excessive Stress on Brake Components Caused by Overspeed	N	N	N	N	Y	Y	N	Turbine Minor Inspection 5yr		5yr	

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Question #							Candidate task	Effective Info	Est Freq	Comments
							1	2	3	4	5	6	7				
8.1	107 & 207	Gearbox Speed Reducer	8.10	Gearbox Bearing or Gear Failure	8.11	Bearing Failure (Age Related)	N	N	N	N	Y	Y	N	Vibration Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Vibration Test
					8.12	Bearing Failure (Lube Related)	N	N	N	N	Y	Y	N	Oil Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Oil Test
					8.13	Gear Failure (Age Related)	N	N	N	N	Y	Y	N	Vibration Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Vibration Test
					8.14	Gear Failure (Lube Related)	N	N	N	N	Y	Y	N	Oil Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Oil Test
					8.15	Coupling Failure (Turbine /Gearbox)	N	N	N	N	Y	Y	N	Vibration Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Vibration Test
					8.16	Coupling Failure (Gearbox Generator)	N	N	N	N	Y	Y	N	Vibration Tests/Turbine Minor Inspection 10yr		10yr	Quarterly Vibration Test
					8.17	Gearbox Seal Failure (Age Related)	N	N	N	N	Y	Y	N	Turbine Minor Inspection 10yr		10yr	
9.1	108 & 208	Rotating Electric Generator	9.10	Generator Stator or Field Failure	9.11	Rotor Winding Resistance (Age Related)	N	N	N	N	Y	Y	N	Generator Electrical Inspection 5yr		5yr	
					9.12	Stator Winding Resistance (Age Related)	N	N	N	N	Y	Y	N	Generator Electrical Inspection 5yr		5yr	
					9.13	Stator Wedges or Bar Failures	N	N	N	N	Y	Y	N	Generator Electrical Inspection 12yr		12yr	
					9.14	End Winding Supports and Connections Failure	N	N	N	N	Y	Y	N	Generator Electrical Inspection 12yr		12yr	
					9.15	Air Cooling and Ventilation Failure	N	N	N	N	Y	Y	N	Generator Electrical Inspection 12yr		12yr	
					9.16	Upstream And Downstream Generator Bearing Failures	N	N	N	N	Y	Y	N	Generator Electrical Inspection 12yr		12yr	
					9.17	Diode Failure	N	N	N	N	Y	Y	N	Generator Electrical Inspection 5yr		5yr	
10.1	109 & 209	Electronic Exciter #1	10.10	Electronic Failure	10.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Clean & Test		3yr	
11.1	109 & 209	Electronic Exciter #1	11.10	Electronic Failure	11.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Clean & Test		3yr	
12.1	110 & 210	HPU	12.10	No Control Hydraulic Oil Pressure or Flow	12.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Clean & Test		3yr	
13.1	111 & 211	Accumulator	13.10	Low Pressure in Bladder	13.11	Broken Bladder	N	N	N	N	Y	Y	N	Vessel Inspection		5yr	
					13.12	Low Nitrogen Charge	N	N	N	N	Y	Y	N	Vessel Inspection		5yr	
14.1	111 & 211	Accumulator	14.10	Low Pressure in Bladder	14.11	Broken Bladder	N	N	N	N	Y	Y	N	Vessel Inspection		5yr	
					14.12	Low Nitrogen Charge	N	N	N	N	Y	Y	N	Vessel Inspection		5yr	
15.1	112 & 212	Governor Oil Tank	15.10	Corroded Oil Tank That Leaks	15.11	Corrosion Due to Age	N	N	N	N	Y	Y	N	Vessel Inspection		5yr	
15.2	112 & 212	Governor Oil Tank	15.20	Catastrophic Failure of Oil Tank Due to Overpressure	15.21	Cannot Be Overpressure	N	N	N	N	N	N	N	No PM Required			

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Question #							Candidate task	Effective Info	Est Freq	Comments
							1	2	3	4	5	6	7				
16.1	113 & 213	LP1&2 Controls Hydraulic Main Floor	16.10	Electronic Failure	16.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Clean & Test			
17.1	114 & 214	HPU Motor #1	17.10	No Control Hydraulic Oil Pressure or Flow	17.11	Motor Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	
					17.12	Electronic Failure	N	N	N	N	N	N	N	RTF			
18.1	115 & 215	HPU Motor #2	18.10	No Control Hydraulic Oil Pressure or Flow	18.11	Motor Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	
					18.12	Electronic Failure	N	N	N	N	N	N	N	RTF			
19.1	116 & 216	Accumulator Motor Fluid Trans	19.10	Overheated Lube & Hydraulic Oil	19.11	Motor Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	
					19.12	Electronic Failure	N	N	N	N	N	N	N	RTF			An Alternative is That Small Electric Motors Could be Either Replaced or Rebuilt on a Time-Based Interval
20.1	117 & 217	Filtration Assembly	20.10	Contaminated Filter	20.12	Defective Filter	N	N	N	N	N	N	N	R&R Filter		As Required	Defective Filter Will Show Signs (Hi DP) at Start of Use, Replace Filter
20.2	117 & 217	Filtration Assembly	20.20	Plugged Filter	20.12	Plugged Filter (Age or Pressure Drop) Trip Off Turbine	N	N	N	N	Y	Y	N	R&R Filter		As Required	Establish Typical Time or Operating Hour Interval and Replace Filter on Routine Basis
21.1	118 & 218	Filtration System Motor	21.10	No Oil Pressure	21.11	Motor Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	
					21.12	Electronic Failure	N	N	N	N	Y	Y	N	RTF			An Alternative is That Small Electric Motors Could be Either Replaced or Rebuilt on a Time-Based Interval
22.1	119 & 219	Lube Oil Motor	22.10	No Oil Pressure	22.11	Motor Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	
					22.12	Electronic Failure	N	N	N	N	N	N	N	RTF			An Alternative is That Small Electric Motors Could be Either Replaced or Rebuilt on a Time-Based Interval
23.1	120 & 220	Lube Oil Pump	23.10	Pump Impeller Worn	23.11	Normal Wear (Age Related)	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
23.2	120 & 220	Lube Oil Pump	23.20	Pump Relief Valve Improperly Set or Failed	23.21	Relief Valve Failure Components Frozen or Rusted in Position	N	N	N	Y	Y	Y	N	Turbine Minor Inspection 5yr		5yr	
24.1	121 & 221	Heat Exchanger Cooling Fan Motor	24.10	Overheated Lube & Hydraulic Oil	24.11	Motor Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	
					24.12	Electronic Failure	N	N	N	N	N	N	N	RTF			An Alternative is That Small Electric Motors Could be Either Replaced or Rebuilt on a Time-Based Interval
25.1	122 & 222	Heat Exchanger	25.10	Fouled Heat Exchanger	25.12	Build Up on Oil Side of Heat Exchanger or Debris on Air Side (Time Factor)	N	N	N	N	N	N	N	RTF			
25.2	122 & 222	Heat Exchanger	25.20	Thermostat Failure	25.21	Buildup of Insulating Contaminant on Temperature Sensor (Mechanical)	N	N	N	N	N	N	N	RTF			
25.3	122 & 222	Heat Exchanger	25.30	Heat Exchanger Tube Failure	25.31	Tube Rupture Due to Overheating & Corrosion	N	N	N	Y	N	N	N	RTF			
26.1	123 & 223	Lube Oil Tank 1 & 2	26.10	Loss Of Integrity of Tank	26.12	Tank Failure Due to Corrosion	N	N	N	Y	Y	Y	N	Vessel Inspection		5yr	

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Question #							Candidate task	Effective Info	Est Freq	Comments
							1	2	3	4	5	6	7				
26.2	123 & 223	Lube Oil Tank 1 & 2	26.20	Loss Of Integrity of Tank	26.21	Tank Failure Due to Corrosion	N	N	N	Y	Y	Y	N	Vessel Inspection		5yr	
27.1	Multi	Electrical Switchgear	27.10	Electronic Failure	27.12	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear IR & Clean & Test		1-3yr	IR Tests Annual, Clean & Test 3yr
28.1	134	Unit #1 &#2 HPU VFD	28.10	Electronic Failure	28.12	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear IR & Clean & Test		1-3yr	
29.1	135	Unit #1 &#2 LOP VFD	29.10	Electronic Failure	29.12	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear IR & Clean & Test		1-3yr	
Intake And Discharge Equipment																	
32.1	300	Trash Rack	32.10	Holes In Trash Rack Allow Debris Through	32.11	Holes Caused by Mechanical Damage Removing Ice and Debris	N	N	Y	N	Y	Y	N	Visual External & NDT Of Flumes		5yr	Coordinate Inspection to Coincide with FERC Part 12D
33.1	301	Trash Rack Cleaner	33.10	Failed Cleaner Mechanism	33.11	Physical Damage to Unit Ruin to Remove Ice and Debris	N	N	Y	N	Y	Y	N	Visual External & NDT Of Flumes		5yr	Coordinate Inspection to Coincide with FERC Part 12D
34.1	302	Intake Flume	34.10	Failed Integrity of Flume	34.11	Flume Failure Cause by Corrosion and Erosion	N	N	Y	N	Y	Y	N	Visual External & NDT Of Flumes		5yr	Coordinate Inspection to Coincide with FERC Part 12D
35.1	303	Draft Tube	35.10	Failed Integrity of Draft Tube	35.13	Draft Tube Failure Caused by Corrosion and Erosion	N	N	Y	N	Y	Y	N	Visual External & NDT Of Flumes		5yr	Coordinate Inspection to Coincide with FERC Part 12D
Electrical																	
36.1	304	Backup Generator	36.10	Failed Generator	36.11	Engine Will Not Start Due to Fuel Issues	Y	Y	Y	N	Y	Y	N	Backup Generator Maintenance		1yr	Yearly Maintenance + Routine Starts
					36.12	Engine Will Not Start Due to Battery and Starter Issues	Y	Y	Y	N	Y	Y	N	Backup Generator Maintenance		1yr	Yearly Maintenance + Routine Starts
					36.13	Engine Will Not Start Due to Ignition Issues	Y	Y	Y	N	Y	Y	N	Backup Generator Maintenance		1yr	Yearly Maintenance + Routine Starts
					36.14	Engine Starts but Fails to Generate Power Due to Electrical Issues	Y	Y	Y	N	Y	Y	N	Backup Generator Maintenance		1yr	Yearly Maintenance + Routine Starts
37.1	305	Breaker De-Watering Use	37.10	Electronic Failure	37.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Ir & Clean & Test		1-3yr	
38.1	306	Battery Storage System	38.10	Batteries Discharged; No Power Available	38.11	Batteries Failed	Y	Y	N	Y	Y	Y	N	Battery Station Maintenance		1yr	
					38.12	Charger Failed Due to Electronic Issues	N	N	N	Y	Y	Y	N	Battery Station Maintenance		1yr	
39.1	307	Sump Starter/Control	39.10	Electronic Failure	39.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Ir & Clean & Test		1-3yr	
40.1	308	Starter/Relays-Sump Pumps	40.10	Electronic Failure	40.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Ir & Clean & Test		1-3yr	
41.1	309	Trolley & Hoist Controls/Disconnect	41.10	Electronic Failure	41.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear IR & Clean & Test		1-3yr	
42.1	Multi	Common Power Elec Tx Equip	42.10	Electronic Failure	42.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear Ir & Clean & Test		1-3yr	
Sump Pumps and Compressors																	
43.1	Multi	Submersible Sump Pump	43.10	Pump Failure	43.11	Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	

Functional Failure #	Asset #	Asset Description	Failure Mode #	Failure Mode Description	Failure Cause #	Failure Cause Description	Question #							Candidate task	Effective Info	Est Freq	Comments
							1	2	3	4	5	6	7				
44.1	326	Emergency B/U Pump	44.10	Pump Failure	44.11	Bearing Failure	N	N	N	N	Y	Y	N	Vibration Tests		Quarterly	
45.1	234	Emergency B/U Pump Motor	45.10	Electronic Failure	45.11	Electronic Failure	N	N	N	N	Y	Y	N	Switch Gear & Clean & Test		1-3yr	
HVAC																	
46.1	Multi	Starter Exhaust Fan VFD	46.10	Electronic Failure	46.11	Electronic Failure								Run To Failure			

Q1 Is the age reliability relationship for this failure known?
Q2 Are there any applicable time dependent (TD) tasks?
Q3 Are there any applicable condition dependent (CD) tasks?
Q4 Is this a category "D" failure mode?
Q5 Are there any applicable failure finding (FF) tasks?
Q6 Are any of these tasks effective?
Q7 Can a design mod eliminate the failure mode or effects?

Table A-6
Preliminary Maintenance Recommendation

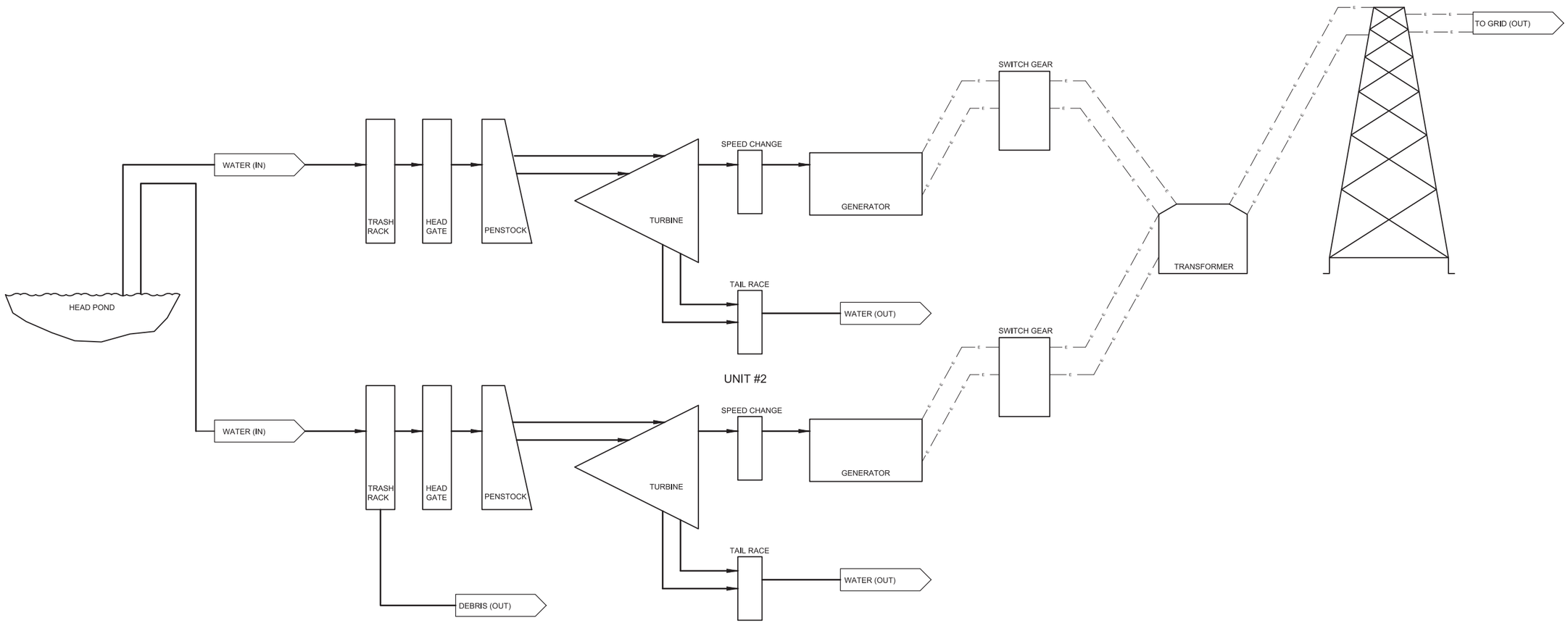
Inspection Title	Equipment	Scope of Work	Frequency	Cost Estimate ($ Per Turbine)	Dewater[4]
Turbine Minor Inspection 5yr	Kaplan Runner Guide and Thrust Bearings, Wicket Gates Hydraulics, Gearbox	Minor Inspection, Visual Internal of Runner, Wicket Gates, Wicket and Blade Tip Clearances Checked, Checked Seals Replaced, Stroke Wicket Gates and Kaplan Blades, Check Oil for Water, Tear Down, Inspect and Repair the Lube Oil Pump & Relief Valve, Brake System Inspection, Seal Bladder Check, Inflatable Seal Bladder Check Before and After Dewatering	5 years	75,000 - 125,000	Yes
Turbine Minor Inspection 10yr	Kaplan Runner Guide and Thrust Bearings, Wicket Gates Hydraulics, Gearbox	Minor Inspection, Visual Internal of Runner, Wicket Gates, Bearing Covers Removed Liner Inspected Alignment and Clearances Checked, Gearbox Cover Removed Clearances Checked Seals Replaced	10 years	125,000 - 250,000	Yes
Turbine Major Inspection 25yr	Kaplan Runner Guide and Thrust Bearings, Wicket Gates Hydraulics, Gearbox	Major Inspection, Complete Turbine Rebuilds, Bearing Replacement, Alignment, Kaplan & Wicket Gate Servo Rebuild, Gearbox Rebuild	25 years	500,000 - 1,000,000	Yes
Vibration Testing	Kaplan Runner Guide and Thrust Bearings, Wicket Gates Hydraulics, Gearbox	Vibration Analysis	Quarterly	3,000 - 5,000	No
Oil Testing	Kaplan Runner Guide and Thrust Bearings, Wicket Gates Hydraulics, Gearbox	Oil Analysis	Quarterly	-	No
Generator Electrical Inspection 5yr	Generator & Exciter Field & Stator	Test The Insulation Resistance, Winding Resistance, Polarization Index the Exciter Stator, Exciter Rotor, Generator Stator and Rotor, Operating Voltage Hi-Pot and Surge Comparison Test the Stator Winding, Ac Volt Drop Test the Rotor Coils, Test the Rotating Diode Assembly and Inspect All Winding and Generator Components for Wear and Deficiencies.	2-5 years	5,000 - 7,000	No
Generator Electrical Inspection 12yr	Generator & Exciter Field & Stator, Bearings, Air Cooler	Minor Inspection, Dry Ice Clean Generator Windings, Inspect All Wedges And Winding Components, Test The Insulation Resistance, Winding Resistance, Polarization Index The Exciter Stator, Exciter Rotor, Generator Stator and Rotor, Operating Voltage Hi-Pot And Surge Comparison Test The Stator Winding, Ac Volt Drop Test the Rotor Coils, Test the Rotating Diode Assembly And Inspect all Winding and Generator Components for Wear and Deficiencies, Check Laser Alignment to Gear Box and Bearing Inspection.	12 years	25,000 - 35,000	No
Generator Rewind	Generator & Exciter Field & Stator, Bearings, Air Cooler	Generator & Excitor Rewind, Bearing Liner Replacement	25 years	200,000 - 300,000	No
Switchgear IR	Switchgear	Infrared Scans	Annual	3,000 - 5,000	No
Switch Gear Clean & Test	Switch Gear	Trip & Relay Tests, Cleaning & Re-Certification	3 years or As Per Jurisdiction	30,000 - 45,000	No
Visual External & NDT Of Vessels	Oil Tanks, Accumulators	Visual External or Internal Inspection NDT, Inspect and Recharge Bladder as Required	5 years	3,000 - 5,000	No
Battery Station Maintenance	Battery Station, Charger, Batteries & Switches	Visual Inspection, Cleaning and Maintenance of Batteries, Load Tests, Hydrometer Test, Charging System and Switch Functionality Test	1 year	3,000 - 5,000	No

Inspection Title	Equipment	Scope of Work	Frequency	Cost Estimate ($ Per Turbine)	Dewater[4]
Backup Generator Maintenance	Backup Generator Engine, Generator, Controls and Switches	Service, Inspection, and Maintenance of Backup Generator as per Manufacturers Recommendations	1 year	3,000 - 5,000	No
Visual External & NDT of Flumes	Intake Flume, Draft Tube and Chest, Trash Rack	Visual External or Internal Inspection NDT	5 years	5,000 - 10,000, Cost could be shared with FERC Part 12D Inspection	Yes, divers or submersible may be required

1) Due to dewatering expenses and logistics, both units are taken down sequentially the same year.
2) Oil analysis currently is done by the plant.
3) Assume that daily & weekly oiling and machine checks that are recommended by the OEM are performed by operations.
4) Dewater costs estimated to be $200,000 for both turbines and should be added to the inspection cost, as appropriate.
5) Minor inspection PM frequency set to match FERC Part 12D Inspection Requirement.
6) Vessel inspection cost per vessel.

Appendix B

Figures



PRELIMINARY DRAFT
NOT FOR CONSTRUCTION

CADD USER: DARRIN.JACKOLA FILE: C:\ADEPTWORKDT.JE\ELECTRICAL FLOWSHEET.DWG PLOT SCALE: 1:1 PLOT DATE: 8/23/2023 10:25 AM

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION
-	-	-	-	——	-

RELEASED TO/FOR

CLIENT	BID	CONSTRUCTION	RECORD
——	——	——	——

A	B	C	0	1	2	3
DATE RELEASED						

BARR
Corporate Headquarters:
Minneapolis, Minnesota
Ph: 1-800-632-2277

Project Office:
BARR ENGINEERING CO.
3128 14TH AVENUE EAST
HIBBING, MN 55746

Ph: 1-800-225-1966
Fax: (218) 262-3460
www.barr.com

Scale	AS SHOWN
Date	--/--/--
Drawn	---
Checked	---
Designed	---
Approved	---

CLIENT NAME
CLIENT LOCATION

PROJECT NAME
PROJECT LOCATION

TITLE LINE 1
TITLE LINE 2

BARR PROJECT No.	
XXXXXXXX.XX	
CLIENT PROJECT No.	
DWG. No.	REV. No.
X-XX	-

Appendix C

Present Value Calculations for Operating and Maintenance Costs

Appendix C

Present Value Calculations for Operating and Maintenance Costs

X-A-01 (a,b)

Item	Factor	Total (approximate)
Revenue		
Average Annual Revenue		$ 716,500
P/A	14.0939	
Revenue Present Worth (P)		**$ 10,098,000**
Operating Costs		
Operating Costs (by City of Hastings)		$ 450,000
P/A	14.0939	
Operations Present Worth (P)		**$ 6,342,000**
Annual Maintenance Expenses		
Battery Station Maintenance		$ 5,000
Backup Generator Maintenance		$ 5,000
Vibration Testing		$ 20,000
Oil Testing		$ 5,000
Miscellaneous		$ 25,000
Total Annual Maintenace		$ 60,000
P/A	14.0939	
Annual Maintenance Present Worth (P)		**$ 846,000**
3 Year Maintenance Expenses		
Switch Gear Clean & Test		$ 45,000
(P/F) n=3	0.8638	$ 38,871
(P/F) n=6	0.7462	$ 33,579
(P/F) n=9	0.6446	$ 29,007
(P/F) n=12	0.5568	$ 25,056
(P/F) n=15	0.481	$ 21,645
(P/F) n=18	0.4155	$ 18,698
(P/F) n=21	0.3589	$ 16,151
(P/F) n=24	0.3101	$ 13,955
3-year Maintenance Present Worth (P)		**$ 197,000**
5 Year Maintenance Expenses		
Turbine Minor Inspection 5yr		$ 125,000
Turbine Minor Inspection 5yr		$ 125,000
Generator Electrical Inspection 5yr		$ 7,000
Generator Electrical Inspection 5yr		$ 7,000
Dewater		$ 450,000
Total Cost Per 5yr		$ 714,000
(P/F) n=5	0.7835	$ 559,419
(P/F) n=15	0.481	$ 343,434
5-year Maintenance Present Worth (P)		**$ 903,000**
10 Year Maintenance Expenses		
Turbine Minor Inspection 10yr		$ 250,000
Turbine Minor Inspection 10yr		$ 250,000
Generator Electrical Inspection 10yr		$ 35,000
Generator Electrical Inspection 10yr		$ 35,000
Dewater		$ 450,000

Appendix C

Present Value Calculations for Operating and Maintenance Costs

X-A-01 (a,b)

Item	Factor	Total (approximate)
Total Cost Per 10yr		$ 1,020,000
(P/F) n=10	0.6139	$ 626,178
(P/F) n=20	0.3769	$ 384,438
10-year Maintenance Present Worth (P)		**$ 1,011,000.00**
25 Year Maintenance Expenses		
Turbine Major Inspection 25yr		$ 1,000,000
Turbine Major Inspection 25yr		$ 1,000,000
Generator Rewind		$ 300,000
Generator Rewind		$ 300,000
Dewater		$ 450,000
Total Cost Per 25yr		$ 3,050,000
(P/F) n=0	1	$ 3,050,000
25-year Maintenance Present Worth (P)		**$ 3,050,000**
Total Present Worth of O&M Costs		**$ 12,349,000**
Total Revenue		**$ 10,098,000**
Net Cash (Revenue - O&M costs)		**$ (2,251,000)**
O&M % of Revenue		**122%**