

To: *Dr. David Willy*

From: *HCC26*

Date: *01/23/2026*

Re: *Engineering Calculations Summary*

## **Top Level Design Summary**

The objective of this project is to design, analyze, and prototype small-scale hydropower generation systems suitable for integration at an existing dam site. The system must be mechanically feasible, economically viable, environmentally responsible, and manufacturable within project constraints. The proposed solution is a modular turbine generation system paired with copower opportunities such as solar, or wind designed to operate within site specific conditions while minimizing environmental impact and maximizing reliability and community benefit.

The primary hydropower subsystem is based on the Voith StreamDiver low-head turbine concept, selected for its ability to operate efficiently under low head and moderate flow conditions while minimizing civil construction and environmental disturbance. Each turbine integrates an axial-flow runner, sealed housing, shaft-mounted generator, and flow-aligned mounting structure designed to operate fully submerged. Multiple turbines may be deployed in parallel to accommodate seasonal flow variability while maintaining continuous operation.

The mechanical support and mounting subsystem transfers hydrodynamic and gravitational loads from the turbine assemblies into the existing dam infrastructure without requiring significant structural modification. This subsystem is designed to satisfy minimum safety factor requirements while maintaining ease of installation, removal, and maintenance.

The electrical subsystem consists of permanent-magnet generators, power conditioning hardware, and grid interconnection components that convert mechanical power into usable electrical energy. This subsystem enables parallel operation of multiple turbines and supports integration with supplemental renewable energy sources.

To mitigate seasonal reductions in hydropower output, a co-located ground-mounted photovoltaic subsystem is incorporated as a secondary generation source. The solar subsystem operates independently of hydrologic conditions and shares electrical infrastructure where feasible, improving annual energy yield and system resilience. Together, these subsystems form a hybrid renewable energy system that meets project objectives while minimizing environmental and civil impacts.

Figure 1 shows the top-level CAD assembly of the hydropower subsystem with labeled components corresponding to the primary subsystems described above.

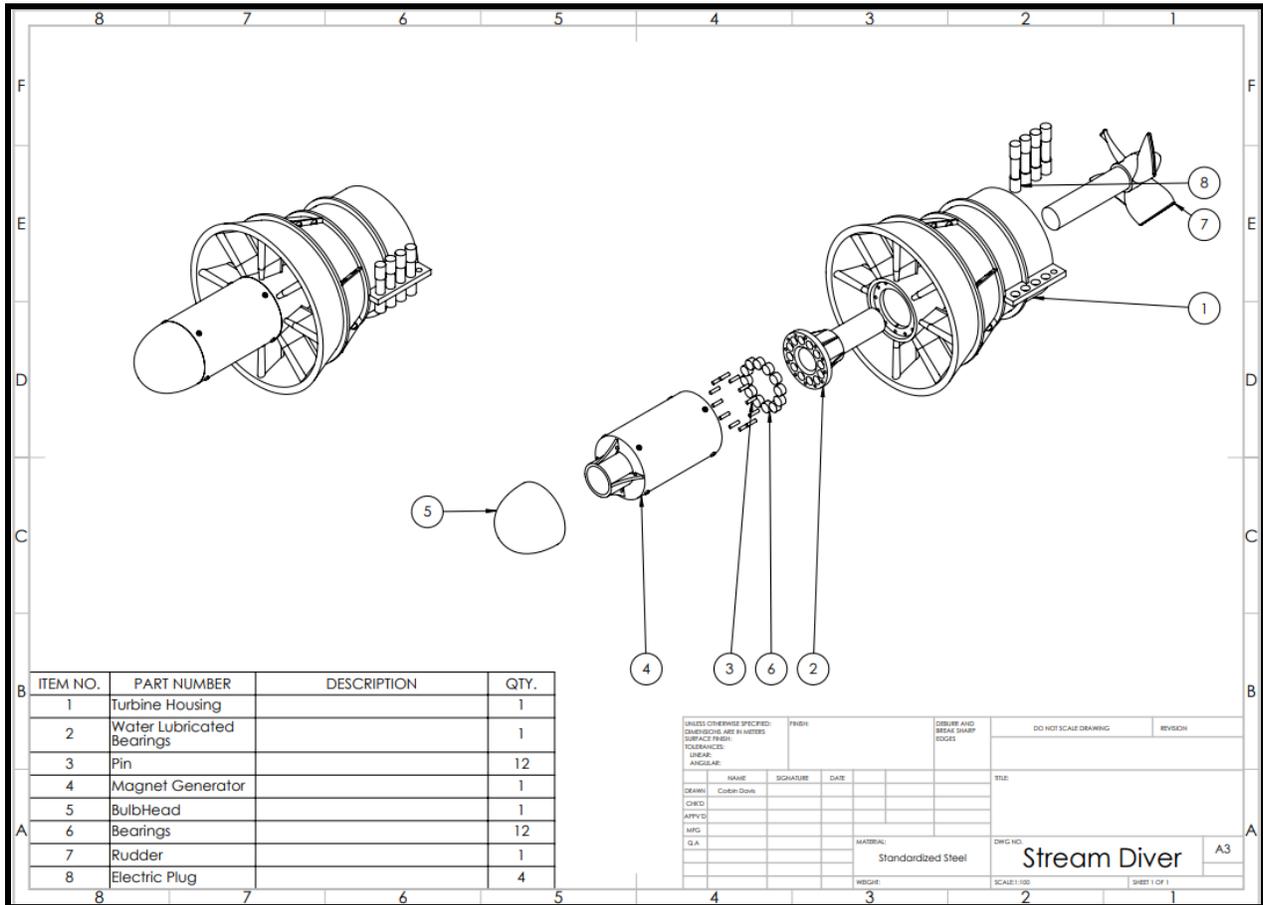


Figure 1. Voith Streamdiver Model

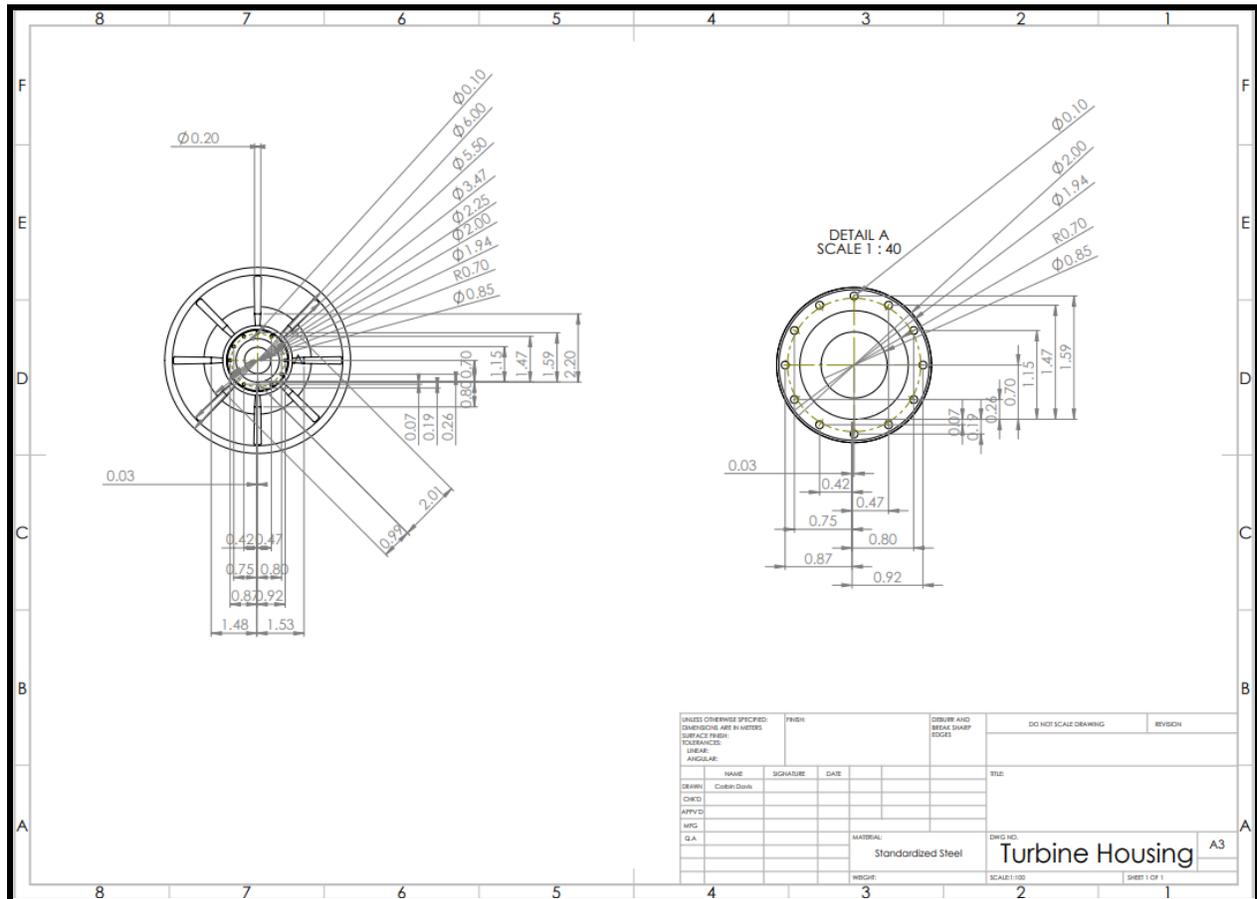


Figure 2. Voith Streamdiver Housing

## House of Quality

This chapter identifies and defines the requirements that guide the design of the hydropower system at the John C. Stennis Dam. Requirements are divided into Customer Requirements (CRs), Engineering Requirements (ERs), and a House of Quality (HoQ) that connects the two. Customer requirements communicate what stakeholders expect from the project, while engineering requirements translate those expectations into measurable and verifiable technical targets. The HoQ allows the team to evaluate how well the engineering requirements support the project goals and provides early insight into design tradeoffs.

Customer Requirements represent the needs of the project sponsor, the Hydropower Collegiate Competition, NAU faculty expectations, and the broader communities affected by hydropower development.

Below is a complete list of customer requirements for the Stennis Dam Hydropower Integration Project:

1. **Safe system operation**  
The system must function without posing hazards to operators, the public, or the surrounding environment.
2. **Environmentally responsible design**  
The solution must minimize impacts to aquatic ecosystems, sediment transport, and local habitat.
3. **Low civil construction impact**  
The design should avoid major structural alterations to the dam or surrounding area.
4. **Reliable and continuous power generation**  
The system should operate under typical flow conditions at the site with minimal downtime.
5. **Cost awareness and financial feasibility**  
The project must make realistic assumptions about material costs, installation costs, and system lifespan.
6. **Integration of renewable energy co-development**  
The design must include a solar co-development component that complements hydropower output.
6. **Educational and community engagement value**  
The system must support meaningful community outreach, public engagement, and educational opportunities.
7. **Clear documentation and communication**  
All design decisions must be well supported, justified, and easy for stakeholders to understand.

Engineering Requirements translate the customer requirements into measurable, testable values. These requirements guide the technical analysis, prototyping, and modeling activities of the project.

Below are the engineering requirements for this project:

1. **Minimum operational head**
  - Target: 1 to 12 feet depending on the selected intake location
  - Type: One sided constraint
  - Rationale: StreamDiver turbines require low to moderate head to operate efficiently.
2. **Minimum flow rate available to the turbine**
  - Target: 20 to 150 cubic feet per second (cfs) depending on seasonal flows
  - Type: One sided constraint
  - Rationale: Adequate flow is required for meaningful power generation.
3. **Estimated power output**
  - Target: 50 kilowatts to 300 kilowatts per turbine (site dependent)
  - Type: Two sided constraint
  - Rationale: Must be feasible and realistic for competition scoring.
4. **Maximum allowable civil modification depth**
  - Target: Less than 5 feet of excavation or structural alteration
  - Type: One sided constraint

- Rationale: Customer requirement emphasizes minimal civil impact.
- 5. **Fish passage impact rating**
  - Target: Must meet criteria for low impact (qualitative rating)
  - Type: Binary requirement
  - Rationale: Ensures environmental compatibility.
- 6. **Electrical integration voltage level**
  - Target: 120 to 480 volts depending on generator configuration
  - Type: Range constraint
  - Rationale: Must support standard low voltage distribution scale.
- 7. **Solar co-development output**
  - Target: 1-3 MWac as a supplemental system
  - Type: Range constraint
  - Rationale: Provides additional renewable energy generation.
- 8. **System lifespan estimate**
  - Target: Minimum 20 years
  - Type: One sided constraint
  - Rationale: Ensures long term feasibility and financial justification.
- 9. **Safety factor for mechanical mounts**
  - Target: Greater than 1.3
  - Type: One sided constraint
  - Rationale: Ensures structural reliability.

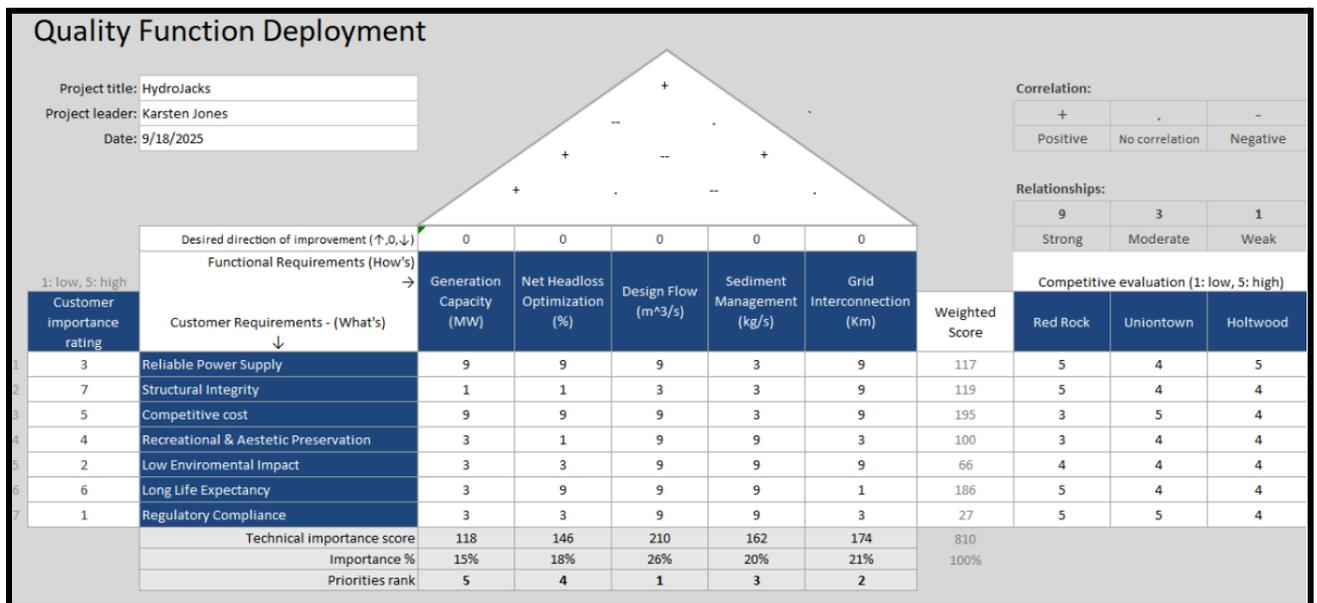


Figure 3. Completed House of Quality for the Stennis Dam Hydropower Integration Project

Figure 3 shows the completed HoQ used for this project. The functional requirements evaluated include Generation Capacity, Net Headloss Optimization, Design Flow, Sediment Management, and Grid Interconnection. These were mapped against the seven Customer Requirements to

generate weighted scores and priority rankings.

**Key findings from the completed HoQ include:**

## **Highest Priority Engineering Parameters**

Based on the technical importance scores and weighted relationships:

1. **Design Flow (210)**
  - Highest overall score
  - Strongly influences reliable power supply, competitive cost, and environmental performance
  - This becomes the most critical parameter for StreamDiver feasibility at Stennis Dam
2. **Sediment Management (162)**
  - Strong correlation with structural integrity and system lifespan
  - Essential at a low head dam where sediment accumulation is common
3. **Net Headloss Optimization (146)**
  - Directly affects power output efficiency
  - Important for maximizing generation with limited head
4. **Generation Capacity (118)**
  - Strongly tied to customer expectations for reliable output
  - Secondary to flow and head optimization because feasibility depends on actual site conditions
5. **Grid Interconnection (174)**
  - High importance due to electrical integration requirements
  - Impacts compliance, safety, and system reliability

## **Highest Priority Customer Requirements**

The most influential CRs are:

- **Competitive Cost (rating 5)**
- **Structural Integrity (rating 7)**
- **Recreational and Aesthetic Preservation (rating 4)**
- **Reliable Power Supply (rating 3)**

These directly shape the engineering direction for mechanical and electrical subsystems.

**Economic feasibility and community impact were evaluated using the NREL JEDI model** for conventional hydropower systems. The JEDI model was used to estimate employment, earnings, and economic output associated with construction and operation of a non-powered dam hydropower installation. Based on preliminary project assumptions, the model estimates approximately 120 total jobs supported during construction and installation, with roughly \$6.4 million in associated earnings and \$16.8 million in total economic output (2025 dollars). During annual operation, the project is estimated to support approximately three ongoing jobs with

approximately \$0.5 million in annual economic output. These results support customer requirements related to cost awareness, financial feasibility, and community and educational value identified in the House of Quality. Detailed JEDI inputs and outputs are provided in the appendix.

## **Summary of Standards, Codes, and Regulations**

This project proposes the conversion of an existing NPD site into a hydroelectric generation facility. Although the Hydropower Collegiate Competition is a conceptual design exercise, the project has been developed with consideration of the real regulatory, engineering and safety frameworks that govern implementation of a system of this type. The standards, codes, and regulations summarized below define the design space, constrain feasible configurations, and inform assumptions related to constructability, operation and long term compliance.

### **Competition and Program Governance**

The project is governed by the original rules of the U.S. Department of Energy (DOE) HCC, administered under DOE prize money. These rules establish eligibility, design scope, deliverable requirements, and evaluation criteria. Because the competition emphasizes real world feasibility, teams are expected to demonstrate awareness of the regulatory environment that would apply if the proposed concept were advanced to implementation. For this project, the competition rules function as the primary governing document, while federal, state, and industry standards are treated as design constraints rather than permitting requirements.

### **Federal Hydropower Licensing and Authorization**

In the United States, most hydropower projects are mainly regulated by the Federal Energy Regulatory Commission under the Federal Power Act. A nonpowered dam would typically require one of the following:

- A FERC Licence
- A FERC Exemption

FERC regulations define the approval pathway for adding generation to existing water control infrastructure and establish requirements related to safety, operations, environmental protection, and stakeholder coordination. Although no licence is required for this competition, the proposed design assumes compatibility with FERC's regulatory framework, including minimal alteration to existing dam functions and preservation to flood control, navigation and water supply purposes.

### **Environmental and Water Quality Regulations**

Implementation of a nonpowered dam conversion would require compliance with key provisions of the Clean Water Act, administered by the Environmental Protection Agency (EPA) in coordination with state agencies. Relevant provisions include:

- Section 402 - Water Quality Certification  
Requires state or tribal certification that the project will comply with applicable water quality standards prior to issuance or federal licence exemption.
- Section 404 - Dredge and Fill Permits

Applies if construction activities involve placement of fill or excavation within waters of the united states

To remain consistent with these requirements, the project concept emphasizes use of existing dam structures, minimal in water construction, avoidance of new impounds or changes to the regime.

### **Dam Safety and Civil Engineering Design Standards**

Because the project interfaces directly with an existing dam, established dam safety and hydraulic engineering standards guide the civil and structural aspects of the intended design. The U.S. Army Corps of Engineers (USACE) publishes widely adopted engineering manuals that inform the best practices in hydraulic structures, including many nonpowered dams nationwide. Relevant guides include:

- Design of intake and outlet works
- Hydraulic steel structures
- Reinforced concrete hydraulic structures

These standards influence assumptions related to:

- Structural attachment of generation equipment
- Hydraulic loading on existing components
- Maintainability and inspection access
- Preservation of dam safety and operational reliability

### **Electrical Design and Interconnection Standards**

The electrical systems associated with the proposed hydropower conversion are assumed to comply with nationally recognized codes and standards.

- NFPA 70(National Electric Code)  
Governs safe electrical design, installation, grounding, and equipment protection
- NFPA 70E  
Establishes electrical safety practices for operation and maintenance, including arc flash and shock hazard mitigation.
- IEEE 1547  
Defines technical requirements for interconnection of distributed energy resources with the electric power system

Together these practices inform protection schemes, disconnects, grounding, and grid interconnection assumptions used in the design.

### **Worker Safety and Operational Regulations**

Construction, operation, and maintenance activities would be subjected to Occupational Safety and Health Administration (OSHA) regulations. Of particular relevance:

- 29 CFR 1910.147 - Control of Hazardous Energy (Lockout/Tagout)

This project design accounts for these requirements by assuming:

- Lockable mechanical and electrical isolation points
- Safe maintenance access paths
- Separation of hydraulic, mechanical, and electrical hazards

## Relevance to the Hydropower Collegiate Competition

While the project does not explicitly require formal permitting or regulatory approval, alignment with applicable standards and regulations strengthens its technical credibility and real world viability. The regulatory framework summarized above directly informs:

- Site selection
- Conceptual layout
- Construction feasibility
- Environmental impact minimization
- Long term operational safety

By grounding the design in established industry and federal standards, the proposed NPD conversion reflects the competition's emphasis on deployable,scalable, and responsible power solutions.

## Top Level CAD & Equation Summary

### Load Case Definition and Status

The analyses completed to date primarily evaluate the system's performance under the range of site operating conditions rather than detailed mechanical failure load cases. For this deliverable, "load cases" are defined as the bounding operating scenarios used to evaluate feasibility and to guide future structural and safety-factor calculations.

### Completed operating scenarios (performance load cases):

1. **High-flow / high-head operation (upper bound performance)**  
Represents periods of maximum available head and high discharge (limited by turbine capacity). This condition governs maximum turbine power output and the highest expected drivetrain torque and electrical loading within normal operation.
2. **Low-flow / low-head operation (lower bound performance)**  
Represents seasonal low discharge conditions where turbines may operate below optimal efficiency or fall below activation thresholds. This condition governs minimum power production and motivates hybridization with PV to maintain annual energy output.
3. **PV peak production condition (electrical/thermal upper bound)**  
Represents peak irradiance and high-temperature conditions that drive maximum module current, inverter loading, and reduced module efficiency due to temperature effects.

### Planned mechanical/structural load cases (for FoS table completion):

#### 4. **Mounting structure worst-case hydrodynamic load** (*planned*)

A conservative case using maximum expected current/flow condition to estimate drag and resulting bending loads on the mounting system and attachment points.

#### 5. **PV racking wind loading** (*planned*)

A code-based wind load case applied to racking members and foundations to verify minimum FoS for structural components.

The above load cases were selected because they represent the most demanding conditions expected during normal operation and provide traceable inputs for both performance modeling (completed) and structural verification (in progress).

### Flow Simulation (Dawson Stevens)

A digital simulation of the proposed dam's potential output was programmed in MATLAB. The code imports a year's worth of water data from the site and checks if each data point is in or out of several "zones" of power output. These zones were obtained from Voith and can be seen in Figure 1. The 14-90 model of Voith's Streamdiver hydroturbine has been selected to be used for the project. Points within the defined zones were then used to determine the total cumulative power output from a six turbine system. The full code for the prototype can be found in Appendix A.

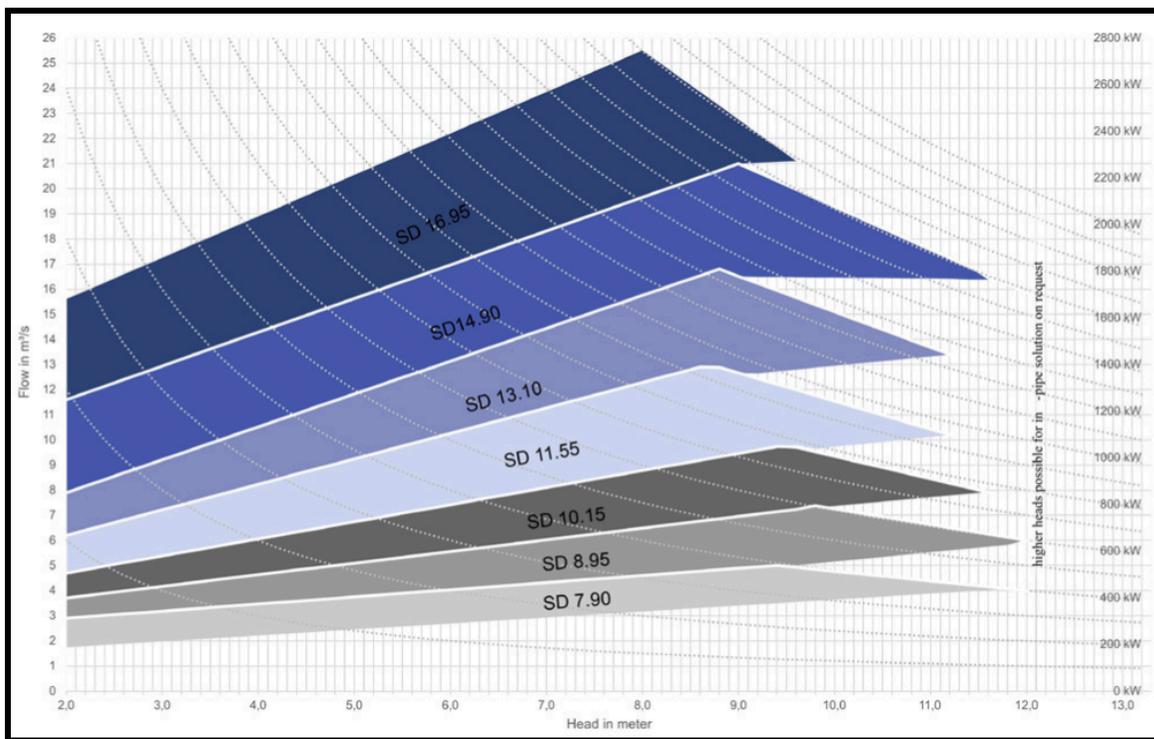


Figure 4. Streamdiver Power Curves

After running the simulation, the following plot was generated. The plot shows how the estimated power output fluctuates throughout the year.

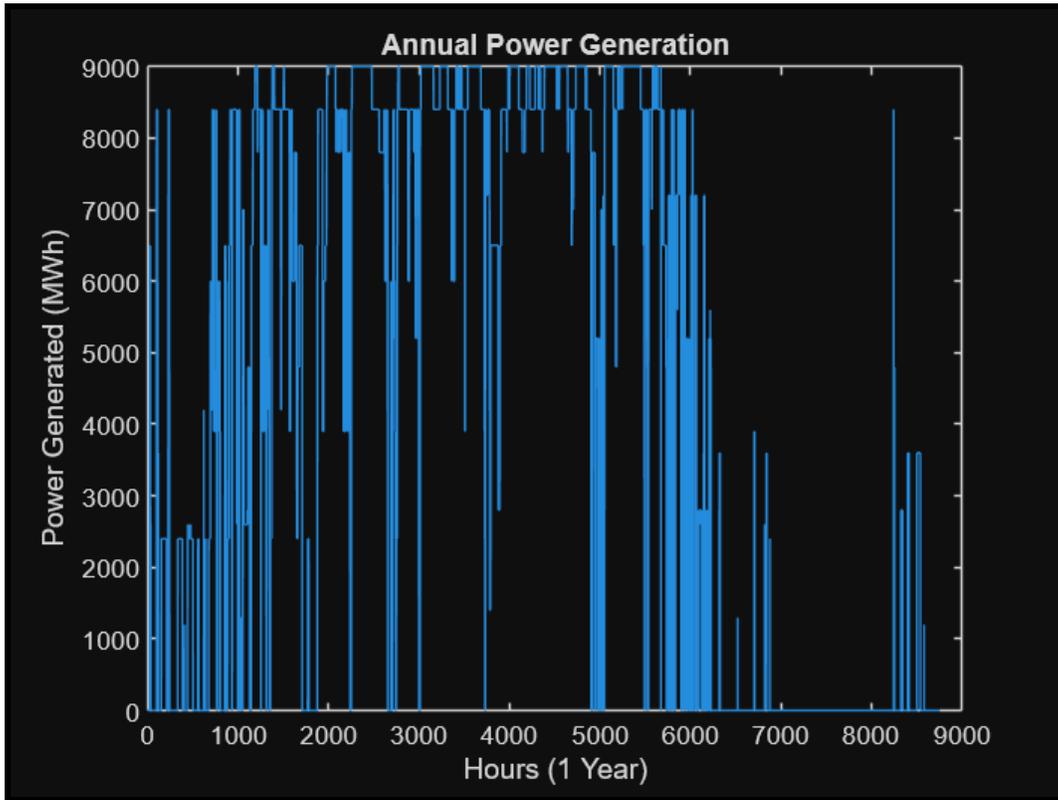


Figure 5. Annual Power Generation

As seen in the above graph, power output drops significantly during the Fall months. This may be due to seasonal drought, or an anomaly in the sample data. Details regarding the seasonal fluctuations in local hydrology are currently being examined. More insight into the simulation’s performance estimates can be found in Table 1.

Measure	Mean (MW)	Min (MW)	Max (MW)	Interquartile Range (MW)	Annual Output (GWh)
Value	3042	0	9000	8400	38963

Table 1. Digital Prototype Output Data

It should be noted that the first iteration of the digital prototype used a different calculation for Section B. Originally, the basic hydropower energy equation (Equation 1) was used. However, after talking with the team’s project mentor, he recommended that the method be changed to the one used in the current updated version of the code.

$$P = \rho \eta g h Q \quad [1]$$

- P = Power Generated (Watts)
- $\rho$  = Water Density (1000 kg/m<sup>3</sup>)
- $\eta$  = Turbine Efficiency
- g = Gravity (9.8 m/s<sup>2</sup>)

Q = Volumetric Flow Rate

The reason for the change in calculation method was to better simulate the Voith Streamdiver, as a turbine's efficiency often fluctuates with different flow rates and/or head.

The flow simulation proved that a reasonable production of energy is possible at this site.

Furthermore, the simulation helped determine that six turbines is the optimal number for the system.

### **Solar PV Integration Feasibility (Anthony Nuzzo)**

This analysis evaluates the feasibility of integrating a 1.5 MWdc groundmount photovoltaic system into the hybrid hydro-solar retrofit concept at John. C. Stennis Lock and Dam. The intent of this analysis is to determine whether a realistically sized PV installation can:

1. Generate meaningful annual energy to supplement low head hydro production
2. Fit entirely into existing USACE property
3. Utilize commercially available hardware and conserve performance assumptions

This section summarizes the modeling approach, assumptions, site justification, and resulting design implications derived from the detailed computational analysis.

The central question addressed is whether a fixed-tilt 1.5 MWdc PV array at John C. Stennis is technically feasible and capable of generating sufficient annual energy to justify the conclusion of a hybrid system concept. Feasibility was evaluated through NREL's PhotoVoltaic modeling System Advisory Model.

The PV system location was approximated using site representative coordinates near the Stennis lock and dam, with solar resource data drawn from the NSRDB typical meteorological year set. This site is assumed to have relatively flat terrain, minimal horizon shading, and negligible snow related losses, consistent with regional climate decisions.

#### System configuration

- DC nameplate capacity:  $P_{DC}=1.50$  MWdc
- AC inverter capacity:  $P_{AC}=1.20$  MWac, 20 × 60 kW Sungrow SG60CX-US
- Inverter loading ratio (DC/AC):  $ILR=P_{DC}/P_{AC}=1.25$
- Mounting: fixed-tilt open rack, tilt = 25°, azimuth = 180° (south).
- Ground coverage ratio (GCR): 0.45 (moderate row spacing).
- Land-use intensity: 3.0 acres/MWac
- PV module: JA Solar JAM72S30-545/MR, 545 W mono-PERC bifacial.
- Electrical configuration: 16 modules per string, 172 parallel strings.

The module was selected because it utilizes similar technology to the new 545 W mono-PERC module and similarly the JA models are commonly used in TVA/SE regions per EPC contracts. There is documented proof of the success of the modules and the team has selected to solidify the choice. The inverter model was similar to the paired inverter for the selected module

however is slightly unconservative in this runthrough and will be reevaluated to further meet specific wiring connectings.

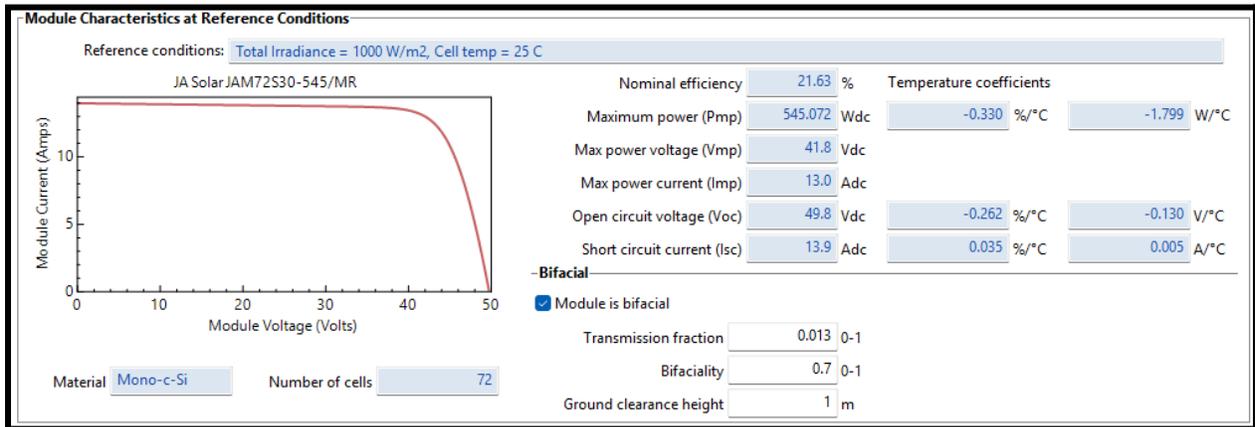


Figure 6. Module Characteristics for JA Solar JAM72S30-545/MR

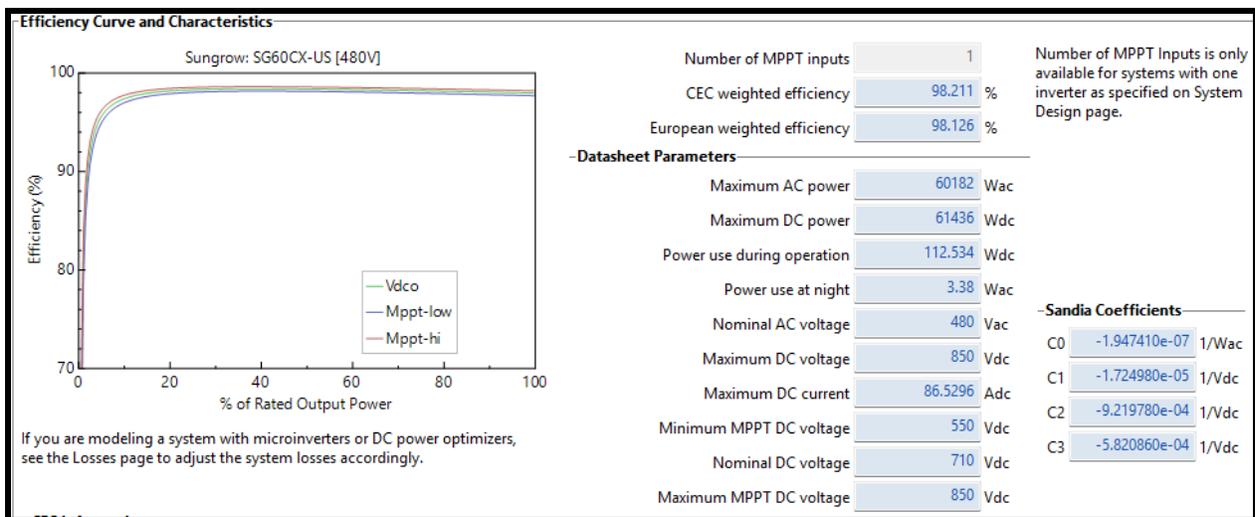


Figure 7. Efficiency Curve of Sungrow SG60CX-US [480 V]

Computational performance was simulated by the SAM model using hourly resolution over a full meteorological year. The model internally accounts for the plane of array radiance, temperature effects, module to inverter behavior, inverter efficiency curves and system losses. Through this trial the team has selected that this iteration is viable however can be enhanced based on slight irregularities between the module and inverter units. Monthly AC production shows strong seasonal consistency with peak generation during peak summer months and reduced output in the colder winter months. Consistent with expected solar resource behavior in the region.

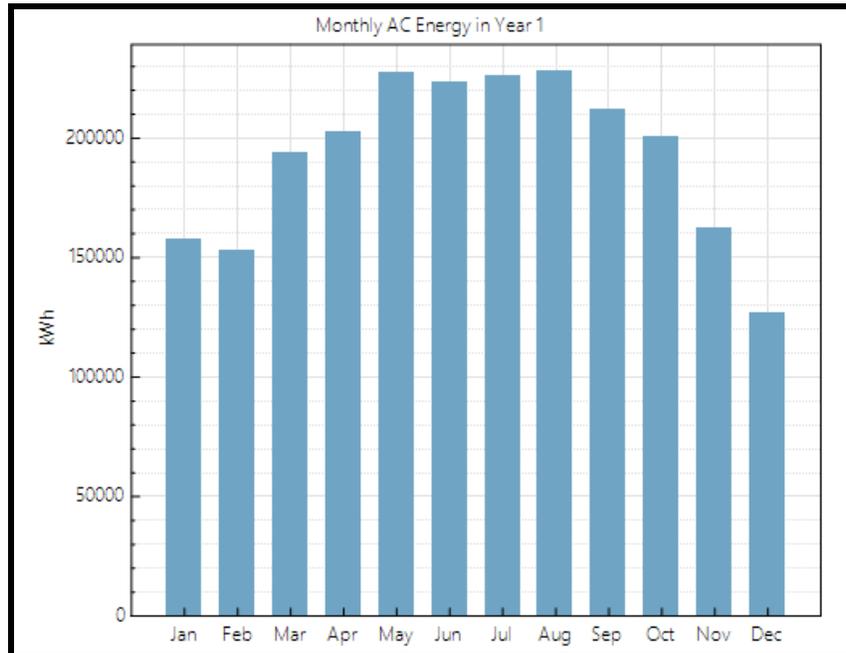


Figure 8. Monthly AC Energy Production

## Site Selection and Land-Use Feasibility

Multiple candidate locations around John C. Stennis were evaluated, including:

- East Bank Recreation Area
- Dredged Material Disposal Sites, AL16, AL18

These sites were selected based on their previously disturbed condition, avoiding the need for new land acquisition and forest clearing. A standard utility to land use intensity is approximately 3 acres per MWac was applied to estimate minimum required land. Results indicate that the PV system would require approximately 3.6 acres of land, well within each of the candidates allotted sizes. East Bank Recreational Center offers about 5 acres of land that is regularly cleared and maintained, open field with plenty of sunlight, and easiest for construction and O&M. Dredged material disposal area 16&18 both offer at least 12 acres of usable land, though slightly farther away from the dam site they would provide site utilization of the land on USACE property. Low ecological footprint due to these areas already being disturbed. Accessible by the USACE road network so construction and O&M would be slightly higher than the East Bank site.

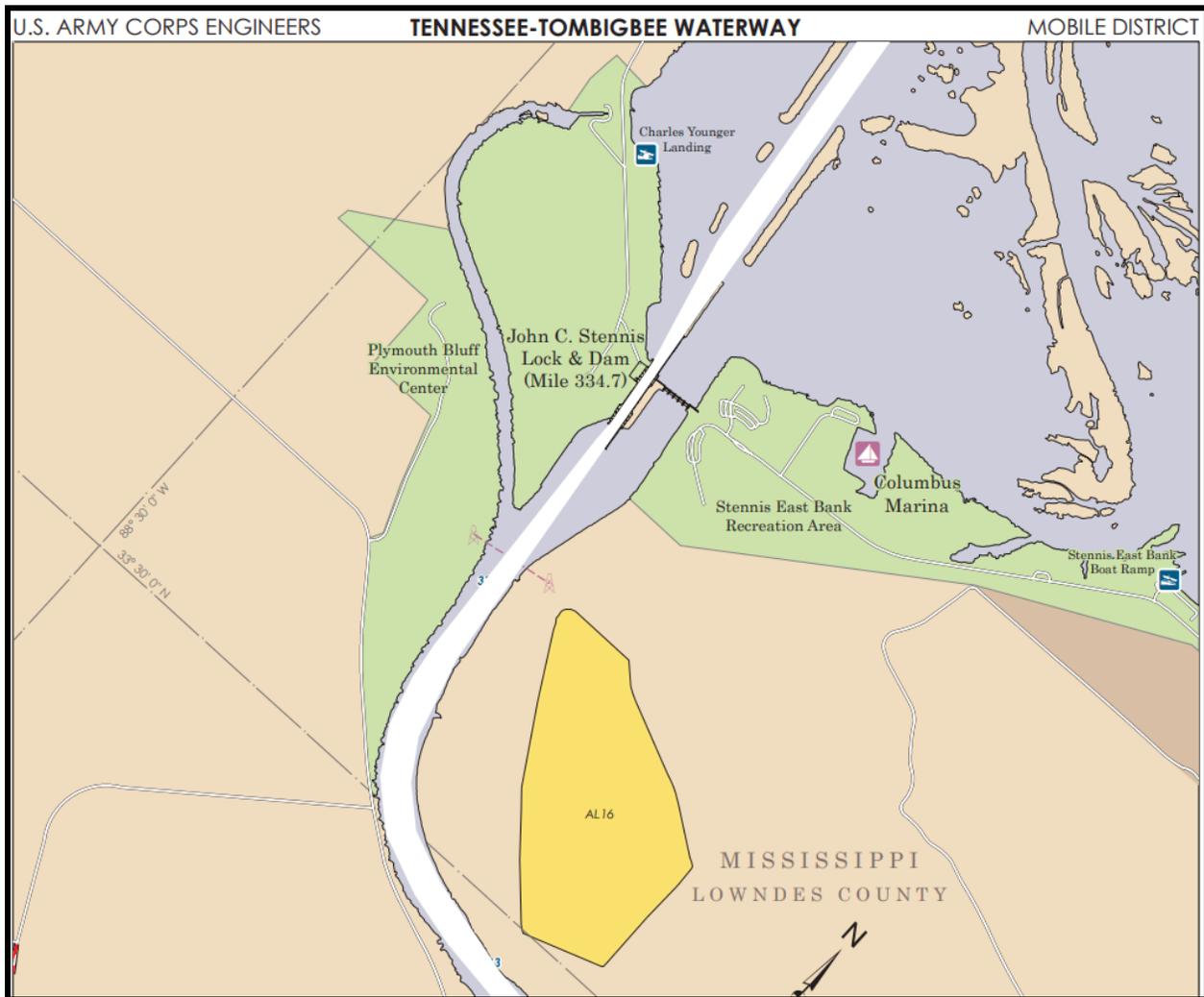


Figure 9. East Bank Recreation Area

### Key Performance Metrics and Results

The simulation results indicate that the proposed PV system produces approximately 2.3GWh per year of AC energy, meeting the original design objective for supplemental generation using a total of 2,772 modules.

Metric	Value
Annual AC energy in Year 1	2,311,302 kWh
DC capacity factor in Year 1	17.6%
Energy yield in Year 1	1,541 kWh/kW
Performance ratio in Year 1	0.81

Table 2. Table Of Resulting Values

Additional calculated metrics include specific energy yield, DC capacity factor, and overall performance ratio, all consistent to comparable utility scale PV installations in the southeastern United States. This analysis provides quantitative justification for including solar generation in the hybrid design and informs subsequent cost analysis, electrical architecture development, and final system integration decisions at this stage.

### Environmental Analysis (Dawson Stevens)

An environmental analysis was performed using the Hydropower Environmental Decision Toolkit created by the Oak Ridge National Laboratory. The toolkit consists of a questionnaire that is used to calculate the relevancy of different categories of environmental importance. Both the relevancy score and the questionnaire were used to help focus research at the site. Below are brief descriptions of relevant environmental information and how impact can be reduced or prevented.

- **Biota & Biodiversity** - Giant Salvinia is an invasive aquatic plant found both upstream and downstream from the site. This means the project itself would not allow for its further spread. However, construction equipment used must be cleaned of the plant to prevent it being spread to new waterways. Additionally, there are no protected/endangered species found in Columbus Lake, the dam’s reservoir and the present aquatic animals are hardy species and should not be heavily impacted by the project.
- **Hydrology & Landscape** - Since this project is only modifying a pre-existing structure, little to no hydrology or landscape impact is expected. The only issue is disrupting the waterway’s flow. To minimize this impact, the bulk of construction should be planned during the site's annual dry season. The team is currently investigating the co-development of a solar power plant with the dam. This would increase the footprint of the site. Fortunately, the adjacent plot of land has minimal vegetation, which will limit habitat disruption.
- **Water Quality** - Turbulent discharge water from a dam can allow more oxygen to dissolve into the tailwater of the dam. This has the potential to negatively affect wildlife. The dam’s current structure likely causes some amount of increased oxygenation, though any relevant data regarding this oxygenation was unable to be found. More research may be needed on this subject matter.

For future convenience, a summary of relevant issues and their precaution measures are listed in Table X.

Issue	Solution
Invasive plant life is in the lake and river	Construction equipment will be cleaned to prevent spread into new waterways
Lake contains an active fishery	A fish screen and bypass will be incorporated into the facilities design
Solar co-development may impact habitat	A nearby plot with minimal vegetation will

	be used for solar installment
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Table 3. Environmental Issues and Solutions

## Factor of Safety Summary and Status

Factors of Safety are used to evaluate whether critical structural and mechanical components can safely withstand the loads encountered during normal operation. For this stage of the project, FoS values are reported for components where sufficient information is available, and planned analyses are identified for components that require further modeling or detailed load definition.

The minimum acceptable FoS for primary mechanical components is guided by the Engineering Requirement specifying a safety factor greater than 1.3. Components not yet fully analyzed are clearly identified, along with the intended method of analysis and planned completion.

Subsystem	Component	Governing Load Case	Material	Method of FoS Evaluation	Minimum FoS
Hydropower	Turbine mounting structure	Max flow / high-head operation (hydrodynamic drag + self-weight)	Structural steel	Hand calculation (planned)	TBD (analysis in progress)
Hydropower	Turbine housing	Internal pressure and hydrodynamic loading	Cast steel / aluminum alloy	FEA (planned)	TBD (analysis in progress)
Hydropower	Shaft and generator interface	Maximum transmitted torque	Steel	Analytical torsion calculation (planned)	TBD (analysis in progress)
Electrical	Electrical enclosure mounts	Static weight + vibration	Steel	Hand calculation	> 1.3
Solar PV	PV racking system	Code-based wind loading	Galvanized steel	Manufacturer spec / code-based calc	≥ 1.5
Solar PV	Module mounting rails	Dead load + wind uplift	Aluminum	Manufacturer data	≥ 1.5

Table 4. Summary of Minimum Factors of Safety for Critical Components

## Discussion of FoS Results

Preliminary FoS values for commercially standardized components, such as PV racking systems and electrical enclosures, meet or exceed minimum safety requirements based on manufacturer specifications and standard design practices. Structural components specific to the hydropower

installation, including turbine mounts and housing interfaces, require further analysis due to site-specific hydrodynamic loading conditions.

Planned FoS calculations will incorporate conservative assumptions for flow velocity, drag coefficients, and load combinations representative of worst-case operating conditions. These analyses will be completed using a combination of hand calculations and finite element analysis to verify compliance with safety requirements prior to final design approval.

## Moving Forward

The next phase of this project will focus on transitioning from feasibility-level analysis to physical validation and prototype development in support of the 33% build milestone. Immediate efforts will prioritize completion of factor of safety calculations for hydropower-specific structural components, including turbine mounting structures, housing interfaces, and drivetrain elements, prior to fabrication and prototype assembly.

Manufacturing confirmation and mechanical fabrication activities will follow final design validation, leading into prototype assembly and initial system testing. Electrical architecture development and subsystem integration have not yet been completed and will be addressed in subsequent project phases after mechanical configuration and component interfaces are finalized.

Future electrical efforts will include generator selection, power conditioning and inverter specification, and development of a safe electrical integration strategy for hybrid operation. Environmental and economic analyses, including refinement of the JEDI economic impact model, will be revisited as component costs and construction assumptions mature.

## Appendix

```
clear; clf; format short;

% SECTION A
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Import head and flow data, align their date-time values and
create
% a unified table made of datetimes, head, and flow
head = readtable('Head.txt');
flow = readtable('Flow.txt');
head.datetime = datetime(head.datetime, 'InputFormat', 'yyyy-MM-dd
HH:mm:ss', 'Format', 'default');
flow.datetime = datetime(flow.datetime, 'InputFormat', 'yyyy-MM-dd
```

```

HH:mm:ss', 'Format', 'default');
head.datetime = dateshift(head.datetime, 'start', 'minute');
flow.datetime = dateshift(flow.datetime, 'start', 'minute');
commonTimes = intersect(head.datetime, flow.datetime);
head = sortrows(head, 'datetime');
flow = sortrows(flow, 'datetime');
head = head(ismember(head.datetime, commonTimes), :);
flow = flow(ismember(flow.datetime, commonTimes), :);
[~, ia, ib] = intersect(head.datetime, flow.datetime);
headAligned = head(ia, :);
flowAligned = flow(ib, :);
headflow = table(headAligned.datetime, headAligned.x79676_00065,
flowAligned.cfs, ...
'VariableNames', {'datetime', 'head', 'flow'});
headflow.head(13753) = 36.7; % estimating a missing value
plot(headflow.datetime, sort(headflow.head, "descend"));
xlabel('Time');
ylabel('Head (ft)');
title('Annual Head (Nov 2024-Nov 2025)');
plot(headflow.datetime, sort(headflow.flow, "descend"));
xlabel('Time');
ylabel('Flow (cfs)');
title('Annual Flow (Nov 2024-Nov 2025)');

% Adjust head/flow data to account for limited capacity
N = 6; % Number of turbines
cappedData = headflow;
cappedData.flow(cappedData.flow > 700*N) = 700*N;
cappedData.head(cappedData.head > 39) = 39;

% Power Curve Lines - 14.90 - 14
kw16 = polyshape([9 11.6 10.9 8.8], [21 16.5 16.5 20.5]);
kw15 = polyshape([8.8 10.9 10.1 8.4], [20.5 16.5 16.5 20]);
kw14 = polyshape([8.4 10.1 9.4 8], [20 16.5 16.5 19.5]);
kw13 = polyshape([8 9.4 8.6 7.6], [19.5 16.5 16.5 19]);
kw12 = polyshape([7.6 8.6 8.2 7.2], [19 16.5 16.2 18.4]);
kw11 = polyshape([7.2 8.2 7.8 6.8], [18.4 16.2 15.7 17.9]);
kw10 = polyshape([6.8 7.8 7.3 6.3], [17.9 15.7 14.9 17.2]);
kw9 = polyshape([6.3 7.3 6.8 5.8], [17.2 14.9 14.2 16.5]);
kw8 = polyshape([5.8 6.8 6.2 5.3], [16.5 14.2 13.5 15.9]);
kw7 = polyshape([5.3 6.2 5.6 4.8], [15.9 13.5 12.9 15.2]);
kw6 = polyshape([4.8 5.6 5 4.1], [15.2 12.9 12 14.5]);
kw5 = polyshape([4.1 5 4.3 3.5], [14.5 12 11 13.5]);
kw4 = polyshape([3.5 4.3 3.6 2.9], [13.5 11 10 12.5]);
kw3 = polyshape([2.9 3.6 2.7 2.1], [12.5 10 8.9 11.5]);
kw2 = polyshape([2.1 2.7 2 2], [11.5 8.9 8 11.4]);

% Determine Active Turbine # at each data point

```

```

cappedData.N_active = zeros(height(cappedData),1);
cappedData.N_active(cappedData.flow <= 700) = 1;
cappedData.N_active(cappedData.flow > 700 & cappedData.flow <=
1400) = 2;
cappedData.N_active(cappedData.flow > 1400 & cappedData.flow <=
2100) = 3;
cappedData.N_active(cappedData.flow > 2100 & cappedData.flow <=
2800) = 4;
cappedData.N_active(cappedData.flow > 2800 & cappedData.flow <=
3500) = 5;
cappedData.N_active(cappedData.flow > 3500) = 6;

% Convert to Metric
cappedData.flow = cappedData.flow * 0.0283168;
cappedData.head = cappedData.head * 0.3048;

% Account for designed head loss
cappedData.head = cappedData.head - 2.5;

% SECTION B
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

% Apply to Data
cappedData.unitFlow = zeros(height(cappedData), 1);
realPowerKW = zeros(height(cappedData), 1);
for i = 1:height(cappedData)
cappedData.unitFlow(i) = cappedData.flow(i)/cappedData.N_active(i);
[in, on] = inpolygon(cappedData.head(i), cappedData.unitFlow(i), [9
11.6 10.9 8.8],[21 16.5 16.5 20.5]);
if in | on
realPowerKW(i) = 1500;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [8.8 10.9 10.1 8.4],[20.5 16.5 16.5 20]);
if in | on
realPowerKW(i) = 1400;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [8.4 10.1 9.4 8],[20 16.5 16.5 19.5]);
if in | on
realPowerKW(i) = 1300;
end
[in, on] = inpolygon(cappedData.head(i), cappedData.unitFlow(i), [8
9.4 8.6 7.6],[19.5 16.5 16.5 19]);
if in | on
realPowerKW(i) = 1200;
end

```

```
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [7.6 8.6 8.2 7.2], [19 16.5 16.2 18.4]);
if in | on
realPowerKW(i) = 1100;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [7.2 8.2 7.8 6.8], [18.4 16.2 15.7 17.9]);
if in | on
realPowerKW(i) = 1000;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [6.8 7.8 7.3 6.3], [17.9 15.7 14.9 17.2]);
if in | on
realPowerKW(i) = 900;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [6.3 7.3 6.8 5.8], [17.2 14.9 14.2 16.5]);
if in | on
realPowerKW(i) = 800;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [5.8 6.8 6.2 5.3], [16.5 14.2 13.5 15.9]);
if in | on
realPowerKW(i) = 700;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [5.3 6.2 5.6 4.8], [15.9 13.5 12.9 15.2]);
if in | on
realPowerKW(i) = 600;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [4.8 5.6 5 4.1], [15.2 12.9 12 14.5]);
if in | on
realPowerKW(i) = 500;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [4.1 5 4.3 3.5], [14.5 12 11 13.5]);
if in | on
realPowerKW(i) = 400;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [3.5 4.3 3.6 2.9], [13.5 11 10 12.5]);
if in | on
realPowerKW(i) = 300;
end
[in, on] = inpolygon(cappedData.head(i),
cappedData.unitFlow(i), [2.9 3.6 2.7 2.1], [12.5 10 8.9 11.5]);
if in | on
```



```

percent_below = (num_below / total_entries) * 100;
fprintf('Less than 1 MW is generated for %.2f%% of the year',
percent_below);
headflow.Energy = realPowerKW;
writetable(headflow, 'PrototypeOutput.txt')
measures = ["Mean", "Median", "Mode", "Min", "Max", "Interquartile
Range", "Annual MWh"];
values = [meanValue, minValue, maxValue, quartileRange, MWh];
summaryTable = table(measures', values', 'VariableNames',
{'Measure', 'Value'});
writetable(summaryTable, 'SummaryStatistics.txt');
disp(summaryTable);

```

*Figure 11. Digital Prototype*

### **Section A**

Section A imports the water data sourced from USACE into MATLAB. The program then organizes the data and generates plots of the annual flow and head at the site. Next, a series of quadrilaterals are generated based off of the SD 14-90 power curve. Each geometry is assigned to a region of power generation.

### **Section B**

Section B goes through each data point of head and flow rate and checks to see which, if any, of the previously generated geometries it fits into and assigns the data point the respective power generated. A minor issue with this method is that it is unable to interpolate when a value is between 2 lines on the power curve diagram. To minimize the impact on determining the viability of the site, each zone is slightly underestimated. This means that a more realistic simulation would have a higher output than this model.

### **Section C**

Section C uses the information from section B to calculate and generate various figures and tables that show the data more effectively than the raw data points.