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To: Dr. David Willy

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Date: *2/1/26*

Re: *Individual Analytical Analysis*

John C Stennis Lock and Dam - Site Operations Analysis

1. Introduction

The John C Stennis Lock and DAm on the Tombigbee River currently operates as a nonpowered navigation and flood control structure. While the dam provides a controlled upstream pool and a measurable hydraulic drop, no power generation infrastructure has been installed. Increasing interest in nonpowered dam (NPD) conversions has raised the question of whether hydropower generation could be practically and operationally implemented at this site.

The objective of this analysis is to determine if power generation at Stennis could operate reliably given mechanical uptime considerations, operational constraints imposed by navigation and flood control, and maintenance requirements. This assessment focuses on whether the site's hydraulic behavior and operational plan support viable generation, rather than theoretical energy production alone.

Hourly hydraulic data collected from the U.S. Geological Survey (USGS) was used to evaluate head availability, discharge variability, and resulting power duration behavior over the period January 2024 through January 2026.

2. Necessary Assumptions

This analysis is based on conservative, screening level assumptions appropriate for an early stage design feasibility assessment. These assumptions will be used for top level and then optimized if a second screening is required.

2.1 Hydraulic and Operational Assumptions

- The dam will continue to operate primarily for navigation and flood control; hydropower generation is secondary
- Headwater and tailwater elevations are accurately represented by the USGS gage data
- Net head losses such as trash rack, intake, draft tube losses are approximated at 5% of gross head
- Minimum net head operating conditions of 2.5 m is assumed for lowest head required as per Voith streamdiver requirements.
- No active flow regulation or power optimization is assumed.

2.2 Turbine and Electrical Assumptions

- Overall turbine generator efficiency, η, is assumed to be .88, consistent with modern low head kaplan turbines.
- Power output is capped at 5MW and 8MW to represent candidate plant sizes.
- Station Service, grid availability, and outages are not explicitly modeled but are qualitatively discussed.

3. Definition of Variables and Governing Equations

3.1 Variables

Table 1. Variables

Symbol	Description	Units
$Q(t)$	Discharge as a function of time	m^3/s
H_{HW}	Headwater elevation	m
H_{TW}	Tailwater elevation	m
H_{Gross}	Gross hydraulic head	m
H_{Net}	Net hydraulic head	m
h_{loss}	Hydraulic losses	m
ρ	Water Density(1000)	kg/m^3
g	Gravitational Acceleration	m/s^2
η	Overall Efficiency	-
$P(t)$	Power output	MW

3.2 Net Head Equation

$$Hnet = (H_{HW} - H_{Tw}) - h_{loss} \tag{1}$$

This equation represents the effective hydraulic head available to the turbine after accounting for hydraulic losses. Headwater and tailwater elevations were obtained directly from USGS data, while losses were approximated as a fixed percentage of gross head.

3.3 Hydropower Equation

$$P(t) \;=\; \frac{\rho\, g\, Q(t)\, Hnet\,(t)\eta}{10^6} \tag{2}$$

This standard hydropower equation converts hydraulic power into electrical power and is widely used for preliminary hydropower feasibility studies. Power values were capped at selected installed capacities to generate power duration curves.

4. Physical modeling Approach

The matlab code used in this analysis is a time series hydraulic screening model. Hourly discharge and stage data found on the USGS database was synchronized and converted into consistent SI units. Gross head was computed as the difference in headwater and tailwater elevations, and net head was estimated using a fixed loss of 5%. This model primarily focuses on temporal availability, which is the dominant factor in site operations analysis for nonpowered dam conversions. This site is navigation first, power operations second, due to the lock aspect of the dam there are multiple instances when the gates open resulting in a net head drop. To continue, there are also many occurrences where the flow is irregular and long drought times have been identified throughout the year mitigating possible power generation.

5. Interpretation of Results and Operations Implications
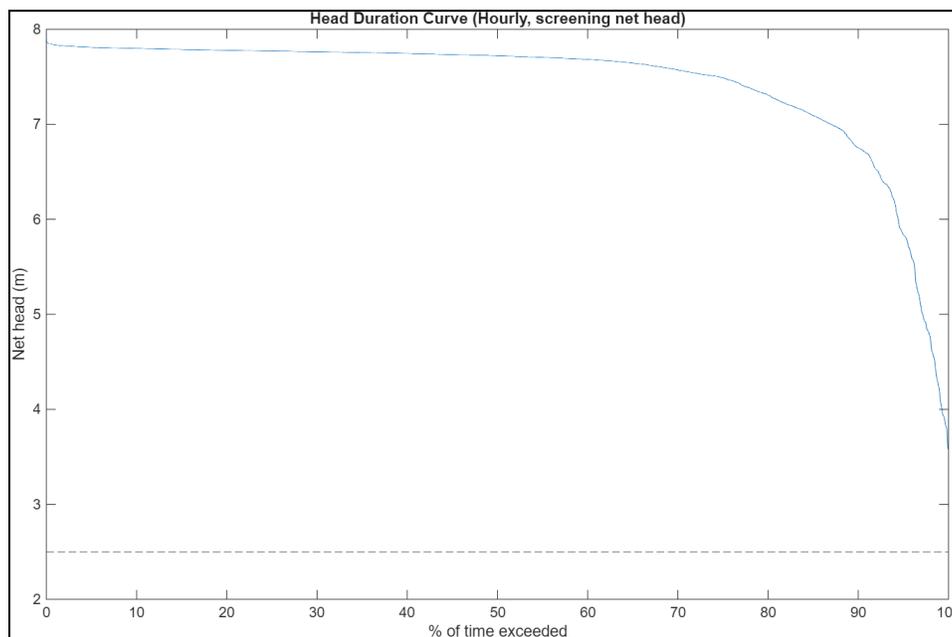
5.1 Head Availability and Mechanical Uptime

Figure 1. Head Duration Curve

The head duration curve shows that net head at the Stennis site typically ranges from 7.5 to 8 m, with rare instances below 4m. The minimum operating threshold of 2.5 m is exceeded essentially 100% of the time during the study period. This indicates that hydro operation at

Stennis is not limited by head availability, and insufficient head would not be a driver of mechanical downtime.

5.2 Discharge Variability and Operational Constraints
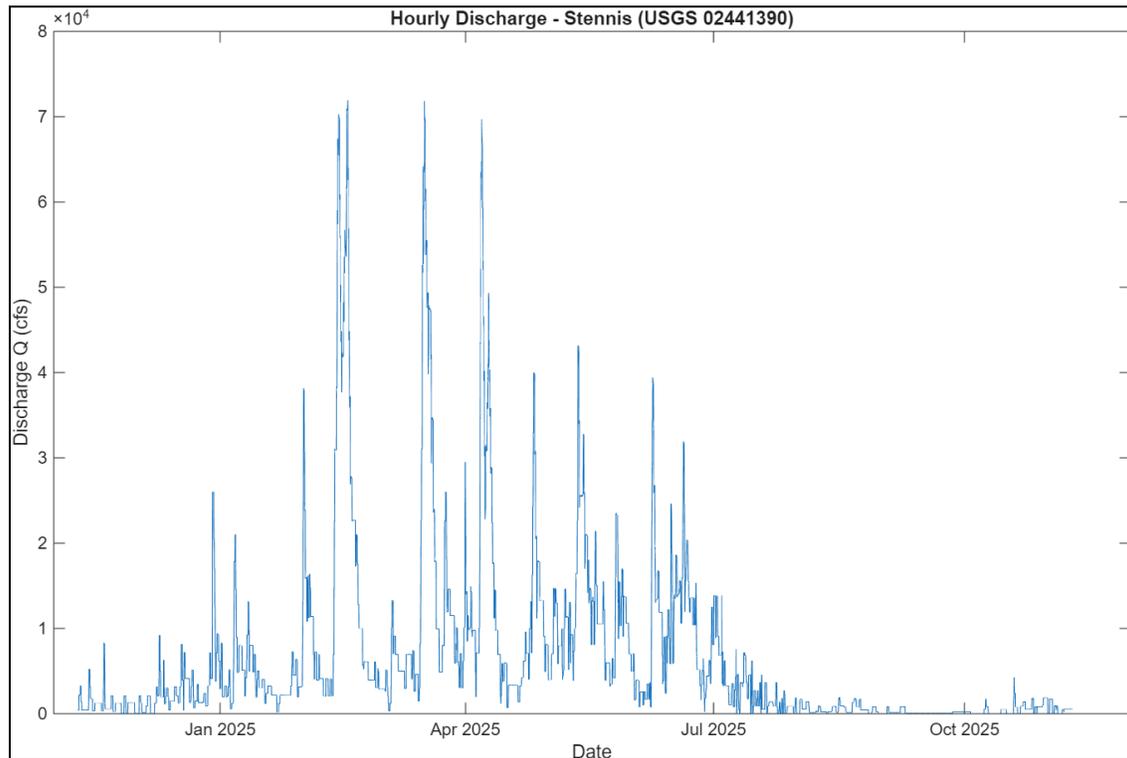

Figure 2. Hourly Discharge Time Series

Discharge at this site exhibits high variability, with frequent flood-driven peaks exceeding 7,000 cfs and low flow periods. This variability introduces operational challenges, including transient loading on turbines, elevated debris transport during floods, and reduced efficiency during low flow duration. Because navigation and flood control priorities govern gate operations, hydropower generation at this site would be opportunistic rather than dispatchable.

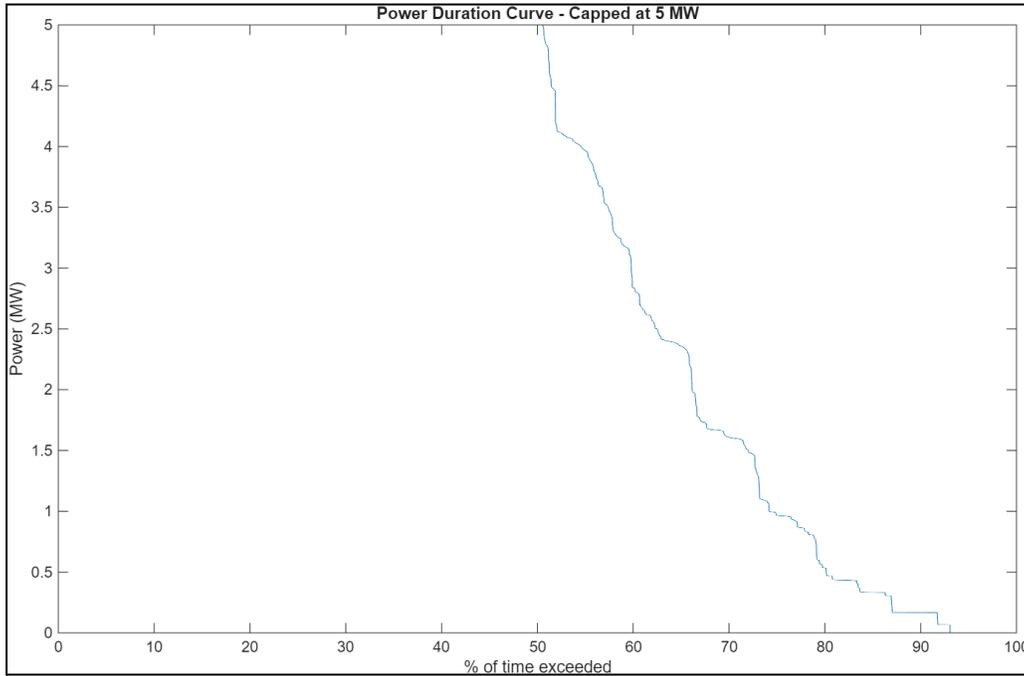## 5.3 Power Duration and Capacity Utilization

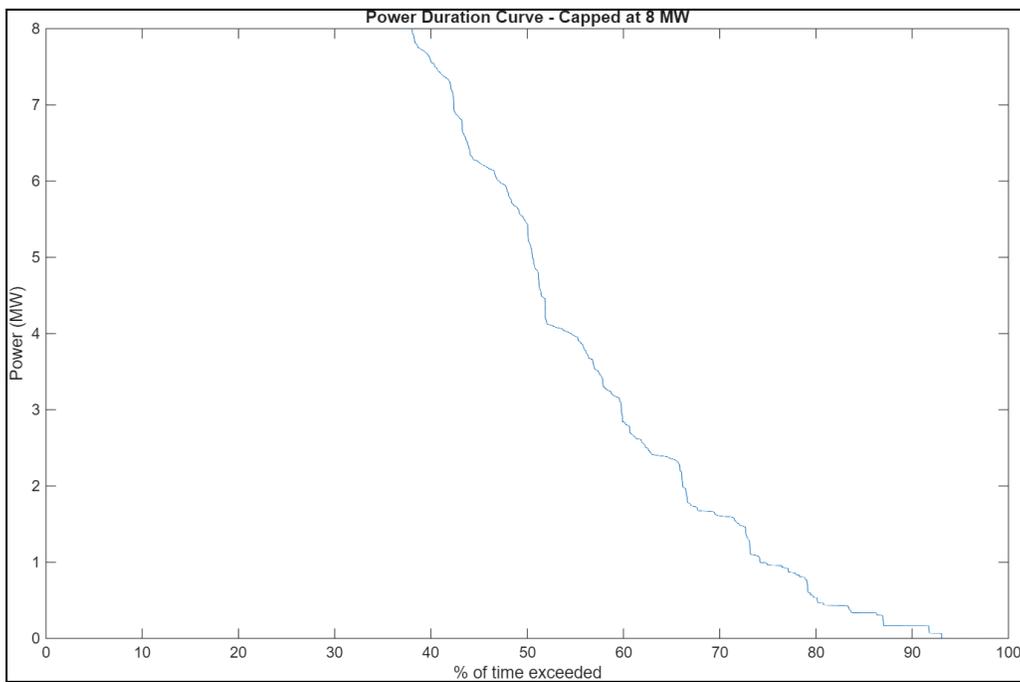*Figure 3. Power Duration Curve For 5 MW*

Figure 4. Power Duration Curve For 8 MW

The power duration curves indicate that a 5 MW installation reaches full capacity for approximately half of the operating period, while an 8 MW installation achieves nameplate

output less frequently at around 40% of the operating period. Increasing installed capacity beyond approximately 5 MW results in diminishing returns due to flow variability rather than head limitations.

6. Maintenance Requirements and Missing Infrastructure

The site lacks all hydropower specific infrastructure. Implementation at the very least would require:
- Turbine-generator units and draft tubes
- Intake structure with debris screening
- Isolation gates or stoplogs for maintenance
- Service station and electrical protection systems
- Cranes and access platforms

Flood driven debris loading significantly increases maintenance demands and is expected to be a primary driver of downtime. Maintenance access would be constrained during high tailwater conditions, reinforcing the need for isolation capability. Regular gate maintenance is continuous throughout the year with outdated technology resulting in low excess funding and continuous operations on site. This severely limits the operational time of the site, furthermore the Lockmaster noted that current outdated infrastructure is expected to have a few more years until a failed test

7. Program Flow

7.1 Matlab Algorithm

1. Import USGS discharge and stage data time series
2. Filter to approved USGS rows and parse timestamps
3. Resample to hourly mean values
4. Compute H_{Gross}, apply loss factor and compute H_{net}
5. Compute Water-window $H_{net} \geq 2.5$ m
6. Compute Power P(t) and cap at 5 MW and 8 MW
7. Produce duration curves and summary metrics
8. Export clean dataset and figures

8. Summary of Findings

Hydroperer generation at the John C. Stennis Lock and Dam is hydraulically feasible and not constrained by insufficient head. However, operational feasibility is governed by discharge variability, debris loading, and the need for extensive new infrastructure. While somewhat reliable generation is possible, at this moment; capacity utilization, maintenance demands, and infrastructure needs outweigh the project viability. A different site may provide more favorable results that align with the project scope.

References

[1] USACE Tennessee-Tombigbee Waterway Appendix C,
https://water.usace.army.mil/cda/documents/wc/1800/Appendix%20C-Stennis%20%28Columbus%29%20WCM.pdf
Describes gate and flood procedures and dated hydrology data

[2] **U.S. Bureau of Reclamation,** *Design of Small Dams*, **3rd ed., 2012.**
https://usbr.gov/pn/programs/ea/wash/potholes/techreport-alta-attachmentK.pdf
Authoritative reference for head losses, intake effects, and operational constraints.

[3] **U.S. Geological Survey,** *National Water Information System (NWIS),* **Station 02441390.**
Primary data source for discharge and stage measurements.

[4] **Voith Hydro,** *StreamDiver® Low Head Hydropower Plant Concept,* **Technical Brochure.**
https://www.voith.com/corp-en/t_3390_e_StreamDiver_20150907_screen.pdf
Industry reference for low-head turbine operating envelopes and minimum head thresholds.

[5] **Hydropower Calculations**,
https://www.weap21.org/webhelp/hydropower_calculations.htm
WEAP21 Users Guide — describes how available hydroelectric power uses discharge, head, and efficiency.

[6] **"Hydro Power,"** *Engineering Toolbox,*
https://www.engineeringtoolbox.com/hydropower-d_1359.html
provides the standard hydropower formula

Matlab Code Appendix

The following figures are main blocks of the code that were then plotted and quantiled to classify data.

```matlab
%% screening assumptions
Hmin_m = 2.5;            % minimum NET head threshold [m]
lossFrac = 0.05;        % screening hydraulic losses as fraction of gross head
eta = 0.88;             % screening turbine+generator efficiency
capMW_list = [5, 8];    % compare capped plant outputs [MW]

% Constants
rho = 1000;             % kg/m^3
g = 9.81;               % m/s^2
cfs_to_m3s = 0.0283168466;
ft_to_m = 0.3048;
```

```matlab
%% COMPUTE HEAD (gross/net) AND POWER
Hgross_ft = TT_h.HW_ft - TT_h.TW_ft;
Hgross_m  = Hgross_ft * ft_to_m;

Hnet_m = Hgross_m * (1 - lossFrac); % screening loss model

Q_m3s = TT_h.Q_cfs * cfs_to_m3s;

% Screening raw power (uncapped)
P_MW_raw = (rho*g .* Q_m3s .* Hnet_m .* eta) / 1e6;

% Water window (net head threshold only;  add Qmin later)
water_window = Hnet_m >= Hmin_m;
```

```matlab
%% CAP POWER AT 5 MW AND 8 MW AND COMPUTE ENERGY
Pcap = zeros(height(TT_h), numel(capMW_list));
E_MWh_annual = zeros(numel(capMW_list),1);
CF = zeros(numel(capMW_list),1);

t0 = t(1);
t1 = t(end);
years = days(t1 - t0) / 365.25;%365.25 days outta year in file

for i = 1:numel(capMW_list)
    capMW = capMW_list(i);
    Pcap(:,i) = min(max(P_MW_raw,0), capMW);      % MW capped
    % Hourly energy: MW * 1 hr = MWh
    annualMWh = sum(Pcap(:,i), "omitnan") / years;
    E_MWh_annual(i) = annualMWh;
    CF(i) = annualMWh / (capMW * 8760);
end
```