PREPARED BY

Mead & Hunt

Updated Study Report

Hydrologic and Hydraulic Modeling: Operations Model

Pensacola Hydroelectric Project
Project No. 1494

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Executive Summary

Mead & Hunt, Inc. (Mead & Hunt) is assisting Grand River Dam Authority (GRDA) with its intent to relicense the Pensacola Hydroelectric Project (Project), which is regulated by the Federal Energy Regulatory Commission (FERC). Flood control operations at the Project are regulated by the United States Army Corps of Engineers (USACE). GRDA proposed certain hydraulic and operations models for the relicensing study. The FERC's study plan determination requires GRDA to prepare an Updated Study Report (USR). Mead & Hunt has performed this task on behalf of GRDA. This report documents the updated results related to the Operations Model (OM) to be presented at the USR meeting.

USACE's RiverWare period-of-record model is a tool used by USACE Southwestern Division, Tulsa District (SWT) to simulate reservoir operations on the Arkansas River system upstream of United States Geological Survey (USGS) gage number 07250500 at Van Buren, Arkansas, including the Project. This model uses a daily time step and includes over 30 reservoirs.

Mead & Hunt developed a Flood Routing Model (FRM) for GRDA to replicate, as closely as possible, the Project flow routing decisions in the USACE RiverWare period-of-record model (RWM) as an input to the OM. The FRM is needed to investigate hypothetical events and operating scenarios that would be difficult and time-consuming to program into the RWM. The FRM includes three reservoirs (Pensacola, Kerr, and Fort Gibson), which operate as a subsystem for flow routing, and uses daily time steps like the RWM.

Mead & Hunt developed an OM for GRDA to simulate flow routing, hydropower scheduling, and other constraints on an hourly time step to support the Project relicensing effort. Because electricity prices vary widely within a day, hourly time steps provide improved accuracy for hydropower operations simulation. Output from the FRM – most importantly the average daily total discharge – is used as an input to the OM. The OM seeks to optimize the hydropower generation revenue at each facility while simultaneously satisfying various physical and operational constraints, including the flow routing decisions based on the RWM model as simulated in the FRM. The OM includes Pensacola Dam and Kerr Dam (Markham Ferry Hydroelectric Project), which is downstream of Pensacola Dam. Both Pensacola Dam and Kerr Dam are owned and operated by GRDA, and flow routing decisions at both projects are regulated by USACE under certain conditions.

The FRM and OM were validated against the RWM using the common metrics of the Coefficient of Determination (R^2) and the Nash-Sutcliffe Efficiency (NSE) to evaluate modeled total discharge and elevation. The OM was also validated by comparing the water surface elevation (WSEL) results to USGS gage data upstream of Pensacola Dam for two historical events recommended by the FERC. Sensitivity of OM results to stage-area-storage table updates were calculated.

The OM was used to simulate the reservoir levels resulting from different combinations of starting elevations, flow events, existing and future stage-storage relationships, and baseline or anticipated operation scenarios. The OM was also used to simulate the effects of changing elevation-storage relationships over time in support of the Sediment Transport Model (STM). Lastly, the OM was also used to simulate the effects of anticipated operations on reservoir water levels in support of the aquatic species study, terrestrial species study, wetlands and riparian habitat study, and assessment of recreation navigation impacts.

List of Abbreviations and Terms

1D........One-Dimensional
AFRC........Allowable Falling Release Change
CADSWES........Center for Advanced Decision Support for Water and Environmental Systems
CFR........Code of Federal Regulations
CFS........Cubic Feet Per Second
CHM........Comprehensive Hydraulic Model
DO........Dissolved Oxygen
EEC........English Electric Company Limited
GRDA........Grand River Dam Authority
FERC........Federal Energy Regulatory Commission
FRM........Flood Routing Model
H&H Study........Hydrologic and Hydraulic Modeling Study
ISR........Initial Study Report
kW........kilowatt
MWh........Megawatt-hour
NAVD88........North American Vertical Datum of 1988
NGVD29........National Geodetic Vertical Datum of 1929
NSE........Nash-Sutcliffe Efficiency
OAC........Oklahoma Administrative Code
OM........Operations Model
PD........Pensacola Datum
POR........Period of Record
Project........Pensacola Hydroelectric Project
PSP........Proposed Study Plan
R^2........Coefficient of Determination
RSP........Revised Study Plan
RWM........RiverWare Model
SPD........Study Plan Determination
STM........Sediment Transport Model
SWT........Southwestern Division, Tulsa District
TW........Tailwater
UHM........Upstream Hydraulic Model
USACE........United States Army Corps of Engineers
USGS........United States Geological Survey
USR........Updated Study Report
VBA........Visual Basic for Applications

1. Introduction and Background

1.1 Project Description

The Pensacola Hydroelectric Project is owned and operated by GRDA and regulated by the FERC. Pensacola Dam is located in Mayes County, Oklahoma on the Grand-Neosho River. Pensacola Dam impounds Grand Lake. Construction of Pensacola Dam was completed in 1940. Authorized purposes for the Project include flood control, recreation, and hydropower. **Figure 1** displays the study area. Downstream of Pensacola Dam, GRDA also owns and operates the Robert S. Kerr Dam as the Markham Ferry Hydroelectric Project. Kerr Dam is also in Mayes County and impounds Lake Hudson, also known as the Markham Ferry Reservoir. Flow routing decisions at both Pensacola Dam and Kerr Dam are regulated by USACE under certain conditions.

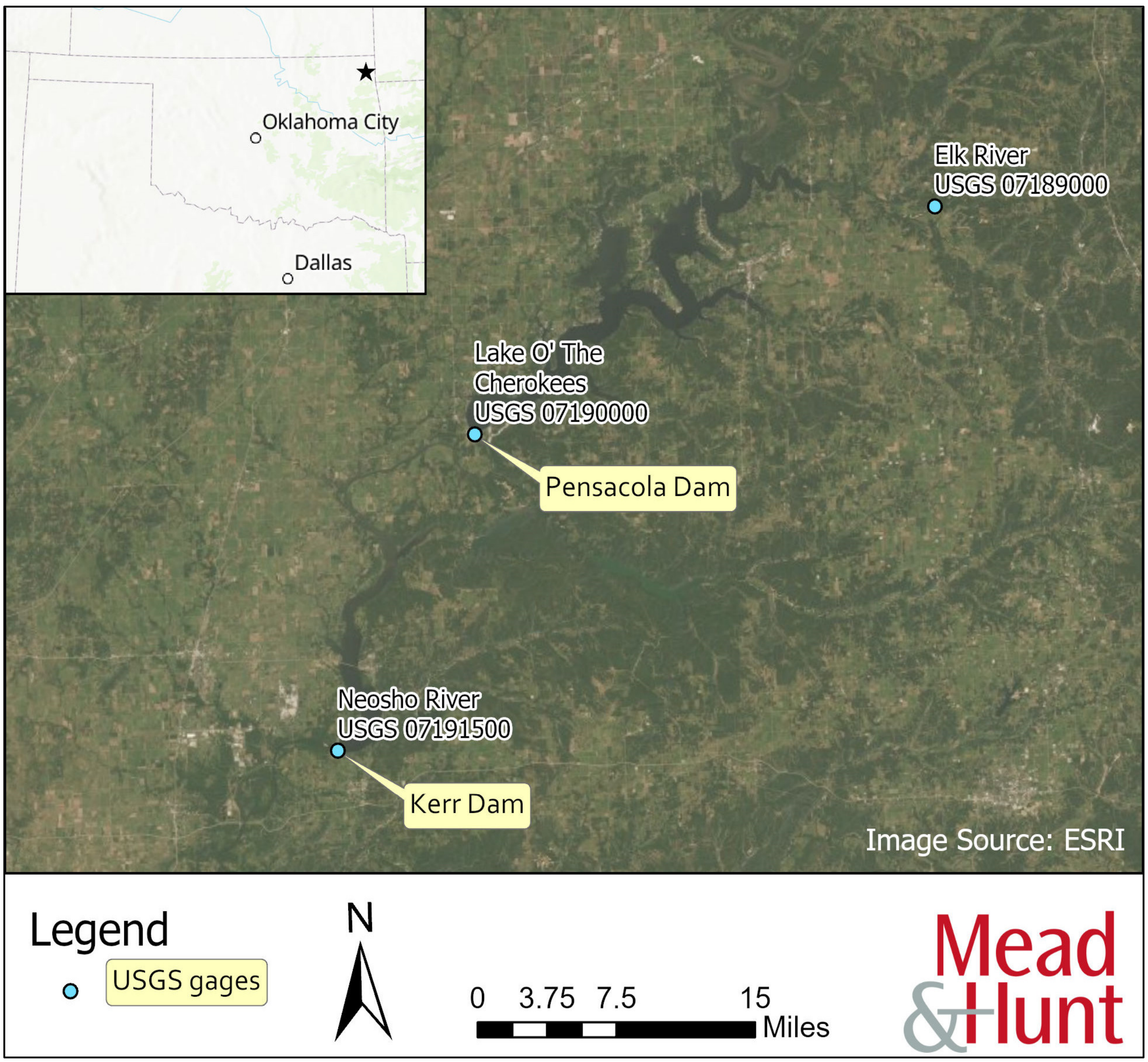


Figure 1. Operations Model Study Area

1.2 Study Plan Proposals and Determination

GRDA is currently in the relicensing of the Project. The timeline of study plan proposals and determination is as follows:

1. On April 27, 2018, GRDA filed its Proposed Study Plan (PSP) to address hydrologic and hydraulic modeling in support of its intent to relicense the Project.
2. On September 24, 2018, GRDA filed its Revised Study Plan (RSP).
3. On November 8, 2018, the FERC issued its Study Plan Determination (SPD) for the Project.
4. On January 23, 2020, the FERC issued an Order on the Request for Clarification and Rehearing, which clarified the timeline for certain milestones applicable to the relicensing study plan.
5. On September 30, 2021, GRDA filed its Initial Study Report (ISR).
6. On February 24, 2022, the FERC issued its Determination on Requests for Study Modifications and New Studies for the Project.
7. On May 27, 2022, the FERC issued its Determination on Requests for Study Modifications for the Pensacola Hydroelectric Project, related to the Sedimentation Study plan.
8. On September 30, 2022, GRDA filed this report, the USR.

The PSP and RSP recommended the development of an OM to synthesize and create events that inform or set boundaries for the Comprehensive Hydraulic Model (CHM). The FERC's SPD included the following determination specific to the OM:

> *We recommend that GRDA demonstrate in the ISR [Initial Study Report, filed September 2021] that it has validated its model results against the RiverWare output.*

The FERC's SPD and Order on Request for Clarification and Rehearing included direction to provide a model input status report by March 30, 2021 and hold a conference call on model inputs and calibration within 30 days of the input status report. The Operations Model Input Status Report was filed with FERC and shared with stakeholders on March 30, 2021 (Mead & Hunt, 2021). A Technical Conference was held on April 21, 2021, to allow relicensing participants to ask questions regarding the Model Input Status Report (MISR). GRDA's ISR was a continuation of the MISR and incorporated comments provided on the MISR. The ISR documented the development of the OM. On April 20, 2022 a Technical Conference was held to allow relicensing participants to ask questions regarding the Operations Model, discuss planned improvements to the model, and present the results of two historical validation cases recommended by the FERC.

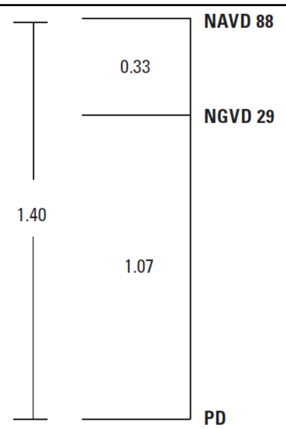
FERC's February 2022 Determination recommended the following modifications relevant to the OM portion of the H&H modeling study:

1. Run the OM to simulate all inflow events with starting reservoir surface elevations of 734 feet to 757 feet PD.
2. Compare water surface elevations observed at the USGS gage on the upstream side of the dam to simulated stage hydrographs for the December 2015 and October 2009 inflow events.
3. Run a sensitivity analysis on the effect of switching to the most recent (i.e., 2019) bathymetry data in the OM.

This report documents the development of the FRM and OM, the validation of results against the RWM output, and the implementation of the OM to provide results in support of the CHM and other relicensing studies. As documented in this USR, GRDA has completed FERC's requested modifications.

1.3 Vertical Datums

Data sources for this study use a variety of vertical datums. Unless otherwise noted, data related to Pensacola Dam and Grand Lake is referenced to the Pensacola Datum (PD) and data related to Kerr Dam and Lake Hudson is referenced to the National Geodetic Vertical Datum of 1929 (NGVD29). To convert from PD to NGVD29, add 1.07 feet. To convert from NGVD29 to the North American Vertical Datum of 1988 (NAVD88), add 0.33 feet. **Figure 2** displays datum transformations and conversions (Hunter, Trevisan, Villa, & Smith, 2020).



	Elevations, in feet		
	NAVD 88	NGVD 29	PD
Conservation pool	743.40	743.07	742.00
Top of the dam	758.40	758.07	757.00

Figure 2. Datum Transformations and Conversions
Source: (Hunter, Trevisan, Villa, & Smith, 2020).

2. USACE RiverWare Model

The RWM is a tool used by USACE Southwestern Division, Tulsa District to simulate reservoir operations on the Arkansas River system upstream of USGS gage no. 07250500 at Van Buren, Arkansas (USACE, 2020). The model simulates hydrologic inflows, evaporation, seepage, water deliveries, reservoir management, flood control, and hydropower production on a daily time step from 1940 through 2019. The model area includes more than 30 reservoirs, and the main control point for flood routing decisions is at the Van Buren gage. When flows at Van Buren are projected to exceed the seasonal guide curve, upstream reservoirs store water to limit flow at Van Buren. Other reservoirs or reservoir subsystems also have their own flood release restrictions. Reservoir balance levels throughout the system are managed to limit flooding systemwide.

Under Section 7 of the Flood Control Act of 1944 (CFR, 1944), the USACE has the responsibility to prescribe releases from Pensacola Dam and Kerr Dam under active or anticipated flood conditions (CFR, 1945). The USACE may exercise direct control over the facilities or provide instructions to GRDA to manage releases for the purpose of basin-wide flood mitigation. The RWM illustrates how reservoir levels at Pensacola Dam and Kerr Dam may be increased during a large flood event impacting Van Buren, not because the spillway capacity or downstream channel capacity is exceeded at either facility, but because water is held back to limit flow at Van Buren.

USACE SWT provided Mead & Hunt, Inc. (Mead & Hunt) with time series, tabular, and other data from the RWM, and examples of these data are included in **Appendix A**. The model domain is shown in **Figure 3**.

Mead & Hunt downloaded the RiverWare Technical Documentation from the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at University of Colorado Boulder, College of Engineering and Applied Science website and referenced it to understand how to replicate the modeling methods applicable to this study (CADSWES, 2020). CADSWES develops RiverWare, a river and reservoir/hydropower planning and management tool that is licensed by the University of Colorado Technology Transfer Office, and widely used by agencies and consultants. Documentation for the related TAPER model was also provided by USACE (Steffen, Stringer, Daylor, Neumann, & Zagona, 2015). USACE SWT and CADSWES staff also provided aid in understanding the RWM and how to apply its objects and methods to this study.

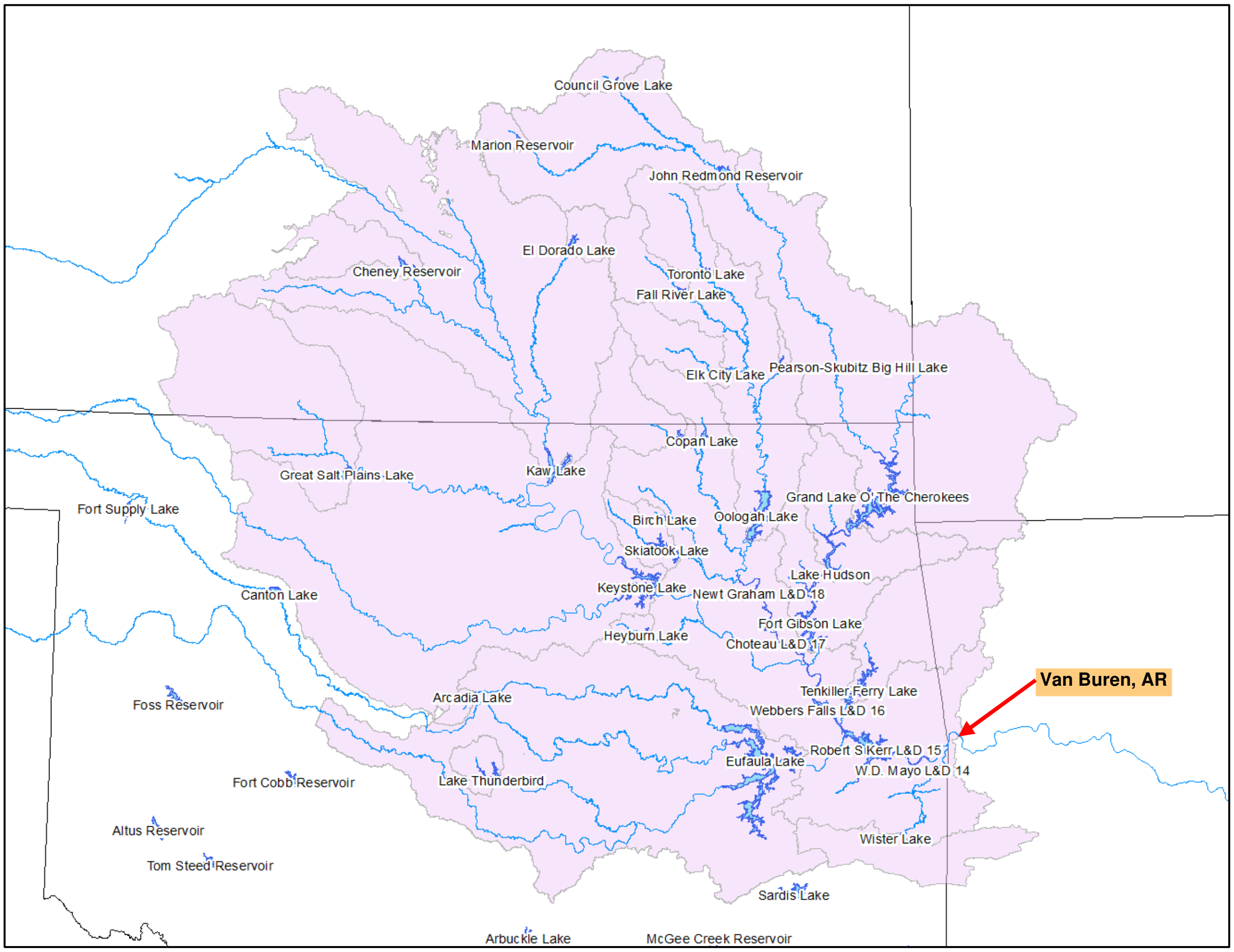


Figure 3. RiverWare Model Domain

3. Flood Routing Model

The FERC SPD recommended GRDA demonstrate it has validated its model results against the RWM output. Mead & Hunt developed the FRM to replicate, as closely as possible, the Project flow routing decisions in the RWM as an input to the OM. The FRM includes (from upstream to downstream) Pensacola Dam, Kerr Dam, and Fort Gibson Dam because these operate as a subsystem for reservoir level balancing. The FRM is needed to investigate hypothetical events and operating scenarios that would be difficult and time-consuming to program into the RWM.

3.1 Input Data

Input data for the FRM includes river discharge upstream of Pensacola Dam, local inflows to each reservoir, evaporation and seepage rates, reservoir stage-storage-area tables, reservoir operating level tables, maximum regulated spill tables, induced surcharge tables, seasonal Project target reservoir elevation table, and hydrologic routing coefficient tables from the RWM.

3.2 Methodology

The FRM was developed using Visual Basic for Applications (VBA) code within an Excel spreadsheet. The VBA code loops through the time series calculations to solve the model. The VBA code computes formulas to calculate the system state and flow routing decisions for each daily time step, then copies the formulas to the next daily time step and stores the results as plain text in the Excel spreadsheet. In this way, the file size is reduced, and the computation speed improved. The VBA code also dynamically updates a table that relates the operating balance level at Pensacola to the seasonal target elevation and corresponding flood pool elevations and volumes based on the current solution day.

Minimum surcharge and maximum regulated outflows are calculated individually for each dam from upstream to downstream. Operating levels are balanced upstream to downstream and highest to lowest, within calculated outflow limits. Individual dam and Lower Grand (Neosho) subsystem limits are checked. Conservation pool rules and hydropower rules are ignored for purposes of flow routing. Modeled objects include reservoirs, control points, and reaches.

Methods from the RWM replicated in the FRM include:

- Flow combined at nodes and routed downstream hydrologically.
- Evaporation calculated using historical evaporation rates considering modeled reservoir area.
- Constant seepage assumed: 10 cubic feet per second (cfs) at Kerr Dam and 20 cfs at Fort Gibson Dam.
- Minimum surcharge and maximum regulated outflow calculated using the USACE SWT flat top surcharge method.
- Allowable rising release change and allowable falling release change limit how quickly the controlled releases are increased or decreased, subject to other limitations such as minimum surcharge.
- Operating level balancing seeks to maintain similar balance levels in each reservoir.
- Regulating discharges of 100,000 cfs established in the water control manual are considered for Pensacola Dam, Kerr Dam, and Fort Gibson Dam (USACE, 1980).

4. Operations Model

Mead & Hunt developed an OM to simulate flow routing, hydropower scheduling, and other Project constraints on an hourly time step. Because electricity prices vary widely within a day, hourly time steps provide improved accuracy for hydropower operations simulation. The OM was developed using VBA code within an Excel spreadsheet, as described in more detail below.

4.1 Input Data and Preparation

Mead & Hunt obtained data for the OM from GRDA and USACE. Input data includes project drawings, rating curves, time series data, and information from the RWM. Most of the time series data was available in hourly or sub-hourly time steps from April 1, 2004 through December 31, 2019 (the end date in the RWM), so this period was selected for analysis. Descriptions and sources of each input data set are described below, along with descriptions of the methods used to prepare the data for input to the OM. **Appendix B** contains a collection of the information described in this section.

4.1.1 Headloss vs. Turbine Discharge

GRDA sent Mead & Hunt drawings of the Pensacola and Kerr hydroelectric facilities showing the dimensions of the water passages from the intake to the tailrace at each powerhouse (GRDA, 1961), (GRDA, 1987). The dimensions shown on these drawings were used to estimate the hydraulic friction and form losses as part of the turbine net head calculation.

Facility drawings for the Pensacola and Kerr facilities were used to identify specific friction loss (i.e., conduit roughness) and minor loss (e.g., bends, contractions, or entrance and exit losses) components between the reservoirs and the turbines. It is common practice for turbine manufacturers to include the hydraulic losses from the scroll case entrance through the tailrace in the turbine hill curve efficiencies, so these losses were specifically excluded from the headloss calculations.

Total headloss was calculated using a combination of the Darcy-Weisbach formula for friction losses and assumed minor loss coefficients. To simplify spreadsheet calculations, major and minor losses are expressed in terms of a flow-based headloss coefficient, Kq, according to the equations below:

$$H_L = Kq * Q^2$$

$$Kq = \frac{0.025 * f * L}{{D_h}^5}$$

$$Kq = \frac{Kv}{2gA^2}$$

where:

H_L = headloss (ft)

Kq = flow-based headloss coefficient

Kv = velocity-based headloss coefficient

Q = turbine discharge (ft^3/s)
L = pipe length (ft)
f = Darcy-Weisbach resistance coefficient
D_h = Hydraulic diameter (ft)
A = pipe wetted area (ft^2)
g = gravity constant (32.146 ft/s^2)

The resistance coefficient varies with pipe size, pipe roughness, fluid kinematic viscosity, and discharge. Resistance coefficients were determined based on the following equations, which approximate the curves of the Moody Diagram.

Von Karman-Prandtl equation for smooth pipe flow:

$$\frac{1}{\sqrt{f}} = 2\log_{10}\left(Re\sqrt{f}\right) - 0.8$$

$$Re{=}D_h V \nu$$

where:
Re = Reynold's Number
V = average velocity (ft/s)
ν = kinematic viscosity of fluid (ft^2/s)

Von Karman-Prandtl equation for rough pipe flow:

$$\frac{1}{\sqrt{f}} = 2\log_{10}\frac{D_h}{2k} + 1.74$$

where:
k = absolute roughness of pipe wall (ft)

Colebrook-White equation for transition flow:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{k}{3.7D_h} + \frac{2.51}{Re\sqrt{f}}\right)$$

Friction losses for Pensacola were calculated assuming water at 50° F, roughness of 0.00015 feet (steel), and acceleration due to gravity of 32.146 ft/s^2. Minor loss coefficients were selected using the appropriate Hydraulic Design Criteria charts (USACE, 1987).

The total calculated flow-based headloss coefficient (Kq) for Pensacola was 4.50×10^{-7}, and for Kerr was 4.11×10^{-9}.

4.1.2 Stage-Area-Storage Tables

For model validation purposes, reservoir stage-area-storage tables for Pensacola and Kerr from the RWM were used in the OM. As discussed in **Section 5.4.4**, other more recent bathymetric survey data were incorporated post-validation to improve later simulations (Dewberry, 2011), (Hunter, Trevisan, Villa, & Smith, 2020).

4.1.3 Turbine Efficiency

Pensacola

Efficiency curves for the Pensacola generators were transcribed from the Siemens efficiency calculations (Siemens, 1999) in terms of generator efficiency vs. percent rated generator load, assuming rated brake power of 18,112 kilowatt (kW) at 0.90 power factor.

Efficiency vs. turbine discharge vs. net head curves for the Pensacola turbines (air valves closed condition) were transcribed from the Voith hill curve (Voith, 1997). Efficiency curves for the condition when the dissolved oxygen (DO) air valves are fully open were transcribed from the Accusonic Unit 3 preliminary performance test report (Walsh, 1999).

Two efficiency curves were developed for Pensacola: one for normal operation with all the DO air valves closed, and one for derated operation with all the DO air valves fully open (90 degrees open).

The normal operation turbine efficiency vs. turbine discharge vs. net head curve was transcribed from the Voith hill curve into an Excel spreadsheet table. The generator efficiency vs. load curve was then multiplied by the turbine efficiencies to develop a total turbine-generator efficiency vs. discharge vs. net head table.

The derated operation (air valves open) turbine efficiencies at a net head of 117.5 feet were transcribed from the Accusonic report. The ratio of derated turbine efficiency to normal turbine efficiency for a given turbine discharge was assumed to be constant across the entire range of net head values used (95 feet to 140 feet). After extrapolating the derated turbine efficiencies, the generator efficiency vs. load curve was again applied to develop a total turbine-generator efficiency vs. turbine discharge vs. net head table for derated operation.

Kerr

Efficiency curves for the Kerr generators were transcribed from the table in Section 2.3.1 of the Alstom generator calculations (Bertrand, 2009) in terms of generator efficiency vs. percent rated generator load, assuming rated brake power of 33,036 kW at 0.93 power factor.

Power vs. turbine discharge vs. net head curves for the Kerr turbines (pre-refurbishment) were transcribed from the original 1962 prototype unit curves (EEC, 1962a). Relative turbine efficiencies for the Kerr turbines (post-refurbishment) were transcribed from the Alstom index test results (Alstom, 2010).

The efficiency curves for Kerr were developed based on the original 1962 prototype efficiency curve and the 2010 post-refurbishment index testing. The total turbine-generator efficiency vs.

turbine discharge vs. net head table for the original units was developed using a similar methodology as for Pensacola. Alstom reported index test results as a relative turbine efficiency (refurbished units relative to the original 1962 prototype units) vs. refurbished turbine power at a net head of 56 feet. Index efficiencies were applied across the entire domain of the original hill curve by multiplying the relative efficiency at an equivalent discharge by the maximum original turbine efficiency value at each net head.

4.1.4 Turbine Maximum Discharge

The maximum allowable turbine discharge (to avoid cavitation) vs. net head limit for Pensacola was determined from the entrance edge cavitation lines on the Voith hill curve (Voith, 1997). The maximum turbine discharge vs. net head limit for Kerr was determined from the limit of Kaplan operation line on the original 1962 prototype unit curves (EEC, 1962b).

4.1.5 Tailwater Rating Curves

The tailwater (TW) elevation vs. total discharge rating curve for Pensacola Dam was developed based on the historical observed TW elevation and discharge paired data provided by GRDA. The elevation-discharge data pairs were plotted, and a table of paired values was developed based on a best fit through the observed points.

The TW elevation vs. total discharge rating curve for Kerr Dam was developed using USGS gage data: Neosho River near Langley, OK (USGS Gage No. 07190500). The gage data pairs were plotted, and a table of paired values was developed based on a best fit through the gage data points.

4.1.6 Unit Outages

Individual turbine unit outages are recorded in terms of the start and end date/time of each outage. The outages can be either scheduled or unscheduled, and the type of outage can be forced, planned, maintenance, or de-rated generation output (e.g., DO air valve operation at Pensacola).

Records of the date and time for the beginning and ending of outages for individual turbine-generator units were used to construct time series of unit outages. Overlapping outages were reconciled when the beginning or ending timestamp of a listed outage fell within the timeframe of another outage for the same unit. An hourly time series was constructed to indicate the status of each individual unit (online or offline) for each time step. Lastly, the total number of units online for each time step at each facility was determined. This data was used by the OM to determine the total turbine discharge capacity available for a given time step.

4.1.7 Dissolved Oxygen Air Valves

Dissolved Oxygen data, including measured DO levels and the status of each of the six Pensacola DO air valves, was available between January 1, 2004 and April 13, 2006 (non-contiguous data). Oklahoma Water Resources Board Title 785.45-5-12 describes seasonal DO concentrations needed to support various subcategories of Fish and Wildlife beneficial use designations for streams (OAC, 2013). The prescribed seasonal DO concentrations were considered along with records of measured DO concentrations and individual air valve status from Pensacola to estimate when the air valves may have typically been opened during the modeled period of analysis, as described below. The model accounts for the status of the air valves by switching between two different turbine efficiency curves to represent the decrease in turbine efficiency when the air valves are open.

For Pensacola, the prescribed seasonal DO concentrations were considered along with records of DO levels; individual air valve status; actual generation output; and head, efficiency, and flow data to estimate when the air valves may have typically been opened during the modeled period of analysis. There are no DO air valves at Kerr.

4.1.8 Electricity Prices

Hourly day-ahead and real-time locational marginal prices (in terms of dollars per megawatt-hour [MWh]) for electrical energy produced at Pensacola and Kerr were available from March 1, 2014 to December 31, 2020.

Daily natural gas settlement prices for the Henry Hub trading point were available from March 1, 2004 through December 31, 2020. Natural gas prices were used to index the electricity prices across the full range of analysis dates.

Hourly electricity prices for both day-ahead and real-time markets over the period between March 1, 2014 and December 31, 2020 were divided by the corresponding daily natural gas price to determine the hourly heat rate pattern for this period. This heat rate pattern was then applied to corresponding dates when no hourly electricity prices were available (prior to March 1, 2014). The assumed hourly heat rate was then multiplied by the actual daily historical natural gas settlement prices going back to April 1, 2004 to estimate the historical electricity prices for the period when actual hourly data was not available.

4.1.9 Spillway Capacity

USACE spillway discharge capacity ratings were reviewed for Pensacola and Kerr, but for the purposes of model validation the rating tables from the RWM will be used instead (USACE, 1990), (USACE, 1991).

4.2 Methodology

The objective function of the OM is to maximize the hydropower generation revenue at each facility while simultaneously satisfying various physical and operational constraints (e.g., reservoir level management, flow routing from the FRM, scheduling of power sales, and operation of the turbines within their allowable range). Many dependent functions comprise the overall objective function and are summarized here:

- Total discharge computed by the FRM is also used by the OM when the reservoir transitions into flood operations, which occurs when the pool is more than 0.5 feet from the target elevation. Otherwise, for normal operations, discharge is determined based on optimal hydropower generation scheduling.
- Modeled revenue is a function of scheduled power and electricity price (both day-ahead and real-time).
- Power is a function of turbine discharge, net head, and total turbine-generator efficiency.

- Net head is a function of headwater, tailwater, and headloss.
- Efficiency is a function of turbine discharge, net head, and DO air valve open/closed status (Pensacola only).
- Turbine discharge is a function of best efficiency point discharge, maximum allowable discharge (avoiding possible cavitation), current reservoir storage volume, forecast inflow volume, electricity price, production cost, the number of units online.
- Reservoir storage volume is a function of inflow, turbine discharge, spillway discharge, evaporation, and seepage (Kerr only, no seepage at Pensacola in RWM).
- Other parameter dependencies have been discussed in the description of the input data preparation in **Section 4.1**.

The OM is driven by VBA code to do two things: 1) solve an iterative loop for the net head values, and 2) step through the time series one day at a time. The Excel spreadsheets contain formulas to optimize the hydroelectric operations for a 24-hour period. The VBA code copies the formulas down from one day to the next as each 24-hour period is solved, preserving the solution values. In this way, the Excel spreadsheets are kept to a manageable size and overall calculation speed is improved.

At the beginning of the solution for a given 24-hour period, an estimated value for net head at each hourly time step is assumed (final values from one day are copied down to the next day to provide the first estimated value). The net head is used to calculate various parameters related to the turbine and spillway discharge, which in turn are used to calculate the TW elevation and headloss, which are then used to calculate the next estimated value for net head.

Each scenario model is solved first for Pensacola. The resulting total discharge (turbines plus spillway) from Pensacola is then hydrologically routed downstream to Kerr Dam in a manner consistent with the RWM hydrologic routing. The routed Pensacola Dam discharge for the given scenario, plus tributary inflows to Lake Hudson, are then combined and copied as inflow to the OM for Kerr.

Hourly time series data produced in the OM includes reservoir elevation, turbine discharge, spillway discharge, net head, power (scheduled day-ahead, real-time buy-back, real-time scheduled, and total), and revenue (day-ahead sales, buy-back cost, real-time sales, and total).

5. Validation

Model variables used to validate performance of the OM and FRM against the RWM output included total discharge from a reservoir and elevation of a reservoir. Reservoir storage and balance level were also available as validation parameters but were simple corollaries for elevation. Because elevation is a more intuitive parameter for understanding the system state, it was used rather than the other corresponding parameters.

The date range for OM validation was April 1, 2004 to December 31, 2019. This was the overlapping date range for which data were available from the RWM and when hourly data were available for the OM. The FRM was validated against the RWM using results as far back as 1940.

Performance metrics included the Coefficient of Determination (R^2) and the Nash-Sutcliffe Efficiency (NSE). R^2 is an index of the degree of linear relationship between source and simulated data. R^2 represents correlation between models and dispersion of data relative to that correlation. It does not evaluate accuracy, only correlation. NSE is an index of how well the source versus simulated data fits a perfect 1:1 correlation slope line. Plotting on a 1:1 line indicates consistent prediction at lower and higher values. However, NSE is more sensitive to extreme values. Formulas for R^2 and NSE are available in literature and given below for reference. The optimal value for both metrics is 1. For R^2, the optimal trendline intercept is 0,0 and the optimal trendline slope is 1. **Table 1** lists qualitative ranges for evaluating model validation using these metrics (Moriasi, Gitau, Pai, & Daggupati, 2015).

$$R^2 \quad \left[\frac{\sum_{i=1}^{n}(O_i-\bar{O})(P_i-\bar{P})}{\sqrt{\sum_{i=1}^{n}(O_i-\bar{O})^2}\sqrt{\sum_{i=1}^{n}(P_i-\bar{P})^2}}\right]^2$$

$$\text{NSE} \quad 1-\frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(O_i-\bar{O})^2}$$

Table 1. Summary of Performance Metrics

Metric	Range	Not Satisfactory	Satisfactory	Good	Very Good
R^2	0 to 1	≤ 0.60	0.60 to ≤ 0.75	0.75 to ≤ 0.85	> 0.85
NSE	-∞ to 1	≤ 0.50	0.50 to ≤ 0.70	0.70 to ≤ 0.80	> 0.80

Validation of the OM against the RWM output was performed using similar inputs as the RWM for historical discharge, evaporation, seepage, stage-storage-area tables, reservoir operating level tables, maximum regulated spill tables, induced surcharge tables, the seasonal Project target reservoir elevation table, and hydrologic routing coefficient tables. Following validation, some of these inputs were updated and expanded to meet the needs of the study, as discussed in **Section 5.4**.

5.1 Validation Results: Flood Routing Model

The first step in model validation was comparison of the FRM to the RWM results. The FRM was validated against the RWM results for the entire RWM period of record, which is Jan 1, 1940 through December 31, 2019 as shown in **Figure 4** below.

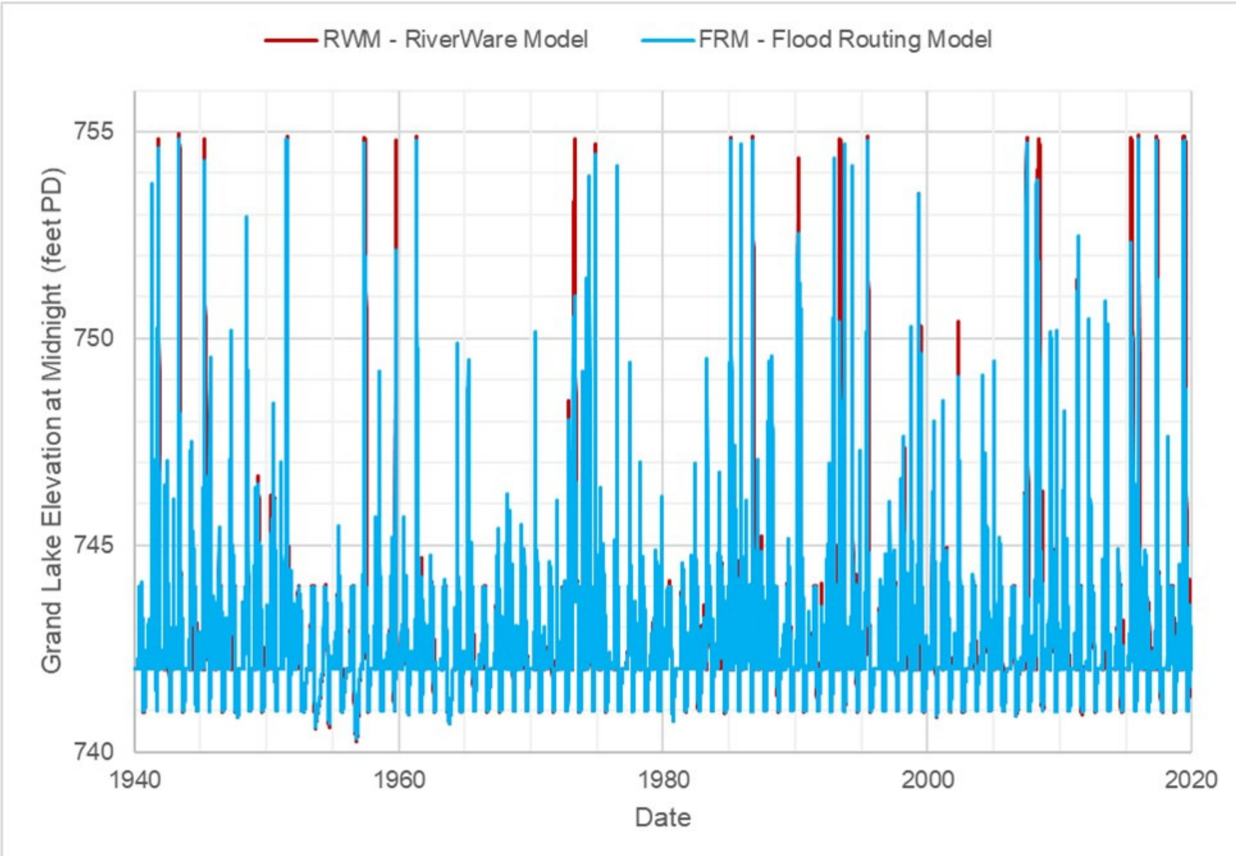


Figure 4. Flood Routing Model Validation Period of Record

The FRM simulates many of the rules and constraints in the RWM, with a notable exception: the FRM cannot account for operating level balancing due to the flow restriction at Van Buren, because it is outside the study area. The allowable maximum discharge at Van Buren is a function of the time of year and the amount of basin storage currently utilized at upstream reservoirs, as shown in **Figure 5**[1].

[1] Copy of Plate 7-58 from (USACE, 1980).

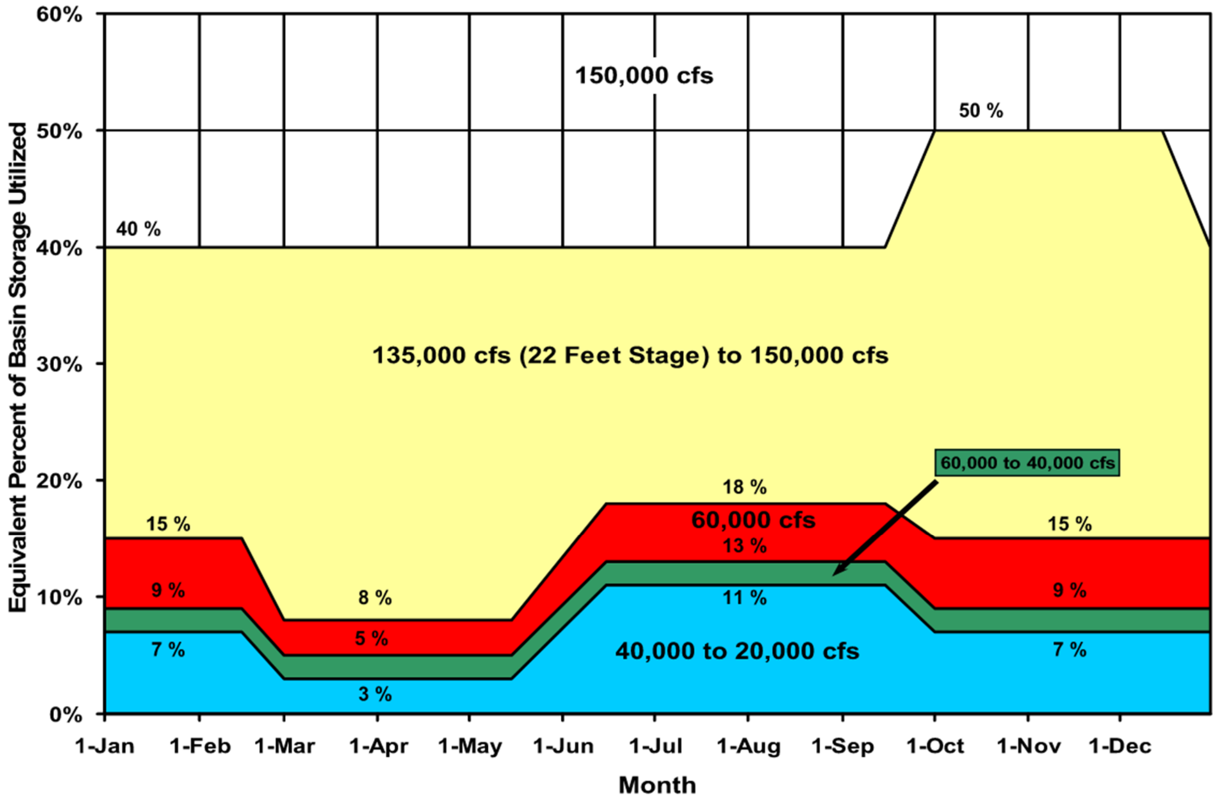


Figure 5. Van Buren Guide Curve

The RWM will sometimes hold the pool higher for extended periods at both Pensacola and Kerr to help manage the discharge at Van Buren. This can result in what appears to be underprediction of peak stages by the FRM on the correlation plots but is more often an underprediction of the duration of those peak stages, as illustrated in **Figure 6** below for the July 2007 event. The modeled peak stages were similar between the FRM and RWM for this event, but the FRM returned the pool to the normal elevation sooner than the RWM. The Van Buren Percent Full Regulation Parameter exceeded 90% for this event, resulting in significant outflow restrictions at upstream dams in the RWM, including at Pensacola and Kerr. Those restrictions were not present in the three-reservoir FRM, and therefore the pool was returned to the normal level soon after the peak inflows subsided. This resulted in a difference between the RWM and FRM stages up to about nine feet for several days, which had the effect of decreasing the correlation metrics.

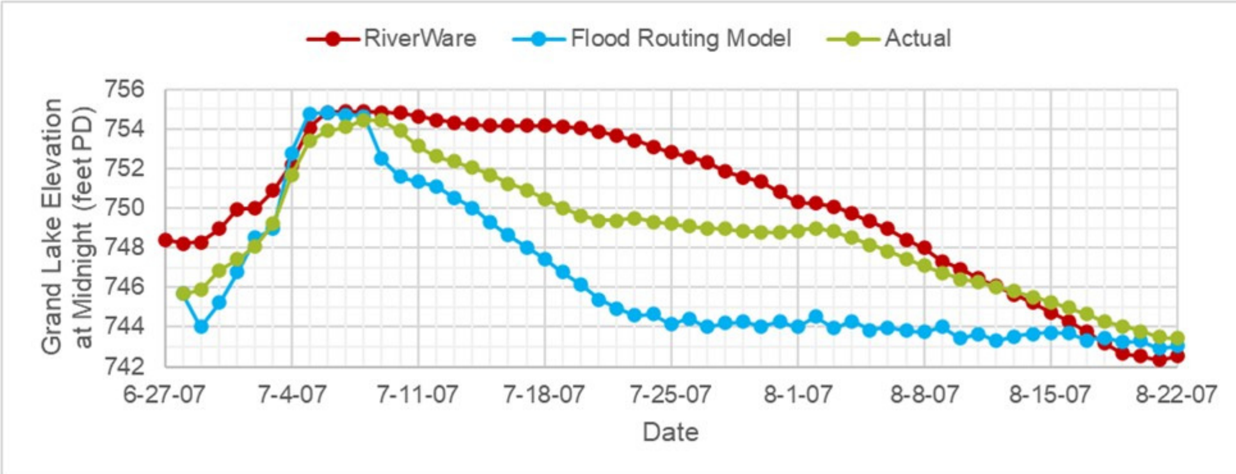


Figure 6. Modeled July 2007 Pensacola Elevations

Another feature of the RWM which decreases the correlation of the models is time step oscillation. As the model shifts between different operating rules at threshold pool levels (i.e., top of conservation pool), and as the total system state changes over time, the decision-making of the model can result in fluctuations from one daily time step to the next. For example, an increased discharge at one time step can increase the downstream reservoir level, resulting in an increased operating balance level and forcing a lower discharge at the next time step, and so on. **Figure 7** illustrates this effect as it occurs in both the RWM and FRM.

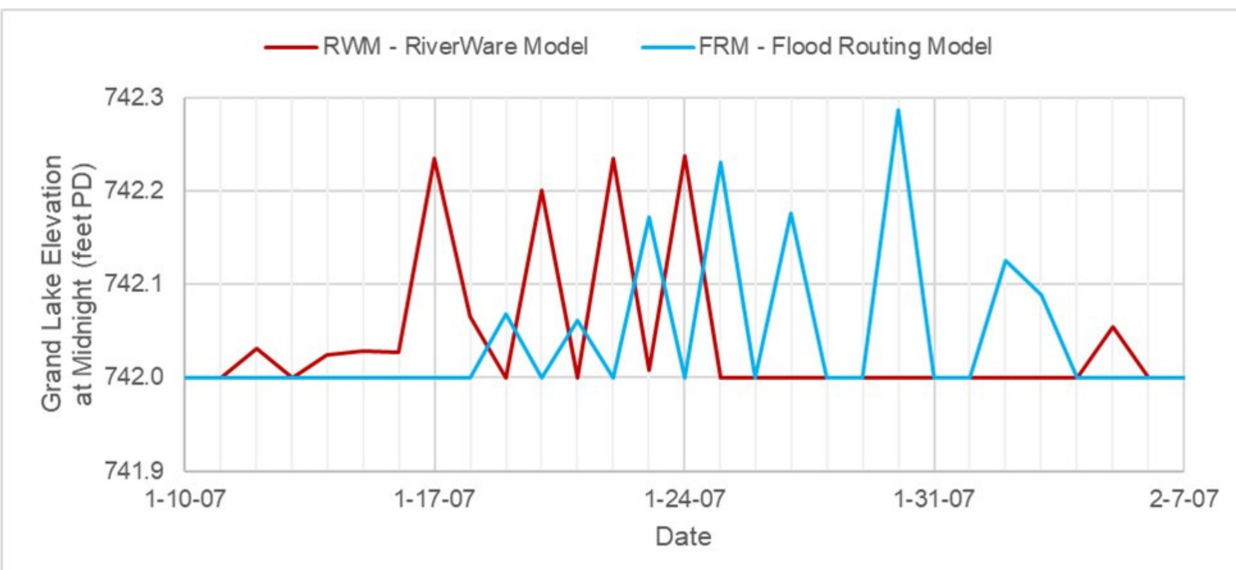


Figure 7. RiverWare vs. Flood Routing Model Oscillation Comparison

Time step oscillation can decrease the apparent correlation between the models, especially when the oscillation happens to begin at different time steps between the two models, so that one model is decreasing while the other is increasing. In order to obtain a clearer comparison between two models, the effect of time step oscillation must first be removed by time-averaging across two daily model time steps. This was done for both models before computing the correlation, and effectively mitigated the problem of oscillation on the model timestep-scale.

Figure 8 and **Figure 9** show the RWM vs. FRM validation plots for Pensacola and Kerr, respectively. The validation metrics are summarized in **Table 2** below.

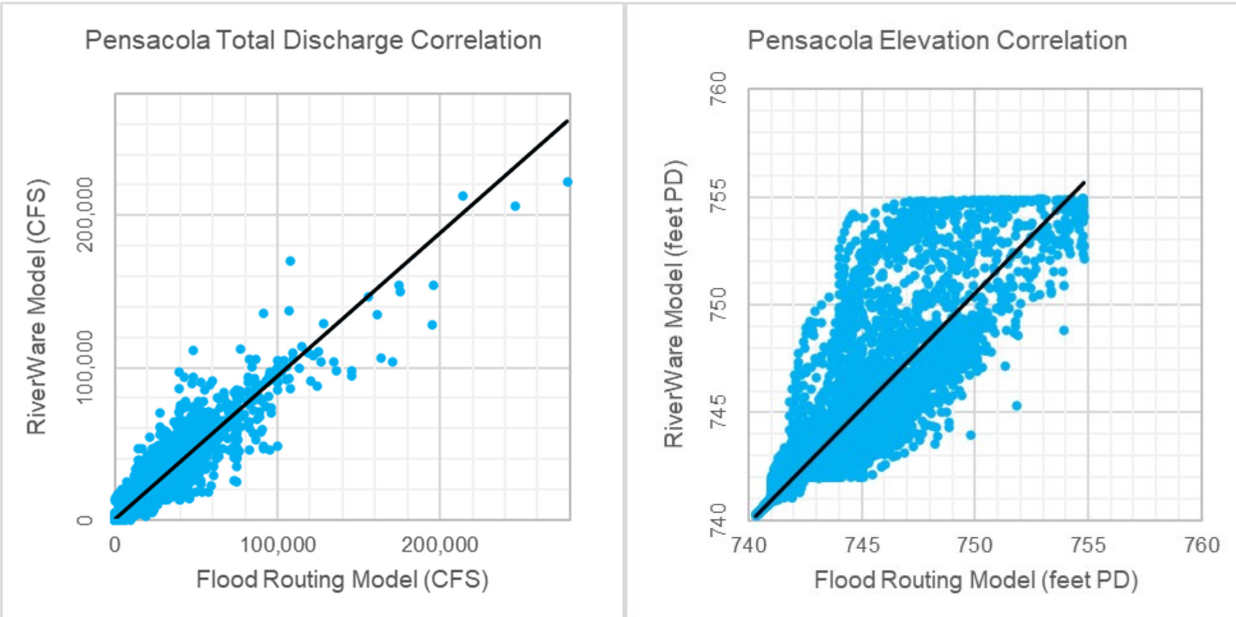


Figure 8. RiverWare Model vs. Flood Routing Model Correlation Plots at Pensacola

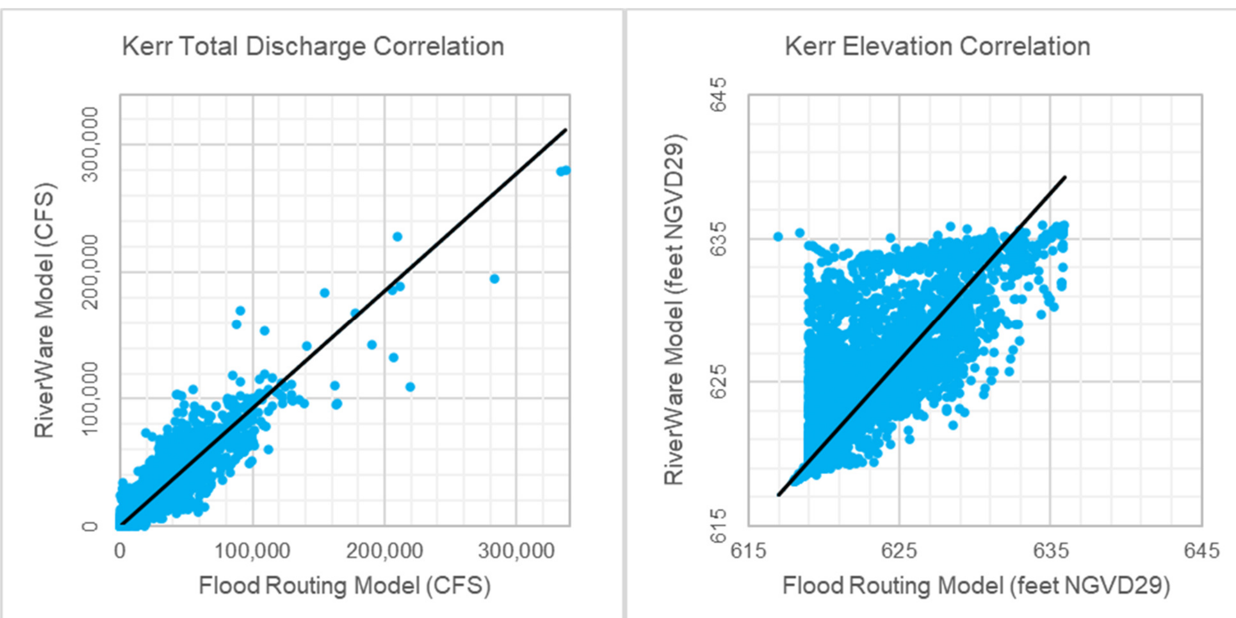


Figure 9. RiverWare Model vs. Flood Routing Model Correlation Plots at Kerr

Table 2. RiverWare Model vs. Flood Routing Model Validation Results

	Pensacola		Kerr	
	Discharge	Elevation	Discharge	Elevation
NSE	0.89 (Very Good)	0.81 (Very Good)	0.87 (Very Good)	0.68 (Satisfactory)
R^2	0.90 (Very Good)	0.81 (Good)	0.88 (Very Good)	0.752 (Good)

5.2 Validation Results: Operations Model

The OM was validated against the RWM results for the period for which hourly data was available for the OM, which is April 1, 2004 through December 31, 2019 as shown in **Figure 10** below.

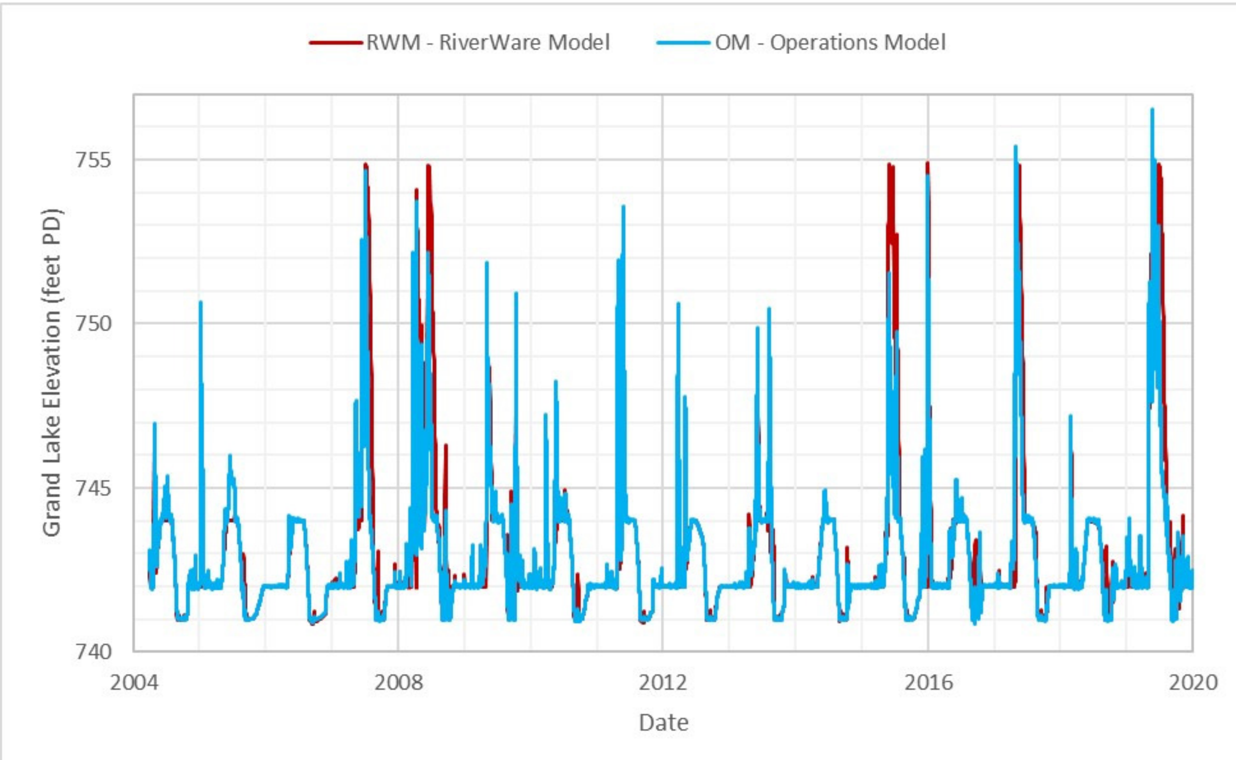


Figure 10. Operations Model Validation Period of Record

The OM builds on the flow routing decisions from the FRM by superimposing hydropower optimization logic onto the total discharge prescribed by the FRM. In order to link the OM to the FRM, a transition must take place between normal low-flow operations, when the hydropower optimization takes precedence, and higher-flow events, when the FRM-predicted releases take precedence. At the time of model validation, this transition was assumed to occur when the current elevation in the OM deviated more than 0.5 feet from the target elevation. When this occurred, the OM attempted to match the total discharge prescribed by the FRM until the pool again returned to within 0.5 feet of the target elevation. This was a simplified approach to linking the models for validation purposes and has since been improved, as discussed in **Section 5.4.3**. Because of this additional degree of separation, the validation results were slightly lower for the RWM vs. OM comparison, shown in **Figure 11** and **Figure 12** and summarized in **Table 3**.

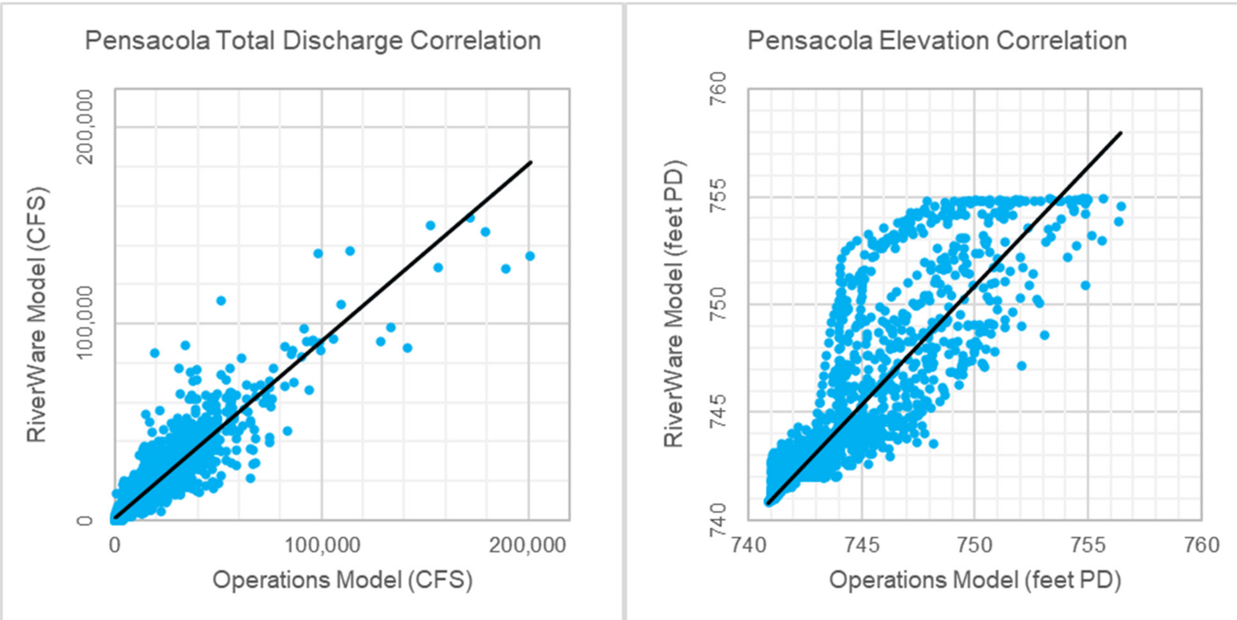


Figure 11. RiverWare Model vs. Operations Model Correlation Plots at Pensacola

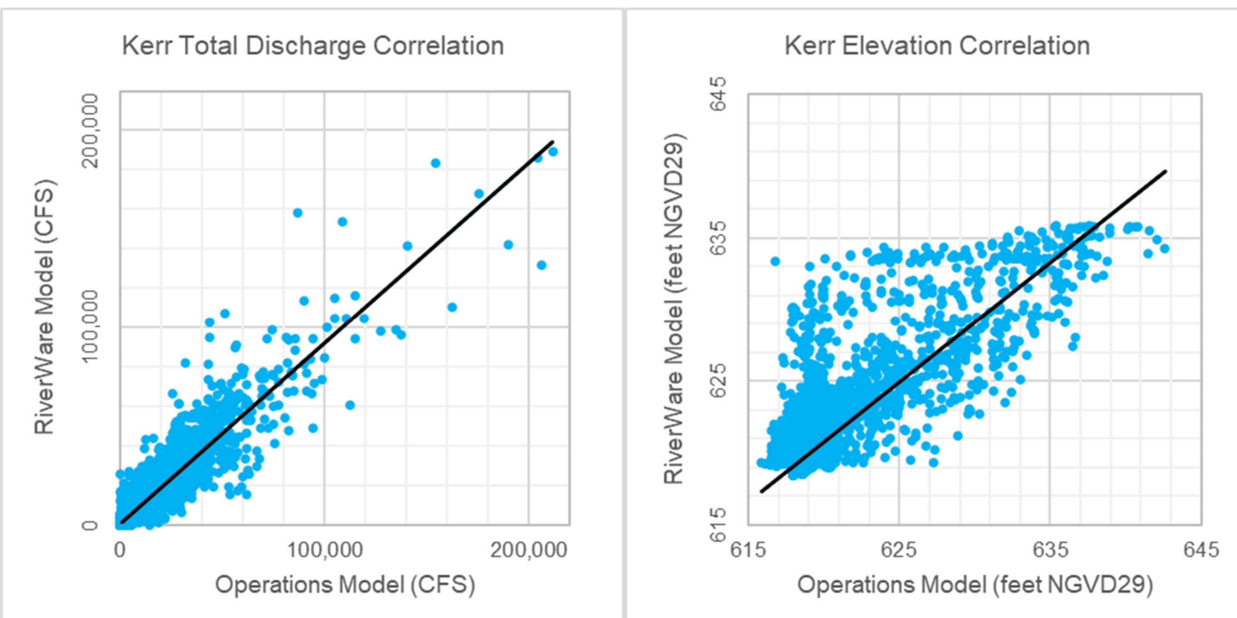


Figure 12. RiverWare Model vs. Operations Model Correlation Plots at Kerr

Table 3. RiverWare Model vs. Operations Model Validation Results

	Pensacola		Kerr	
	Discharge	Elevation	Discharge	Elevation
NSE	0.87 (Very Good)	0.80 (Very Good)	0.87 (Very Good)	0.61 (Satisfactory)
R^2	0.86 (Very Good)	0.81 (Good)	0.86 (Very Good)	0.69 (Satisfactory)

Despite the aforementioned limitations of the RWM, which has been replicated in the FRM with only three reservoirs while incorporating detailed hourly hydropower optimization calculations in the OM, the validation metrics are in the range of satisfactory to very good. Therefore, the models have been validated against the RWM results and the study has since proceeded to improve the model inputs and logic beyond the limitations of the RWM, as discussed in **Section 5.4** below.

5.3 Validation Against USGS Gage Data

In its February 22, 2022 determination, FERC recommended that GRDA compare water surface elevations observed at the USGS gage on the upstream side of the dam to the simulated HEC-RAS stage hydrographs for the December 2015 and October 2009 inflow events and provide a graphical comparison of the simulated and observed water surface elevations over a daily time step for the duration of each flood event. GRDA included the FERC-requested comparison in this OM report because the HEC-RAS stage hydrographs at the dam are calculated by the OM.

Because the RWM and FRM do not reflect actual real-time decisions during past inflow events, but rather initial planning-level flow routing decisions, GRDA used the historical records of spillway gate openings to simulate operations for these two historical validation simulations. The reservoir inflow hydrographs for the December 2015 and October 2009 inflow events were back-calculated using GRDA's records of Project discharge and reservoir elevation and the stage-storage table from the 2019 USGS bathymetry survey. The USACE discharge rating for the spillway gates was used to calculate the spillway discharge for each time step based on the gate openings and the OM-simulated reservoir level. The OM made hydropower generation decisions as for the other simulations, but the spillway discharge was calculated using the historical spillway gate openings, which were set in response to USACE directives when the reservoir level was above, or expected to go above, Elevation 745 feet PD. The OM reservoir level simulated showed very good agreement with the observed USGS gage No. 07190000 data, as shown in **Figure 13** and **Figure 14**.

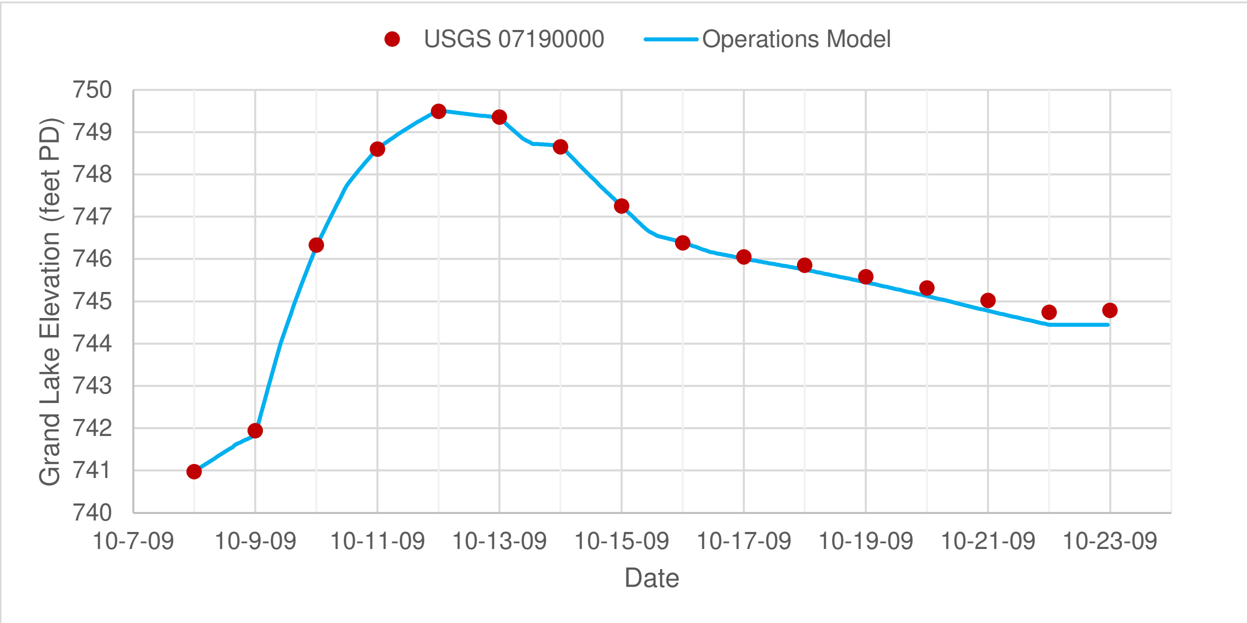


Figure 13. Validation Against USGS Gage Data, October 2009

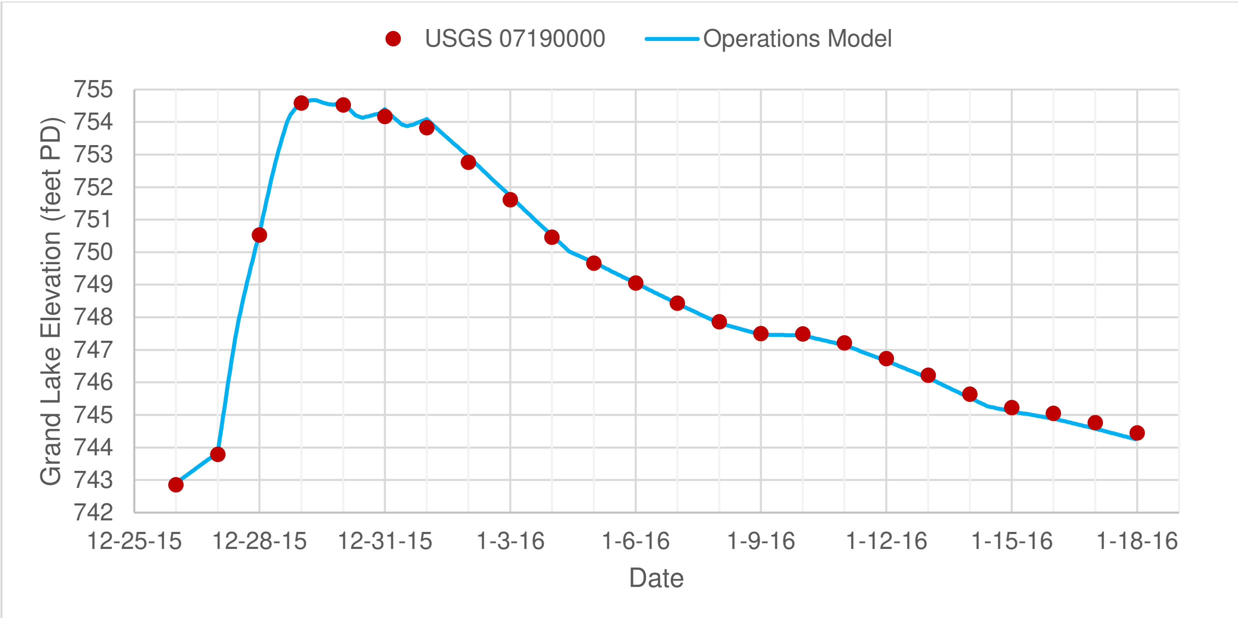


Figure 14. Validation Against USGS Gage Data, December 2015

5.4 Post-Validation Model Improvements

Following model validation, improvements were made to address known issues, as discussed below.

5.4.1 Flood Routing Model Ramping Rate Restrictions

In addition to the period-of-record model used to validate the FRM against the RWM results, various single-event simulations were previously computed to provide inputs to the CHM, as discussed below. One of those single-event simulations included a synthetic 100-year event, the development of which is documented in the USR report. It was noted that for the 100-year event simulation, the FRM caused the pool at Pensacola to drop below the target elevation on the falling limb of the hydrograph. This occurred because the RWM allowable falling release change (AFRC) of 99,174 AF/day disrupted the flow routing logic and resulted in too much discharge as the pool approached the target elevation. The AFRC does not typically interfere in this way for Pensacola, but the steeply falling discharge hydrograph of the hypothetical 100-year event simulation caused it to behave differently than for historical events. This issue was observed to affect the results for Kerr in some historical events, in addition to the 100-year event simulation.

This issue was corrected by adding logical checks to ensure that the target elevation would take precedence over the AFRC criterion.

5.4.2 Operations Model Turbine Shutoff Compensation

When power prices on the day-ahead market were positive, the OM scheduled the turbines to generate. If this occurred during a high-flow event, the OM subtracted the scheduled turbine discharge from the total discharge prescribed by the FRM when calculating the spillway discharge needed for that day. The spillway discharge was assumed to be constant for each day. If the power prices on the real-time market dropped below the production cost or went negative, the OM would buy back the scheduled generation, which resulted in total discharge less than the average prescribed by the FRM for that day. This resulted in pool levels increasing above those predicted by the FRM in some cases.

This issue was corrected by allowing the spillway discharge to adjust on an hourly time step to compensate when the turbines shut down due to unprofitable market conditions.

5.4.3 Flood Routing Model Stage Matching

Total discharge computed by the FRM was also used by the OM when the reservoir transitioned into flood operations, which was assumed to occur when the current elevation in the OM drifted more than 0.5 feet from the target elevation. When this occurred, the OM attempted to match the total discharge prescribed by the FRM until the pool again returned to within 0.5 feet of the target elevation. Different initial conditions, such as alternative assumed starting elevations, in some cases resulted in inconsistencies in reservoir elevation for two simulations of the same event which continued throughout the peak of the event.

This issue was corrected by adding criteria for the OM to gradually bring the reservoir elevation back in line with the FRM results when the pool is in flood stage. Because most of the rules and constraints in the RWM relate to discharge, not stage (e.g., AFRC, spillway minimum surcharge, spillway maximum regulated discharge, downstream channel regulating discharges), the OM was originally set up to match discharge and not stage. The methodology used to constrain the OM to the FRM using both discharge and stage strikes a balance between attempting to match peak stages and keeping as closely aligned as possible to the discharge-related limitations in the RWM.

The criteria used to implement this solution included a two-step adjustment:

1. First, the model used the projected midnight reservoir level in the case of no spill to compute a ratio (FRM discharge vs. elevation ratio) to bring the OM back in line with the FRM discharge and/or elevation results based on a sliding scale:
    a. If the projected midnight reservoir level with no spill was below the midnight target elevation, then the FRM total discharge result was maintained (FRM discharge vs. elevation ratio = 1).
    b. If the projected midnight reservoir level with no spill was between the midnight target elevation and the top of flood pool (Elevation 755), then a ratio was assigned based on linearly interpolated storage values corresponding to those elevations (1 > FRM discharge vs. elevation ratio > 0).
    c. If the projected midnight reservoir level with no spill was at or above the top of flood pool (Elevation 755), then the FRM elevation result was maintained (FRM discharge vs. elevation ratio = 0).
2. Second, the magnitude of the adjustment used to match the FRM total discharge result was also computed as a ratio (FRM discharge multiplier) between 0 and 1 based on the difference in elevation between the projected midnight reservoir level in the case of no spill and the midnight target elevation:
    a. For differences less than 0.25 feet, no adjustment was made to spill discharge based on the FRM total discharge result (FRM discharge multiplier = 0).

b. For differences between 0.25 and 0.5 feet, the ratio was linearly interpolated by elevation between 0 and 0.75 (0 < FRM discharge multiplier < 0.75).
c. For differences between 0.5 and 0.75 feet, the ratio was linearly interpolated by elevation between 0.75 and 1 (0.75 < FRM discharge multiplier < 1).
d. For differences of 0.75 feet or more, the entire adjustment for matching FRM total discharge was used (FRM discharge multiplier = 1), but the OM spill discharge could still be adjusted down based on the FRM discharge vs. elevation ratio discussed above.

The final calculation to determine the spillway discharge at each time step was:

$$Q = a*Qq + (1-a)*(b*Qe)$$

where:
- Q = spillway discharge for OM time step (cfs)
- Qq = OM spillway discharge needed to match total discharge of FRM (cfs)
- Qe = OM spillway discharge needed to match midnight elevation of FRM (cfs)
- a = FRM discharge vs. elevation ratio ($0 < a < 1$)
- b = FRM discharge multiplier ($0 < b < 1$)

This approach allows the OM to optimize operations freely when the reservoir is within the conservation pool, and gradually shift to matching the FRM results as the reservoir begins to climb into the flood pool.

The cumulative result of the model improvements described above is more consistent in matching OM results to the FRM results during large events.

5.4.4 Updated Stage-Area-Storage Table

The Grand Lake stage-area-storage table used for the FRM and OM was updated following validation to use the data developed by USGS in 2019 and 2020 (Hunter, Trevisan, Villa, & Smith, 2020). The USGS data was interpolated at half-foot intervals and linearly extrapolated to Elevation 780. In response to stakeholder comments following the ISR, GRDA performed a sensitivity analysis of the OM to evaluate the impacts of the updated stage-area-storage table on computed reservoir level.

The OM results using the 2019 bathymetry data were very similar to the OM results using the RWM stage-area-storage table. **Table 4** compares reservoir level metrics for the hourly POR and for individual flow events that occurred within the POR. Differences are small and within the range of model oscillation typical for the RWM and FRM. The RWM and FRM make flow routing decisions based on key elevations, not fixed values of storage, so it is unsurprising that the results were similar after updating the stage-area-storage table. Therefore, the updated stage-area-storage table was used in the study.

Table 4. Sensitivity Analysis Results for Stage-Area-Storage Update

Sensitivity Parameter	RWM Stage-Storage Table	2019 Stage-Storage Table	Difference (feet)
POR Average (Mean) Grand Lake Elevation (feet PD)	742.87	742.86	0.01
POR Median Grand Lake Elevation (feet PD)	742.05	742.04	0.01
POR Minimum Grand Lake Elevation (feet PD)	740.87	740.88	0.01
POR Maximum Grand Lake Elevation (feet PD)	754.82	754.82	0.00
Peak Grand Lake Elevation (feet PD), June 2004 (1 year)	744.87	744.83	0.04
Peak Grand Lake Elevation (feet PD), July 2007 (4 year)	754.74	754.73	0.01
Peak Grand Lake Elevation (feet PD), Oct 2009 (3 year)	750.21	750.04	0.17
Peak Grand Lake Elevation (feet PD), Dec 2015 (15 year)	754.82	754.82	0.00

6. Scenarios Computed for H&H and Sedimentation Studies

The OM provides stage and discharge hydrograph inputs to other components of the hydrologic and hydraulic modeling study (H&H study), as well as other relicensing studies. For the upstream hydraulic model (UHM) and STM, only the stage hydrographs at Pensacola Dam are needed because the inflow hydrographs at the upstream boundary come from other sources. For the downstream hydraulic model, the stage hydrographs at Kerr Dam, lateral inflow hydrographs to Lake Hudson, and discharge hydrographs at Pensacola Dam are needed.

6.1 Single Events for CHM, Baseline Operations

The OM was used to provide CHM inputs for various single-event simulations, consisting of different combinations of historical or hypothetical flow events and initial reservoir elevations within GRDA's anticipated operating range or extreme, hypothetical range, summarized in **Table 5**. These simulations were computed using the baseline operating rules as represented in the RWM, which reflects the seasonal midnight rule curve that was in place prior to license amendment in 2015. For consistency throughout the model development and validation process, these baseline (pre-2015) operating rules were used to reflect what was in the RWM information provided by USACE SWT, which was the baseline for model validation as recommended in the FERC SPD. This is referred to as baseline operations.

Table 5. Single Events for CHM, Baseline Operations

	Pensacola Initial Elevation (feet PD)	Sep 1993 (21 year)	Jun 2004 (1 year)	Jul 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	100-year
Extreme, Hypothetical Range	757.0	✔	✔	✔	✔	✔	✔
	753.0	✔	✔	✔	✔	✔	✔
	749.0	✔	✔	✔	✔	✔	✔
Anticipated Range	745.0	✔	✔	✔	✔	✔	✔
	744.5	✔	✔	✔	✔	✔	✔
	744.0	✔	✔	✔	✔	✔	✔
	743.5	✔	✔	✔	✔	✔	✔
	743.0	✔	✔	✔	✔	✔	✔
	742.5	✔	✔	✔	✔	✔	✔
	742.0	✔	✔	✔	✔	✔	✔
Extreme, Hypothetical Range	734.0	✔	✔	✔	✔	✔	✔
	Historical (Varies)	✔	✔	✔	✔	✔	N/A
POR Simulation, 746.46				✔*			

*Corresponds to **Table 6**, see description below.

6.2 Single Events for CHM, Anticipated Operations

As proposed in Section 2.6.5 of the H&H Study RSP, "an additional suite of model runs following the same parameters" was run for the operational scenario anticipated by GRDA. As discussed in Section 1.6.2 of GRDA's December 29, 2021 filing with FERC, GRDA anticipates the following operational parameters will apply during the new license term:

1. GRDA will no longer utilize a rule curve with seasonal target elevations.
2. GRDA will maintain the conservation pool between elevations 742 and 745 feet PD for purposes of normal hydropower operations. While hydropower operations may occur when water surface elevations are outside this range (e.g., maintenance drawdowns and high-flow events), GRDA expects to generally maintain water surface elevations between 742 and 745 feet PD during normal project operations.
3. Instead of managing the project to target a specified seasonal elevation, GRDA's anticipated operations may fluctuate reservoir levels within the elevational range of 742 and 745 feet PD, for purposes of responding to grid demands, market conditions, and the public interest, such as environmental and recreational considerations.
4. GRDA will continue to adhere to USACE's direction on flood control operations in accordance with the Water Control Manual.

This operational scenario is referred to as "anticipated operations." The modeling approach used to demonstrate the potential value of the anticipated operations for hydropower production relies on a statistical comparison of the electricity prices for the current day/hour versus the previous 24-hour or 2-day price patterns. For power scheduled on the day-ahead market, each hourly price for the current calculation day is compared to all the hourly prices within the current and previous calculation days (2-day pattern). The average (mean) and standard deviation is calculated from the 48 hourly values. The number of standard deviations above or below the 2-day mean is calculated for each hour in the current calculation day. These values are then compared to an incentive table which relates the reservoir level (based on forecast reservoir volume at midnight) to a threshold value (in terms of standard deviations of price) above which generation may be scheduled, subject to other constraints as described in **Section 4 Operations Model**. The incentive table is shaped somewhat like an S-curve so that power scheduling can transition gradually to be more conservative as the pool drops closer to Elevation 742 PD or less conservative (more generation scheduled) as the pool rises closer to Elevation 745 PD. Above and below Elevations 745 and 742 PD, respectively, there is a sharp decrease or increase, respectively, in the standard deviation threshold values so that power generation is always scheduled (subject to other constraints) or never scheduled, respectively, outside of this range.

For power sold on the real-time market, the approach is similar except a moving 24-hour price pattern window is used, comparing the current hourly price to the previous 24 hours. The relationship between elevation and minimum generation price (in standard deviations) is shown in **Figure 15**.

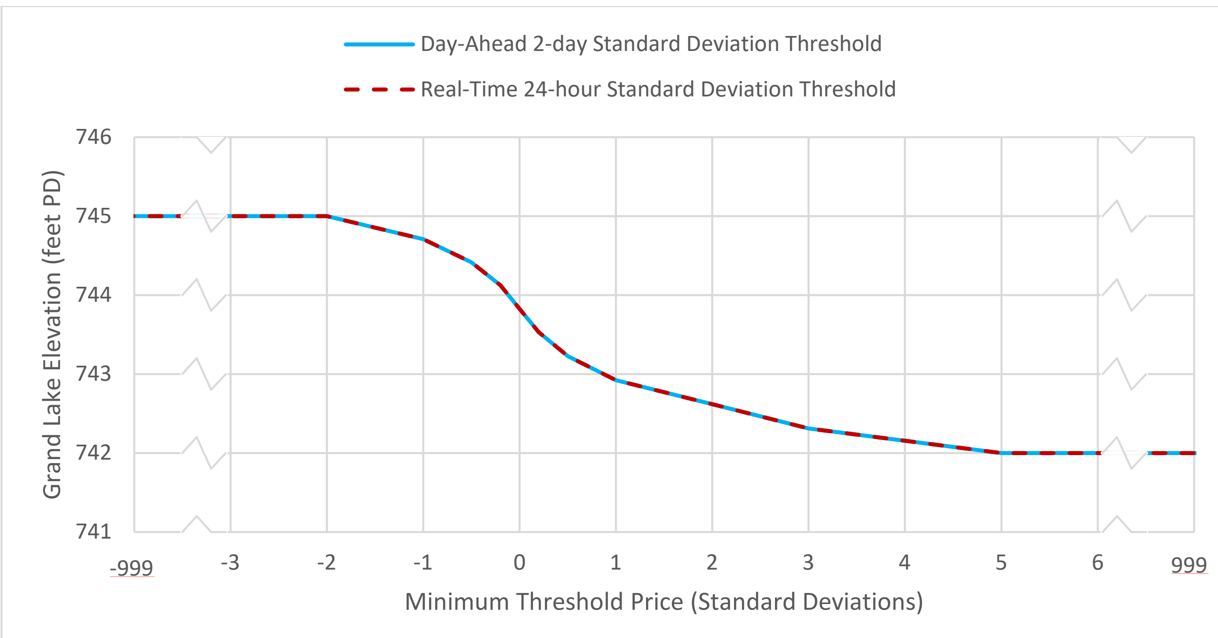


Figure 15. Minimum Threshold Price for Generation (Anticipated Operations)

Because the reservoir level fluctuates in response to water availability and electricity market conditions, the average (mean) reservoir level below 745 feet PD was used as the guide curve elevation in the FRM. For the hourly period of record from April 1, 2004 through December 31, 2019, this average elevation was 743.1 feet PD.

The OM was used to provide CHM inputs for single-event simulations consisting of the minimum and maximum bounding cases for flow events and initial reservoir elevations in the extreme, hypothetical range. Another event of historical importance to upstream communities (July 2007 [4 year]) was also simulated using the expected initial reservoir elevation based on the OM period-of-record simulation with anticipated operations. These simulations were computed using the anticipated operating rules and are summarized in **Table 6**.

Table 6. Single Events for CHM, Anticipated Operations

Pensacola Initial Elevation (feet PD)		Jun 2004 (1 year)	Jul 2007 (4 year)	100-year
Extreme, Hypothetical Range	757.0	✓		✓
POR Simulation	745.9		✓	
Extreme, Hypothetical Range	734.0	✓		✓

Differences in WSEL computed for these anticipated operation scenarios have been compared to the corresponding baseline operation scenarios, and that information is presented in the UHM report. One additional baseline operation scenario was added for this purpose: the July 2007 (4 year) event with the expected initial reservoir elevation (746.46 feet PD) based on the OM period-of-record simulation with baseline operations.

6.3 50-year Simulations for STM

The STM was used to predict changes in river and lake bathymetry based on sediment transport processes occurring over the expected license term of 50 years, as discussed in the STM report. The OM was used to provide STM inputs in terms of stage hydrographs at Pensacola Dam for various scenarios related to baseline and anticipated operations, including a sensitivity analysis for higher and lower sedimentation rates.

Another version of the OM was developed to calculate the STM inputs for the 50-year period from January 1, 2020 through December 31, 2069. The hydrologic inputs over this timeframe were randomized from the historical RWM data between January 1, 1970 and December 31, 2019. For the OM-specific inputs, data from the 12-year period from January 1, 2008 through December 31, 2019 was repeated to cover the rest of the 50-year simulation. This applied to electricity price factors, turbine air valve status, and the number of units online.

The OM was modified so that the reservoir stage-area-storage table could be interpolated through time as the average storage volume changed. For the first iteration, the OM was computed for the 50-year simulation using existing stage-area-storage data only, for both baseline and anticipated operations, and the resulting stage hydrographs at Pensacola Dam were passed to the STM. Then the STM was computed for both baseline and anticipated operation scenarios, and the resulting stage-storage tables at the end of the 50-year period were passed back to the OM. Because the simplified 1D geometry of the STM does not predict the reservoir surface area as well as the USGS survey data, the 2019 table for Grand Lake was modified to calculate future area based on the proportional changes in storage at a given elevation as computed by the STM. For the second iteration, the OM interpolated between the existing and future stage-area-storage tables using linear interpolation for each day in the 50-year simulation. The OM stage results were again passed to the STM, and the STM re-computed. The stage-area-storage tables resulting from this second iteration were compared to the first to confirm that no further iteration was needed. The future stage-area-storage tables thus computed could then be used to examine the effect of sedimentation over the license term on upstream water levels using the 1D UHM, as discussed in the following section.

In addition to the STM scenarios computed using the expected parameters for sedimentation, two sensitivity cases were computed using lower and higher rates of sedimentation. The 50-year OM scenarios computed in support of the STM are summarized in **Table 7**.

Table 7. 50-year Simulations for STM

Operations	Lower Sediment Rate	Expected Sediment Rate	Higher Sediment Rate
Baseline		✔	
Anticipated	✔	✔	✔

6.4 Single Events for 1D UHM, Anticipated Operations

The OM was used to provide 1D UHM inputs for single-event simulations consisting of three initial reservoir elevations, two inflow events, and five different sedimentation conditions. The 1D UHM is a version of the STM reconfigured to run short-duration events to predict the resulting upstream water surface profiles, as described in the STM report. The simulations included the July 2007 (4 year) and 100-year events and initial reservoir elevations of 740-, 745-, and 750-feet PD as recommended in the May 27, 2022 FERC Determination. Scenarios were computed to compare:

- future vs. existing (2019) bathymetry conditions for anticipated operations,
- expected sedimentation rate vs. lower and higher sensitivity cases, and
- anticipated vs. baseline operations using future bathymetry.

Scenarios computed in support of the 1D UHM are summarized in **Table 8**.

Table 8. Single Events for 1D UHM

Stage-Storage Condition	July 2007 (4 year)			100-year		
	740	745	750	740	745	750
Existing, Anticipated Operations	✔	✔	✔	✔	✔	✔
Future, Anticipated Operations, Lower Sediment Rate	✔	✔	✔	✔	✔	✔
Future, Anticipated Operations, Expected Sediment Rate	✔	✔	✔	✔	✔	✔
Future, Anticipated Operations, Higher Sediment Rate	✔	✔	✔	✔	✔	✔
Future, Baseline Operations, Expected Sediment Rate	✔	✔	✔	✔	✔	✔

7. Scenarios Computed for Other Studies

The OM was used to calculate statistical changes in water levels and to provide UHM inputs in support of other relicensing studies, including the Aquatic Species Study, Terrestrial Species Study, and Wetlands and Riparian Habitat Study. For each study and certain specific resources within a study, specific seasons were identified as key for determining impacts. The hourly period-of-record OM was truncated slightly to November 1, 2004 through November 1, 2019 so that a whole number of years was used to calculate statistics. The OM was computed for both baseline and anticipated operations using stage-area-storage tables based on the USGS 2019 bathymetry. The specific results computed for each study and resource are discussed below.

7.1 Aquatic Species Study

For the Aquatic Species Study, a comparison between anticipated operations and baseline operations during normal operations and inflows was completed. The Aquatic Species Study team identified the annual seasonal period of May 15 to July 8 as a critical time period surrogate for all lake spawning fish, based upon the nursery period for largemouth bass. For this season, the median reservoir elevation was 744.14 and 744.73 feet PD for baseline and anticipated operations, respectively. The seasonal median inflows on the Neosho River and other Grand Lake tributaries were also calculated from the RWM data for this timeframe. These median reservoir elevations and inflows were then used by the UHM to calculate the upstream water levels and extent of inundation for baseline and anticipated operations.

7.2 Terrestrial Species Study

For the Terrestrial Species Study, the entire calendar year, January 1 through December 31 was recommended by the Terrestrial Species Study Team as the seasonal analysis period because several critical terrestrial species could be most impacted during both their active and inactive or hibernation periods each year. For this season, the median reservoir elevation was 742.04 and 743.10 feet PD for baseline and anticipated operations, respectively. The seasonal median reservoir elevations and inflows were then used by the UHM to calculate the upstream water levels and extent of inundation for baseline and anticipated operations.

Additionally, a seasonal period from April 1 to July 31 was calculated to quantify potential impacts to gray bats. For this season, the percentage of time the reservoir elevation exceeded threshold values of 746, 751, and 752 feet PD were calculated for baseline and anticipated operations.

7.3 Wetlands and Riparian Habitat Study

For the Wetland and Riparian Habitat Study, the annual seasonal period of March 30 to November 2 was recommended by the Wetland and Riparian Habitat Study Team as critical for identifying areas that could change from seasonally flooded to permanently flooded. The critical period corresponds with the growing season as determined from Tulsa, OK climatological records. For this season, the median reservoir elevation was 742.92 and 743.46 feet PD for baseline and anticipated operations, respectively. The seasonal median reservoir elevations and inflows were then used by the UHM to calculate the upstream water levels and extent of inundation for baseline and anticipated operations.

7.4 Recreation and Navigation

Although not part of an official study, an additional case was calculated for the season from June 1 through October 31, which is the peak season for recreation / boating navigation on Grand Lake. For this season, the median reservoir elevation was 743.14 and 743.07 feet PD for baseline and anticipated operations, respectively.

8. Summary

On behalf of GRDA, Mead & Hunt developed a three-reservoir version of the RiverWare model, referred to as the FRM, to investigate operating alternatives and hypothetical (non-historical) events. The FRM includes Pensacola, Kerr, and Fort Gibson Dams. Mead & Hunt also developed an OM to simulate hourly hydropower operations at Pensacola and Kerr. GRDA validated its model results against the RWM output, as recommended in the FERC SPD. The OM was also validated by comparing the WSEL results to USGS gage data upstream of Pensacola Dam for two historical events recommended by the FERC. Sensitivity of OM results to stage-area-storage table updates were calculated. The OM was then improved to fix known issues and expanded to include anticipated operations. All FERC-requested modifications have been completed. The OM was used to provide inputs for the CHM, STM, 1D UHM, and other relicensing studies and resource evaluations. This report documents the development of the OM updated results that will be presented at the USR meeting.

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Appendix A. USACE RiverWare Data

USACE SWT RiverWare Period-of-Record Model, Daily Time Series Data

Element		PARS	PARS-COMM	PARS-COMM	COMM	COMM-PENS	COMM-PENS	PENS	PENS	PENS	PENS	PENS	PENS	PENS-HUDS	PENS-HUDS	HUDS	HUDS
Parameter		FLOW-LOC CUM	INFLOW	OUTFLOW	FLOW-LOC CUM	INFLOW	OUTFLOW	ELEV	STORAGE	FLOOD-STORAGE	FLOW-RES IN	OPLEVEL	FLOW-RES OUT	INFLOW	OUTFLOW	ELEV	FLOOD-STORAGE
Units		cfs	cfs	cfs	cfs	cfs	cfs	ft	acre-ft	acre-ft	cfs	-	cfs	cfs	cfs	ft	acre-ft
1	01Jan1940	50	50	50	51	51	51	742.00	1392694	16	262	8.00001	238	238	238	619.02	263
2	02Jan1940	50	50	50	53	53	52	742.00	1392686	8	81	7.07267	69	69	69	619.01	54
3	03Jan1940	50	50	50	52	52	53	742.00	1392682	4	134	6.08950	120	120	120	619.00	0
4	04Jan1940	50	50	50	54	54	53	742.00	1392681	3	347	5.84333	331	331	331	619.00	0
5	05Jan1940	50	50	50	56	56	55	742.00	1392682	4	280	6.17988	264	264	264	619.04	462
6	06Jan1940	50	50	50	54	54	55	742.00	1392682	4	252	6.19854	235	235	235	619.01	141
7	07Jan1940	50	50	50	55	55	55	742.00	1392682	4	261	6.03920	245	245	245	619.01	135
8	08Jan1940	50	50	50	50	50	52	742.00	1392681	3	297	5.64767	282	282	282	619.00	34
9	09Jan1940	51	51	51	51	51	50	742.00	1392680	2	393	5.57045	377	377	377	619.02	229
10	10Jan1940	51	51	51	51	51	51	742.00	1392681	3	367	5.63389	351	351	351	619.02	189
11	11Jan1940	50	50	50	50	50	51	742.00	1392682	4	372	6.08029	356	356	356	619.02	225
12	12Jan1940	50	50	50	51	51	51	742.00	1392682	4	372	6.03123	356	356	356	619.01	128
13	13Jan1940	50	50	50	51	51	51	742.00	1392682	4	433	6.08367	417	417	417	619.02	249
14	14Jan1940	50	50	50	57	57	55	742.00	1392683	5	434	6.32674	418	418	418	619.03	307
15	15Jan1940	50	50	50	53	53	55	742.00	1392683	5	325	6.31415	308	308	308	619.01	128
16	16Jan1940	50	50	50	50	50	51	742.00	1392682	4	396	6.01742	381	381	381	619.02	166
17	17Jan1940	50	50	50	51	51	51	742.00	1392681	3	420	5.97649	405	405	405	619.03	313
18	18Jan1940	50	50	50	52	52	51	742.00	1392682	4	318	6.33774	302	302	302	619.02	213
19	19Jan1940	50	50	50	50	50	51	742.00	1392683	5	302	6.57443	286	286	286	619.02	168
20	20Jan1940	50	50	50	50	50	50	742.00	1392682	4	325	6.26857	309	309	309	619.02	229
21	21Jan1940	50	50	50	50	50	50	742.00	1392682	4	296	6.24674	280	280	280	619.02	192
22	22Jan1940	50	50	50	50	50	50	742.00	1392682	4	292	6.34733	275	275	275	619.02	189
23	23Jan1940	50	50	50	50	50	50	742.00	1392683	5	288	6.51573	271	271	271	619.02	186
24	24Jan1940	50	50	50	50	50	50	742.00	1392683	5	274	6.49099	257	257	257	619.01	146
25	25Jan1940	50	50	50	50	50	50	742.00	1392683	5	284	6.57288	268	268	268	619.01	125
26	26Jan1940	50	50	50	50	50	50	742.00	1392683	5	300	6.62145	284	284	284	619.01	150
27	27Jan1940	50	50	50	50	50	50	742.00	1392683	5	291	6.47114	275	275	275	619.01	120
28	28Jan1940	50	50	50	50	50	50	742.00	1392682	4	320	6.17769	305	305	305	619.02	172
29	29Jan1940	50	50	50	50	50	50	742.00	1392682	4	299	6.01550	283	283	283	619.01	104
30	30Jan1940	50	50	50	50	50	50	742.00	1392681	3	362	5.91130	347	347	347	619.02	221
31	31Jan1940	50	50	50	50	50	50	742.00	1392682	4	346	6.09173	330	330	330	619.02	221
32	01Feb1940	50	50	50	50	50	50	742.00	1392682	4	424	6.18151	458	458	458	619.04	470
33	02Feb1940	50	50	50	51	51	50	742.00	1392683	5	393	6.47594	426	426	426	619.04	457
34	03Feb1940	50	50	50	52	52	52	742.00	1392683	5	399	6.58737	433	433	433	619.05	510
35	04Feb1940	50	50	50	54	54	53	742.00	1392683	5	363	6.46727	397	397	397	619.04	398
36	05Feb1940	60	60	53	53	53	54	742.00	1392681	3	416	5.68030	452	452	452	619.04	411
37	06Feb1940	63	63	59	59	59	57	742.00	1392680	2	400	5.54077	435	435	435	619.04	401
38	07Feb1940	55	55	59	59	59	59	742.00	1392680	2	306	5.49845	341	341	341	619.02	200
39	08Feb1940	68	68	61	64	64	62	742.00	1392680	2	329	5.53507	363	363	363	619.02	226
40	09Feb1940	72	72	67	69	69	67	742.00	1392680	2	380	5.48346	415	415	415	619.04	441
41	10Feb1940	63	63	68	73	73	72	742.00	1392680	2	331	5.52878	366	366	366	619.02	236
42	11Feb1940	59	59	63	73	73	73	742.00	1392680	2	393	5.54404	428	428	428	619.03	357
43	12Feb1940	52	52	57	67	67	70	742.00	1392680	2	362	5.44471	397	397	397	619.03	368
44	13Feb1940	50	50	53	62	62	64	742.00	1392680	2	297	5.56904	331	331	331	619.03	306
45	14Feb1940	50	50	51	56	56	59	742.00	1392680	2	286	5.72258	320	320	320	619.02	194
46	15Feb1940	50	50	50	57	57	57	742.00	1392681	3	321	6.03727	355	355	355	619.02	203
47	16Feb1940	50	50	50	80	80	71	742.00	1392682	4	355	6.19091	389	389	389	619.03	325
48	17Feb1940	50	50	50	194	194	149	742.00	1392681	3	357	5.82935	392	392	392	619.03	313
49	18Feb1940	57	57	53	190	190	192	742.00	1392679	1	437	5.19429	473	473	473	619.06	597
50	19Feb1940	60	60	57	125	125	151	742.00	1392679	1	377	5.31640	412	412	412	619.04	380
51	20Feb1940	57	57	58	109	109	115	742.00	1392679	1	488	5.19398	523	523	523	619.04	451
52	21Feb1940	50	50	55	99	99	103	742.00	1392680	2	508	5.55060	542	542	542	619.05	512
53	22Feb1940	50	50	51	91	91	94	742.00	1392680	2	491	5.47451	526	526	526	619.04	484
54	23Feb1940	51	51	51	80	80	84	742.00	1392679	1	418	5.19442	454	454	454	619.04	399
55	24Feb1940	52	52	51	86	86	83	742.00	1392679	1	412	5.34691	446	446	446	619.03	348
56	25Feb1940	59	59	54	74	74	79	742.00	1392680	2	423	5.55188	457	457	457	619.02	234
57	26Feb1940	68	68	61	64	64	68	742.00	1392679	1	488	5.19397	524	524	524	619.04	431
58	27Feb1940	50	50	60	80	80	73	742.00	1392681	3	454	5.83498	488	488	488	619.04	466
59	28Feb1940	50	50	53	86	86	83	742.00	1392681	3	412	5.70285	447	447	447	619.04	393
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28435	06Nov2017	155	155	165	179	179	188	742.00	1392679	1	566	5.20849	537	537	537	619.00	0
28436	07Nov2017	148	148	155	175	175	177	742.00	1392679	1	565	5.20675	453	453	453	619.03	367
28437	08Nov2017	126	126	142	164	164	169	742.01	1393189	511	564	8.00827	195	195	195	619.00	0
28438	09Nov2017	112	112	126	153	153	158	742.00	1392679	1	464	5.21000	610	610	610	619.08	869
28439	10Nov2017	117	117	118	132	132	141	742.00	1392679	1	464	5.20465	352	352	352	619.02	173
28440	11Nov2017	117	117	117	127	127	129	742.00	1392679	1	464	5.20465	352	352	352	619.02	170
28441	12Nov2017	126	126	120	129	129	128	742.00	1392679	1	464	5.20465	352	352	352	619.02	220
28442	13Nov2017	122	122	123	133	133	131	742.00	1392679	1	414	5.20361	302	302	302	619.00	0
28443	14Nov2017	128	128	124	132	132	132	742.00	1392679	1	764	5.21088	652	652	652	619.02	171
28444	15Nov2017	136	136	130	134	134	133	742.00	1392679	1	1064	5.21711	952	952	952	619.00	0
28445	16Nov2017	133	133	133	149	149	143	742.00	1392679	1	664	5.20881	552	552	552	619.08	936
28446	17Nov2017	122	122	129	132	132	139	742.00	1392679	1	564	5.20673	452	452	452	619.00	0
28447	18Nov2017	137	137	129	129	129	130	742.00	1392679	1	467	5.20472	355	355	355	619.06	648
28448	19Nov2017	126	126	131	131	131	130	742.00	1392679	1	466	5.20470	354	354	354	619.03	266
28449	20Nov2017	114	114	123	123	123	126	742.00	1392679	1	465	5.20467	353	353	353	619.04	399
28450	21Nov2017	121	121	119	119	119	121	742.00	1392679	1	467	5.20473	356	356	356	619.00	0
28451	22Nov2017	117	117	119	119	119	119	742.00	1392679	1	469	5.23644	357	357	357	619.03	321
28452	23Nov2017	103	103	113	113	113	115	742.00	1392679	1	468	5.20474	357	357	357	619.02	236
28453	24Nov2017	107	107	107	107	107	110	742.00	1392679	1	468	5.20474	356	356	356	619.00	0
28454	25Nov2017	106	106	107	107	107	107	742.00	1392679	1	466	5.20470	355	355	355	619.02	192
28455	26Nov2017	106	106	107	107	107	107	742.00	1392679	1	466	5.20469	354	354	354	619.02	245
28456	27Nov2017	97	97	103	103	103	105	742.00	1392679	1	469	5.20476	358	358	358	619.00	0
28457	28Nov2017	91	91	97	97	97	99	742.00	1392679	1	1173	5.21938	1061	1061	1061	619.00	0
28458	29Nov2017	99	99	95	98	98	97	742.00	1392679	1	2318	5.24315	2206	2206	2206	619.00	0
28459	30Nov2017	93	93	96	108	108	104	742.00	1392679	1	1084	5.21753	972	972	972	619.01	148
28460	01Dec2017	85	85	91	98	98	102	742.00	1392679	1	714	5.20693	632	632	632	619.05	487
28461	02Dec2017	116	116	98	98	98	98	742.00	1392678	0	571	5.00761	490	490	490	619.03	369
28462	03Dec2017	119	119	112	112	112	106	742.00	1392678	0	483	5.00646	401	401	401	619.04	485
28463	04Dec2017	141	141	124	124	124	119	742.00	1392678	0	593	5.00813	511	511	511	619.05	531
28464	05Dec2017	137	137	134	134	134	130	742.00	1392678	0	493	5.00663	412	412	412	619.03	342
28465	06Dec2017	112	112	127	127	127	130	742.00	1392678	0	490	5.00660	409	409	409	619.03	268
28466	07Dec2017	125	125	121	121	121	123	742.00	1392678	0	493	5.00664	412	412	412	619.02	241
28467	08Dec2017	120	120	122	122	122	122	742.00	1392678	0	507	5.00682	425	425	425	619.04	433
28468	09Dec2017	114	114	118	118	118	120	742.00	1392678	0	460	5.00606	378	378	378	619.04	430
28469	10Dec2017	101	101	111	111	111	114	742.00	1392678	0	404	5.00519	323	323	323	619.02	231
28470	11Dec2017	87	87	99	99	99	104	742.00	1392678	0	400	5.00510	318	318	318	619.02	202
28471	12Dec2017	87	87	91	91	91	94	742.00	1392678	0	397	5.00505	315	315	315	619.02	210
28472	13Dec2017	98	98	92	92	92	91	742.00	1392678	0	403	5.00514	321	321	321	619.00	0
28473	14Dec2017	101	101	97	97	97	95	742.00	1392678	0	404	5.00515	322	322	322	619.03	327
28474	15Dec2017	105	105	101	101	101	100	742.00	1392678	0	402	5.00512	320	320	320	619.03	310
28475	16Dec2017	111	111	106	106	106	104	742.00	1392678	0	307	5.00369	226	226	226	619.00	0
28476	17Dec2017	138	138	119	119	119	114	742.00	1392678	0	814	5.01304	733	733	733	619.00	0
28477	18Dec2017	182	182	148	148	148	136	742.00	1392678	0	632	5.00913	550	550	550	619.09	1040
28478	19Dec2017	189	189	175	175	175	164	742.00	1392678	0	1855	5.02728	1773	1773	1773	619.18	1977
28479	20Dec2017	157	157	174	174	174	174	742.00	1392678	0	709	5.00982	627	627	627	619.05	564
28480	21Dec2017	135	135	154	154	154	162	742.00	1392678	0	1352	5.01957	1270	1270	1270	619.08	956
28481	22Dec2017	127	127	138	138	138	145	742.00	1392678	0	1342	5.01943	1261	1261	1261	619.03	291
28482	23Dec2017	110	110	124	124	124	130	742.00	1392678	0	974	5.01384	893	893	893	619.05	549
28483	24Dec2017	116	116	116	116	116	119	742.00	1392678	0	1210	5.01741	1128	1128	1128	619.07	833
28484	25Dec2017	136	136	123	123	123	120	742.00	1392678	0	917	5.01296	835	835	835	619.00	0
28485	26Dec2017	117	117	126	126	126	125	742.00	1392678	0	723	5.01002	642	642	642	619.06	635
28486	27Dec2017	94	94	112	112	112	117	742.00	1392678	0	614	5.00836	533	533	533	619.05	543
28487	28Dec2017	78	78	94	94	94	101	742.00	1392678	0	251	5.00283	169	169	169	619.00	0
28488	29Dec2017	79	79	83	83	83	87	742.00	1392678	0	1495	5.02167	1414	1414	1414	619.09	1015
28489	30Dec2017	89	89	84	84	84	83	742.00	1392678	0	1552	5.02251	1470	1470	1470	619.14	1537
28490	31Dec2017	83	83	86	114	114	102	742.00	1392678	0	939	5.01321	857	857	857	619.08	888
28491	01Jan2018		73	80		80	94		1393467	789		8.01287		0	0		868
28492	02Jan2018		45	65		65	71		1394061	1383		8.02271		0	0		848
28493	03Jan2018		24	43		43	52		1394504	1826		8.03004		0	0		828
28494	04Jan2018		12	26		26	33		1394823	2145		8.03534		0	0		808
28495	05Jan2018		6	14		14	19		1395051	2373		8.03911		0	0		788
28496	06Jan2018		3	7		7	10		1395214	2536		8.04180		0	0		769
28497	07Jan2018		1	4		4	5		1395331	2653		8.04374		0	0		749
28498	08Jan2018		1	2		2	2		1395416	2738		8.04516		0	0		729
28499	09Jan2018		0	1		1	1		1395479	2801		8.04620		0	0		709

USACE SWT RiverWare Period-of-Record Model, Daily Time Series Data																	
Element		HUDS	HUDS	HUDS	HUDS-FGIB	HUDS-FGIB	FGIB	FGIB	FGIB	FGIB	FGIB	FT GIBSON-MUSKOGEE	FT GIBSON-MUSKOGEE	PENS	HUDS	FGIB	Van Buren
Parameter		FLOW-RES IN	OPLEVEL	OUTFLOW	INFLOW	OUTFLOW	ELEV	FLOOD-STORAGE	FLOW-RES IN	FLOW-RES OUT	OP-LEVEL	INFLOW	OUTFLOW	EVAP	EVAP	EVAP	Percent Full Regulation Parameter
Units		cfs	-	cfs	cfs	cfs	ft	acre-ft	cfs	cfs	-	cfs	cfs	in/day	in/day	in/day	-
1	01Jan1940	238	8.01077	91	91	91	554.00	67	91	0	8.00075	0	0	0.0094	0.0087	0.0232	0.000
2	02Jan1940	69	8.00222	160	160	160	553.98	0	160	368	4.90163	368	276	0.0094	0.0087	0.0232	0.000
3	03Jan1940	145	5.41351	158	158	158	553.98	0	158	91	4.90570	91	161	0.0094	0.0087	0.0232	0.000
4	04Jan1940	365	5.21055	351	351	351	554.01	140	351	0	8.00157	0	23	0.0094	0.0087	0.0232	0.000
5	05Jan1940	264	8.01894	17	17	17	554.00	60	17	0	8.00067	0	0	0.0094	0.0087	0.0232	0.000
6	06Jan1940	244	8.00576	392	392	392	554.03	497	392	114	8.00558	114	86	0.0094	0.0087	0.0232	0.000
7	07Jan1940	245	8.00553	234	234	234	553.99	0	234	486	4.97502	486	393	0.0094	0.0087	0.0232	0.000
8	08Jan1940	312	8.00138	349	349	349	554.01	123	349	171	8.00138	171	250	0.0094	0.0087	0.0232	0.000
9	09Jan1940	434	8.00939	321	321	321	554.02	397	321	126	8.00445	126	137	0.0094	0.0087	0.0232	0.000
10	10Jan1940	407	8.00776	413	413	413	553.99	0	413	670	4.95146	670	534	0.0094	0.0087	0.0232	0.000
11	11Jan1940	432	8.00924	400	400	400	554.01	260	400	97	8.00292	97	240	0.0094	0.0087	0.0232	0.000
12	12Jan1940	370	8.00526	405	405	405	553.99	0	405	548	4.97057	548	435	0.0094	0.0087	0.0232	0.000
13	13Jan1940	494	8.01020	419	419	419	554.02	335	419	123	8.00376	123	229	0.0094	0.0087	0.0232	0.000
14	14Jan1940	443	8.01260	399	399	399	553.98	0	399	680	4.92797	680	541	0.0094	0.0087	0.0232	0.000
15	15Jan1940	308	8.00524	385	385	385	554.00	0	385	167	4.99589	167	296	0.0094	0.0087	0.0232	0.000
16	16Jan1940	424	8.00679	390	390	390	553.87	0	390	1541	4.48341	1541	1197	0.0094	0.0087	0.0232	0.000
17	17Jan1940	455	8.01282	367	367	367	553.90	0	367	0	4.61478	0	385	0.0094	0.0087	0.0232	0.000
18	18Jan1940	302	8.00873	338	338	338	553.93	0	338	0	4.73378	0	0	0.0094	0.0087	0.0232	0.000
19	19Jan1940	286	8.00691	294	294	294	553.96	0	294	0	4.83413	0	0	0.0094	0.0087	0.0232	0.000
20	20Jan1940	309	8.00939	265	265	265	553.97	0	265	67	4.89346	67	50	0.0094	0.0087	0.0232	0.000
21	21Jan1940	280	8.00785	285	285	285	553.99	0	285	96	4.94909	96	89	0.0094	0.0087	0.0232	0.000
22	22Jan1940	275	8.00777	262	262	262	554.00	0	262	118	4.98610	118	112	0.0094	0.0087	0.0232	0.000
23	23Jan1940	277	8.00764	265	265	265	554.01	86	265	131	8.00097	131	128	0.0094	0.0087	0.0232	0.000
24	24Jan1940	269	8.00598	275	275	275	554.02	306	275	107	8.00343	107	113	0.0094	0.0087	0.0232	0.000
25	25Jan1940	291	8.00511	287	287	287	553.99	0	287	460	4.96792	460	372	0.0094	0.0087	0.0232	0.000
26	26Jan1940	310	8.00616	283	283	283	554.00	33	283	133	8.00037	133	215	0.0094	0.0087	0.0232	0.000
27	27Jan1940	294	8.00493	295	295	295	554.01	205	295	151	8.00230	151	146	0.0094	0.0087	0.0232	0.000
28	28Jan1940	329	8.00707	289	289	289	554.02	414	289	126	8.00464	126	132	0.0094	0.0087	0.0232	0.000
29	29Jan1940	293	8.00425	314	314	314	553.99	0	314	518	4.97749	518	420	0.0094	0.0087	0.0232	0.000
30	30Jan1940	404	8.00905	331	331	331	554.01	254	331	92	8.00285	92	199	0.0094	0.0087	0.0232	0.000
31	31Jan1940	454	8.00906	440	440	440	553.73	0	440	3031	3.93044	3031	2296	0.0094	0.0087	0.0232	0.000
32	01Feb1940	609	8.01927	497	497	497	553.79	0	507	0	4.14142	0	758	-0.0207	-0.0507	-0.0376	0.000
33	02Feb1940	604	8.01875	624	624	624	553.85	0	646	0	4.41167	0	0	-0.0207	-0.0507	-0.0376	0.000
34	03Feb1940	615	8.02089	602	602	602	553.92	0	648	0	4.68285	0	0	-0.0207	-0.0507	-0.0376	0.000
35	04Feb1940	577	8.01631	647	647	647	553.99	0	647	0	4.95357	0	0	-0.0207	-0.0507	-0.0376	0.000
36	05Feb1940	576	8.01686	582	582	582	554.04	745	582	89	8.00835	89	66	-0.0207	-0.0507	-0.0376	0.000
37	06Feb1940	499	8.01644	517	517	517	553.98	0	517	1105	4.90614	1105	851	-0.0207	-0.0507	-0.0376	0.000
38	07Feb1940	374	8.00821	489	489	489	554.02	309	489	102	8.00347	102	353	-0.0207	-0.0507	-0.0376	0.000
39	08Feb1940	430	8.00927	430	430	430	553.99	0	430	710	4.94358	710	558	-0.0207	-0.0507	-0.0376	0.000
40	09Feb1940	549	8.01810	454	454	454	554.03	540	454	40	8.00606	40	207	-0.0207	-0.0507	-0.0376	0.000
41	10Feb1940	444	8.00969	561	561	561	553.99	0	561	963	4.94139	963	732	-0.0207	-0.0507	-0.0376	0.000
42	11Feb1940	507	8.01465	460	460	460	554.02	447	460	88	8.00501	88	306	-0.0207	-0.0507	-0.0376	0.000
43	12Feb1940	469	8.01507	477	477	477	553.68	0	477	3673	3.73568	3673	2777	-0.0207	-0.0507	-0.0376	0.000
44	13Feb1940	418	8.01257	462	462	462	553.73	0	466	0	3.92962	0	918	-0.0207	-0.0507	-0.0376	0.000
45	14Feb1940	362	8.00794	432	432	432	553.78	0	432	0	4.10903	0	0	-0.0207	-0.0507	-0.0376	0.000
46	15Feb1940	394	8.00833	403	403	403	553.82	0	403	0	4.27613	0	0	-0.0207	-0.0507	-0.0376	0.000
47	16Feb1940	499	8.01333	451	451	451	553.86	0	451	0	4.46341	0	0	-0.0207	-0.0507	-0.0376	0.000
48	17Feb1940	538	8.01285	557	557	557	553.93	0	610	0	4.71835	0	0	-0.0207	-0.0507	-0.0376	0.000
49	18Feb1940	738	8.02447	609	609	609	554.01	163	755	0	8.00182	0	0	-0.0207	-0.0507	-0.0376	0.000
50	19Feb1940	621	8.01559	744	744	744	553.98	0	818	1102	4.91057	1102	826	-0.0207	-0.0507	-0.0376	0.000
51	20Feb1940	683	8.01851	660	660	660	554.04	758	694	92	8.00850	92	345	-0.0207	-0.0507	-0.0376	0.000
52	21Feb1940	715	8.02101	697	697	697	553.97	0	697	1348	4.88231	1348	1034	-0.0207	-0.0507	-0.0376	0.000
53	22Feb1940	642	8.01983	670	670	670	553.64	0	694	3790	3.56475	3790	3180	-0.0207	-0.0507	-0.0376	0.000
54	23Feb1940	579	8.01635	635	635	635	553.71	0	684	0	3.85093	0	948	-0.0207	-0.0507	-0.0376	0.000
55	24Feb1940	546	8.01426	586	586	586	553.77	0	591	0	4.09763	0	0	-0.0207	-0.0507	-0.0376	0.000
56	25Feb1940	510	8.00958	581	581	581	553.84	0	581	0	4.34035	0	0	-0.0207	-0.0507	-0.0376	0.000
57	26Feb1940	629	8.01765	544	544	544	553.89	0	546	0	4.56819	0	0	-0.0207	-0.0507	-0.0376	0.000
58	27Feb1940	623	8.01911	618	618	618	553.96	0	629	20	4.82258	20	15	-0.0207	-0.0507	-0.0376	0.000
59	28Feb1940	562	8.01611	612	612	612	554.02	324	678	88	8.00363	88	71	-0.0207	-0.0507	-0.0376	0.000
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28435	06Nov2017	1968	8.00000	1939	1939	1939	554.05	1027	2184	2907	8.01152	2907	2203	0.0665	0.0399	0.0782	0.000
28436	07Nov2017	615	8.01503	402	402	402	554.01	163	402	736	8.00183	736	1279	0.0665	0.0399	0.0782	0.000
28437	08Nov2017	822	8.00000	978	978	978	554.11	2133	1183	89	8.02392	89	250	0.0665	0.0399	0.0782	0.000
28438	09Nov2017	610	8.03564	143	143	143	554.00	0	143	1136	4.99200	1136	874	0.0665	0.0399	0.0782	0.000
28439	10Nov2017	402	8.00709	725	725	725	554.05	861	725	170	8.00965	170	412	0.0665	0.0399	0.0782	0.000
28440	11Nov2017	402	8.00695	375	375	375	554.01	202	375	606	8.00227	606	497	0.0665	0.0399	0.0782	0.000
28441	12Nov2017	402	8.00903	348	348	348	554.02	430	348	132	8.00482	132	250	0.0665	0.0399	0.0782	0.000
28442	13Nov2017	352	8.00000	435	435	435	554.03	638	435	228	8.00715	228	204	0.0665	0.0399	0.0782	0.000
28443	14Nov2017	852	8.00700	738	738	738	554.00	40	988	1188	8.00045	1188	948	0.0665	0.0399	0.0782	0.000
28444	15Nov2017	2094	8.00000	2152	2152	2152	554.17	3288	2152	413	8.03686	413	607	0.0665	0.0399	0.0782	0.000
28445	16Nov2017	552	8.03837	52	52	52	553.99	0	602	2235	4.96717	2235	1780	0.0665	0.0399	0.0782	0.000
28446	17Nov2017	1275	8.00000	1718	1718	1718	554.13	2493	1868	432	8.02796	432	883	0.0665	0.0399	0.0782	0.000
28447	18Nov2017	355	8.02659	0	0	0	554.00	0	180	1381	4.98061	1381	1144	0.0665	0.0399	0.0782	0.000
28448	19Nov2017	354	8.01092	518	518	518	554.02	445	518	147	8.00499	147	456	0.0665	0.0399	0.0782	0.000
28449	20Nov2017	676	8.01635	581	581	581	553.98	0	650	993	4.90668	993	781	0.0665	0.0399	0.0782	0.000
28450	21Nov2017	1083	8.00000	1255	1255	1255	554.00	0	1705	1403	4.99195	1403	1300	0.0665	0.0399	0.0782	0.000
28451	22Nov2017	531	8.01314	341	341	341	554.02	394	341	22	8.00442	22	367	0.0665	0.0399	0.0782	0.000
28452	23Nov2017	371	8.00968	385	385	385	554.03	637	385	161	8.00714	161	126	0.0665	0.0399	0.0782	0.000
28453	24Nov2017	1043	8.00000	1134	1134	1134	553.96	0	1184	1752	4.85221	1752	1354	0.0665	0.0399	0.0782	0.000
28454	25Nov2017	437	8.00787	311	311	311	553.98	0	361	89	4.92480	89	505	0.0665	0.0399	0.0782	0.000
28455	26Nov2017	477	8.01004	422	422	422	554.00	56	422	115	8.00063	115	108	0.0665	0.0399	0.0782	0.000
28456	27Nov2017	474	8.00000	569	569	569	554.04	724	593	154	8.00812	154	144	0.0665	0.0399	0.0782	0.000
28457	28Nov2017	1311	8.00000	1283	1283	1283	553.96	0	1433	2067	4.84289	2067	1589	0.0665	0.0399	0.0782	0.000
28458	29Nov2017	4522	8.00000	4494	4494	4494	554.09	1683	5090	3770	8.01887	3770	3344	0.0665	0.0399	0.0782	0.000
28459	30Nov2017	1836	8.00606	1733	1733	1733	554.02	342	1733	2308	8.00383	2308	2673	0.0665	0.0399	0.0782	0.000
28460	01Dec2017	632	8.01997	438	438	438	553.96	0	1715	2153	4.85453	2153	2192	0.0485	0.0300	0.0472	0.000
28461	02Dec2017	490	8.01513	525	525	525	553.99	0	525	210	4.95579	210	696	0.0485	0.0300	0.0472	0.000
28462	03Dec2017	823	8.01988	741	741	741	554.06	1109	741	1	8.01243	1	53	0.0485	0.0300	0.0472	0.000
28463	04Dec2017	717	8.02179	670	670	670	553.97	0	1459	2228	4.87834	2228	1671	0.0485	0.0300	0.0472	0.000
28464	05Dec2017	575	8.01404	646	646	646	554.04	679	796	91	8.00761	91	625	0.0485	0.0300	0.0472	0.000
28465	06Dec2017	491	8.01098	505	505	505	553.82	0	505	2504	4.26447	2504	1900	0.0485	0.0300	0.0472	0.000
28466	07Dec2017	412	8.00987	402	402	402	553.85	0	402	0	4.40240	0	626	0.0485	0.0300	0.0472	0.000
28467	08Dec2017	620	8.01775	499	499	499	553.92	0	704	1	4.66834	1	1	0.0485	0.0300	0.0472	0.000
28468	09Dec2017	578	8.01762	556	556	556	553.97	0	556	1	4.87124	1	1	0.0485	0.0300	0.0472	0.000
28469	10Dec2017	423	8.00947	499	499	499	554.01	90	499	74	8.00101	74	55	0.0485	0.0300	0.0472	0.000
28470	11Dec2017	341	8.00830	332	332	332	554.02	340	332	129	8.00381	129	115	0.0485	0.0300	0.0472	0.000
28471	12Dec2017	315	8.00861	287	287	287	554.02	461	287	149	8.00517	149	144	0.0485	0.0300	0.0472	0.000
28472	13Dec2017	771	8.00000	853	853	853	554.00	0	853	1027	4.99243	1027	807	0.0485	0.0300	0.0472	0.000
28473	14Dec2017	622	8.01340	433	433	433	554.04	671	433	1	8.00752	1	257	0.0485	0.0300	0.0472	0.000
28474	15Dec2017	420	8.01270	405	405	405	553.67	0	405	3720	3.70426	3720	2790	0.0485	0.0300	0.0472	0.000
28475	16Dec2017	376	8.00000	508	508	508	553.72	0	508	0	3.88742	0	930	0.0485	0.0300	0.0472	0.000
28476	17Dec2017	1867	8.00000	1843	1843	1843	553.91	0	1843	3	4.63563	3	2	0.0485	0.0300	0.0472	0.000
28477	18Dec2017	550	8.04262	2	2	2	553.90	0	2	2	4.60315	2	2	0.0485	0.0300	0.0472	0.000
28478	19Dec2017	1873	8.08107	1376	1376	1376	554.00	9	1376	360	8.00010	360	271	0.0485	0.0300	0.0472	0.000
28479	20Dec2017	1670	8.02314	2359	2359	2359	553.86	0	2359	3590	4.44696	3590	2782	0.0485	0.0300	0.0472	0.000
28480	21Dec2017	1620	8.03921	1398	1398	1398	554.06	1142	2298	342	8.01281	342	1154	0.0485	0.0300	0.0472	0.000
28481	22Dec2017	2386	8.01192	2697	2697	2697	553.99	0	2697	3284	4.96278	3284	2549	0.0485	0.0300	0.0472	0.000
28482	23Dec2017	1950	8.02250	1796	1796	1796	553.97	0	2131	2262	4.87461	2262	2517	0.0485	0.0300	0.0472	0.000
28483	24Dec2017	1197	8.03416	1030	1030	1030	554.03	610	1030	350	8.00684	350	828	0.0485	0.0300	0.0472	0.000
28484	25Dec2017	2060	8.00000	2456	2456	2456	553.69	0	2656	5772	3.77607	5772	4417	0.0485	0.0300	0.0472	0.000
28485	26Dec2017	872	8.02605	528	528	528	553.76	0	715	0	4.04690	0	1443	0.0485	0.0300	0.0472	0.000
28486	27Dec2017	533	8.02227	555	555	555	553.61	0	555	1905	3.44187	1905	1429	0.0485	0.0300	0.0472	0.000
28487	28Dec2017	669	8.00000	919	919	919	553.78	0	1669	1	4.11732	1	477	0.0485	0.0300	0.0472	0.000
28488	29Dec2017	1814	8.04160	1278	1278	1278	553.93	0	1828	342	4.71544	342	257	0.0485	0.0300	0.0472	0.000
28489	30Dec2017	1769	8.06303	1482	1482	1482	554.08	1543	1832	306	8.01730	306	315	0.0485	0.0300	0.0472	0.000
28490	31Dec2017	857	8.03640	1161	1161	1161	553.95	0	1261	2428	4.80211	2428	1898	0.0485	0.0300	0.0472	0.000
28491	01Jan2018		8.03558								4.81059						0.000
28492	02Jan2018		8.03477								4.80890						0.000
28493	03Jan2018		8.03396								4.80313						0.000
28494	04Jan2018		8.03314								4.79573						0.000
28495	05Jan2018		8.03233								4.78768						0.000
28496	06Jan2018		8.03152								4.77936						0.000
28497	07Jan2018		8.03070								4.77095						0.000
28498	08Jan2018		8.02989								4.76249						0.000
28499	09Jan2018		8.02908								4.75402						0.000

		USACE SWT RiverWare Period-of-Record Model, Daily Time Series Data																	
Element		El Dorado	Kaw	Keystone	Birch	Skiatook	Hulah	Copan	Toronto	Fall River	Elk City	Big Hill	Oologah	Marion	Council Grove	John Redmond	Tenkiller	Eufaula	Wister
Parameter		Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level
Units		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	01Jan1940	5	5	5	5	4.99901	5	5	5	5	5	5	4.99	5	5	5	5	5	5
2	02Jan1940	5	5	5	5	4.99803	4.99	5	4.99	5	4.99	5	4.98	5	5	4.99	4.98	4.98	5
3	03Jan1940	5	5	4.98	5	4.99706	4.99	4.99	4.99	4.99	4.99	5	4.98	5	5	4.99	4.98	4.98	4.99
4	04Jan1940	5	5	4.96	4.99	4.99609	4.99	4.99	4.99	4.99	4.98	5	4.97	5	5	4.99	4.96	4.95	4.99
5	05Jan1940	5	5	4.96	4.99	4.99512	4.99	4.99	4.98	4.99	4.98	5	4.97	5	5	4.99	4.96	4.95	4.99
6	06Jan1940	5	5	4.96	4.99	4.99414	4.98	4.99	4.98	4.99	4.98	5	4.97	5	5	4.99	4.96	4.95	4.99
7	07Jan1940	5	5	4.96	4.99	4.99317	4.98	4.99	4.98	4.98	4.97	5	4.97	5	5	4.98	4.96	4.95	4.98
8	08Jan1940	5	5	4.96	4.99	4.99221	4.98	4.99	4.98	4.98	4.97	5	4.96	5	5	4.98	4.97	4.95	4.98
9	09Jan1940	5	5	4.94	4.99	4.99123	4.97	4.98	4.97	4.98	4.96	5	4.96	4.99	5	4.98	4.94	4.93	4.98
10	10Jan1940	4.99	5	4.94	4.98	4.99026	4.97	4.98	4.97	4.98	4.96	5	4.96	4.99	4.99	4.98	4.95	4.93	4.98
11	11Jan1940	4.99	5	4.94	4.98	4.9893	4.97	4.98	4.97	4.97	4.95	5	4.95	4.99	4.99	4.98	4.92	4.91	4.98
12	12Jan1940	4.99	5	4.94	4.98	4.98833	4.97	4.98	4.96	4.97	4.95	5	4.95	4.99	4.99	4.98	4.9	4.91	4.97
13	13Jan1940	4.99	5	4.94	4.98	4.98736	4.96	4.98	4.96	4.97	4.95	5	4.95	4.99	4.99	4.98	4.9	4.91	4.97
14	14Jan1940	4.99	5	4.94	4.98	4.98639	4.96	4.98	4.96	4.97	4.94	4.99	4.95	4.99	4.99	4.98	4.91	4.91	4.97
15	15Jan1940	4.99	5	4.94	4.98	4.98542	4.96	4.97	4.95	4.96	4.94	4.99	4.94	4.99	4.99	4.97	4.91	4.91	4.97
16	16Jan1940	4.99	5	4.94	4.97	4.98445	4.96	4.97	4.95	4.96	4.93	4.99	4.94	4.99	4.99	4.97	4.91	4.89	4.97
17	17Jan1940	4.99	5	4.94	4.97	4.98348	4.95	4.97	4.95	4.96	4.93	4.99	4.94	4.99	4.99	4.97	4.91	4.89	4.97
18	18Jan1940	4.99	5	4.93	4.97	4.98251	4.95	4.97	4.94	4.96	4.93	4.99	4.93	4.99	4.99	4.97	4.89	4.86	4.96
19	19Jan1940	4.99	5	4.88	4.97	4.98154	4.95	4.97	4.94	4.95	4.92	4.99	4.93	4.99	4.99	4.97	4.87	4.86	4.96
20	20Jan1940	4.99	5	4.88	4.97	4.98057	4.94	4.97	4.94	4.95	4.92	4.99	4.92	4.99	4.99	4.97	4.87	4.86	4.96
21	21Jan1940	4.99	5	4.88	4.97	4.9796	4.94	4.96	4.94	4.95	4.91	4.99	4.92	4.99	4.99	4.96	4.87	4.86	4.96
22	22Jan1940	4.99	5	4.87	4.97	4.97863	4.94	4.96	4.93	4.95	4.91	4.99	4.92	4.99	4.99	4.96	4.87	4.86	4.95
23	23Jan1940	4.99	5	4.87	4.96	4.97766	4.94	4.96	4.93	4.94	4.91	4.99	4.92	4.99	4.99	4.96	4.88	4.86	4.95
24	24Jan1940	4.99	5	4.86	4.96	4.97669	4.93	4.96	4.93	4.94	4.9	4.99	4.91	4.99	4.99	4.96	4.85	4.84	4.95
25	25Jan1940	4.99	5	4.86	4.96	4.97572	4.93	4.96	4.92	4.94	4.9	4.99	4.91	4.98	4.99	4.96	4.83	4.82	4.95
26	26Jan1940	4.99	5	4.86	4.96	4.97475	4.93	4.96	4.92	4.94	4.89	4.99	4.91	4.98	4.99	4.96	4.83	4.82	4.95
27	27Jan1940	4.99	5	4.86	4.96	4.97377	4.92	4.96	4.92	4.93	4.89	4.99	4.9	4.98	4.99	4.95	4.83	4.82	4.94
28	28Jan1940	4.99	5	4.84	4.96	4.9728	4.92	4.95	4.91	4.93	4.88	4.99	4.9	4.98	4.99	4.95	4.84	4.82	4.94
29	29Jan1940	4.98	5	4.84	4.95	4.97183	4.92	4.95	4.91	4.93	4.88	4.99	4.9	4.98	4.99	4.95	4.81	4.8	4.94
30	30Jan1940	4.98	5	4.84	4.95	4.97086	4.92	4.95	4.91	4.93	4.88	4.99	4.9	4.98	4.98	4.95	4.82	4.8	4.94
31	31Jan1940	4.98	5	4.84	4.95	4.96989	4.91	4.95	4.91	4.92	4.87	4.99	4.9	4.98	4.98	4.95	4.82	4.8	4.93
32	01Feb1940	4.98	5	4.84	4.95	4.96933	4.91	4.95	4.9	4.92	4.87	4.99	4.9	4.98	4.98	4.95	4.8	4.79	4.93
33	02Feb1940	4.98	5	4.84	4.95	4.96878	4.91	4.95	4.9	4.92	4.86	4.99	4.89	4.98	4.98	4.94	4.8	4.79	4.93
34	03Feb1940	4.98	5	4.85	4.95	4.96822	4.91	4.95	4.9	4.92	4.86	4.99	4.89	4.98	4.98	4.94	4.8	4.79	4.93
35	04Feb1940	4.98	5	4.85	4.95	4.96766	4.91	4.95	4.89	4.91	4.86	4.99	4.89	4.98	4.98	4.94	4.8	4.79	4.93
36	05Feb1940	4.98	5	4.86	4.95	4.9671	4.91	4.94	4.89	4.91	4.85	4.99	4.88	4.98	4.98	4.94	4.8	4.79	4.93
37	06Feb1940	4.98	5	4.81	4.95	4.96654	4.9	4.94	4.89	4.91	4.85	4.99	4.88	4.98	4.98	4.94	4.8	4.77	4.93
38	07Feb1940	4.98	5	4.82	4.95	4.96598	4.9	4.94	4.88	4.91	4.85	4.99	4.88	4.98	4.98	4.93	4.78	4.77	4.94
39	08Feb1940	4.98	5	4.82	4.95	4.96542	4.9	4.94	4.88	4.9	4.84	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.95
40	09Feb1940	4.98	5	4.83	4.95	4.96487	4.9	4.94	4.88	4.9	4.84	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.95
41	10Feb1940	4.98	5	4.83	4.95	4.96431	4.9	4.94	4.87	4.9	4.83	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.96
42	11Feb1940	4.98	5	4.83	4.95	4.96374	4.89	4.94	4.87	4.89	4.83	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.97
43	12Feb1940	4.98	5	4.84	4.95	4.96319	4.89	4.94	4.87	4.89	4.83	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.98
44	13Feb1940	4.98	5	4.84	4.94	4.96263	4.89	4.94	4.86	4.89	4.82	4.99	4.88	4.98	4.98	4.93	4.76	4.75	4.98
45	14Feb1940	4.97	5	4.85	4.94	4.96206	4.89	4.94	4.86	4.89	4.82	4.99	4.87	4.97	4.98	4.93	4.76	4.75	4.99
46	15Feb1940	4.97	5	4.85	4.94	4.96151	4.89	4.94	4.86	4.88	4.82	4.99	4.87	4.97	4.98	4.93	4.76	4.75	5
47	16Feb1940	4.97	5	4.86	4.94	4.96095	4.89	4.94	4.86	4.88	4.81	4.99	4.86	4.97	4.98	4.93	4.74	4.73	5
48	17Feb1940	4.97	5	4.87	4.94	4.96043	4.88	4.94	4.85	4.88	4.81	4.99	4.86	4.97	4.98	4.93	4.74	4.73	5
49	18Feb1940	4.97	5	4.89	4.94	4.95993	4.88	4.94	4.85	4.88	4.81	4.99	4.86	4.97	4.98	4.93	4.75	4.73	5
50	19Feb1940	4.97	5	4.8	4.94	4.95944	4.88	4.94	4.85	4.87	4.8	4.99	4.86	4.97	4.98	4.93	4.75	4.73	8
51	20Feb1940	4.97	5	4.82	4.94	4.959	4.88	4.93	4.85	4.87	4.8	4.99	4.86	4.97	4.98	4.93	4.75	4.72	8.01
52	21Feb1940	4.97	5	4.84	4.94	4.95858	4.88	4.93	4.84	4.87	4.79	4.99	4.86	4.97	4.98	4.93	4.73	4.72	8.01
53	22Feb1940	4.97	5	4.86	4.94	4.95814	4.88	4.93	4.84	4.87	4.79	4.99	4.86	4.97	4.98	4.93	4.73	4.72	8.01
54	23Feb1940	4.97	5	4.77	4.94	4.95767	4.87	4.93	4.84	4.86	4.79	4.99	4.86	4.97	4.98	4.93	4.74	4.72	8.01
55	24Feb1940	4.97	5	4.79	4.94	4.95716	4.87	4.93	4.84	4.86	4.78	4.99	4.86	4.97	4.98	4.93	4.74	4.72	8
56	25Feb1940	4.97	5	4.8	4.94	4.95665	4.87	4.93	4.83	4.86	4.78	4.98	4.86	4.97	4.98	4.93	4.74	4.73	5
57	26Feb1940	4.97	5	4.81	4.94	4.95613	4.87	4.93	4.83	4.86	4.78	4.98	4.85	4.97	4.98	4.93	4.75	4.73	5
58	27Feb1940	4.97	5	4.83	4.94	4.9556	4.87	4.93	4.83	4.85	4.77	4.98	4.85	4.97	4.97	4.93	4.73	4.73	5
59	28Feb1940	4.97	5	4.84	4.94	4.95507	4.87	4.93	4.82	4.85	4.77	4.98	4.85	4.97	4.97	4.93	4.73	4.73	5
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28435	06Nov2017	4.82	7.05	7.05	4.95	4.99311	4.99	4.99	4.99	4.99	4.97	4.99	7.05	4.68	4.87	4.99	7.08	7.1	4.85
28436	07Nov2017	4.82	5	7	4.95	4.99232	4.99	4.99	4.98	4.99	4.97	4.99	5	4.68	4.87	4.99	5	7	4.85
28437	08Nov2017	4.82	5	7.03	4.94	4.99154	4.99	4.98	4.98	4.99	4.96	4.99	5	4.68	4.87	4.99	7	7	4.84
28438	09Nov2017	4.82	5	6.11	4.94	4.99072	4.99	4.98	4.98	4.98	4.96	4.99	5	4.68	4.87	4.99	5	7	4.84
28439	10Nov2017	4.82	5	5.09	4.94	4.98987	4.98	4.98	4.98	4.98	4.95	4.98	5	4.68	4.87	4.99	5	5	4.84
28440	11Nov2017	4.82	5	5.1	4.94	4.98902	4.98	4.98	4.98	4.98	4.95	4.98	5	4.68	4.87	4.99	5	5	4.83
28441	12Nov2017	4.82	5	5.09	4.94	4.98816	4.98	4.97	4.97	4.98	4.95	4.98	4.99	4.68	4.86	4.99	5	5	4.83
28442	13Nov2017	4.82	5	7	4.93	4.9873	4.98	4.97	4.97	4.98	4.95	4.98	4.99	4.68	4.86	4.99	5	5	4.82
28443	14Nov2017	4.82	5	7	4.93	4.98645	4.98	4.97	4.97	4.98	4.95	4.98	4.99	4.68	4.87	4.99	4.98	4.98	4.82
28444	15Nov2017	4.82	5	5.09	4.93	4.9856	4.98	4.97	4.98	4.99	4.94	4.98	4.99	4.68	4.87	4.99	4.99	4.98	4.82
28445	16Nov2017	4.81	5	4.99	4.93	4.98477	4.98	4.97	4.99	5.05	4.94	4.98	4.99	4.68	4.87	4.99	4.96	4.98	4.81
28446	17Nov2017	4.81	5	7	4.93	4.98393	4.98	4.96	4.99	8	4.94	4.98	4.99	4.68	4.87	4.99	4.97	4.96	4.81
28447	18Nov2017	4.81	5	5.08	4.92	4.98311	4.98	4.97	4.98	8	4.94	4.98	4.99	4.68	4.86	4.99	4.97	4.96	4.8
28448	19Nov2017	4.81	5	7	4.92	4.98229	4.97	4.96	4.98	5	4.94	4.98	4.99	4.68	4.86	4.99	4.97	4.96	4.8
28449	20Nov2017	4.81	5	4.97	4.92	4.98147	4.97	4.96	4.98	5	4.94	4.98	4.99	4.68	4.86	4.99	4.95	4.96	4.8
28450	21Nov2017	4.81	5	4.99	4.92	4.98065	4.97	4.96	4.97	4.99	4.93	4.98	4.99	4.68	4.86	4.99	4.95	4.94	4.79
28451	22Nov2017	4.81	5	4.95	4.92	4.97993	4.96	4.96	4.97	4.99	4.93	4.97	4.99	4.68	4.86	4.99	4.92	4.93	4.79
28452	23Nov2017	4.81	5	4.96	4.91	4.97918	4.96	4.95	4.97	4.99	4.93	4.97	4.99	4.68	4.86	4.99	4.93	4.91	4.79
28453	24Nov2017	4.81	5	4.98	4.91	4.97846	4.96	4.95	4.97	4.99	4.93	4.97	4.98	4.68	4.86	4.99	4.9	4.91	4.78
28454	25Nov2017	4.81	5	5	4.91	4.97773	4.95	4.95	4.96	4.99	4.93	4.97	4.98	4.68	4.86	4.99	4.91	4.91	4.78
28455	26Nov2017	4.8	5	7	4.91	4.9773	4.95	4.95	4.96	4.98	4.92	4.97	4.98	4.67	4.86	4.99	4.91	4.91	4.77
28456	27Nov2017	4.8	5	4.93	4.9	4.97688	4.96	4.94	4.96	4.98	4.92	4.97	4.98	4.67	4.86	4.99	4.91	4.89	4.77
28457	28Nov2017	4.81	5	4.94	4.9	4.97631	4.96	4.94	4.96	4.98	4.92	4.97	4.98	4.67	4.86	5	4.89	4.89	4.77
28458	29Nov2017	4.81	5	4.94	4.9	4.97584	4.96	4.94	4.96	4.97	4.92	4.97	4.98	4.67	4.85	5	4.89	4.89	4.76
28459	30Nov2017	4.8	5	4.96	4.9	4.97532	4.96	4.94	4.96	4.97	4.92	4.97	4.98	4.67	4.85	5	4.89	4.89	4.76
28460	01Dec2017	4.8	5	4.99	4.9	4.97473	4.96	4.94	4.96	4.97	4.91	4.97	4.98	4.67	4.85	5	4.87	4.87	4.76
28461	02Dec2017	4.8	5	5.07	4.9	4.97417	4.96	4.93	4.96	4.97	4.91	4.97	4.97	4.67	4.85	5	4.88	4.87	4.75
28462	03Dec2017	4.8	5	5.08	4.9	4.97362	4.96	4.93	4.96	4.97	4.91	4.97	4.97	4.67	4.85	5	4.88	4.87	4.75
28463	04Dec2017	4.8	5	4.94	4.89	4.97357	4.96	4.93	4.96	4.99	4.91	4.97	4.97	4.67	4.85	5	4.89	4.87	4.75
28464	05Dec2017	4.8	5	4.89	4.89	4.97314	4.96	4.93	4.97	5.08	4.91	4.97	4.97	4.66	4.85	5	4.86	4.85	4.75
28465	06Dec2017	4.8	5	4.92	4.89	4.97268	4.96	4.93	4.97	6.24	4.91	4.97	4.97	4.66	4.85	5	4.87	4.85	4.74
28466	07Dec2017	4.8	5	4.93	4.89	4.972	4.96	4.92	4.97	5	4.9	4.96	4.97	4.66	4.85	5	4.87	4.83	4.74
28467	08Dec2017	4.8	5	4.89	4.89	4.97122	4.96	4.92	4.97	5	4.9	4.96	4.97	4.66	4.85	5	4.85	4.83	4.73
28468	09Dec2017	4.8	5	4.91	4.88	4.97042	4.95	4.92	4.96	5.02	4.9	4.96	4.97	4.66	4.85	5	4.85	4.83	4.73
28469	10Dec2017	4.8	5	4.92	4.88	4.96961	4.95	4.92	4.96	5	4.89	4.96	4.96	4.66	4.85	5	4.85	4.82	4.73
28470	11Dec2017	4.79	5	4.86	4.88	4.96886	4.94	4.91	4.96	5	4.89	4.96	4.96	4.66	4.84	5	4.83	4.8	4.72
28471	12Dec2017	4.79	5	4.87	4.88	4.96808	4.94	4.91	4.96	5	4.89	4.96	4.96	4.66	4.84	5	4.83	4.8	4.72
28472	13Dec2017	4.79	5	4.89	4.88	4.96731	4.94	4.91	4.96	8	4.88	4.96	4.96	4.66	4.84	5	4.81	4.78	4.72
28473	14Dec2017	4.79	5	4.85	4.88	4.96649	4.93	4.91	4.96	8	4.88	4.96	4.96	4.65	4.84	5	4.81	4.78	4.71
28474	15Dec2017	4.79	5	4.89	4.87	4.96567	4.93	4.91	4.96	8	4.88	4.96	4.96	4.65	4.84	5	4.79	4.76	4.71
28475	16Dec2017	4.79	5	4.91	4.87	4.96486	4.93	4.9	4.95	8	4.88	4.96	4.96	4.65	4.84	5	4.79	4.76	4.71
28476	17Dec2017	4.79	5	4.93	4.87	4.96405	4.94	4.9	4.96	5	4.88	4.96	4.96	4.65	4.84	5	4.79	4.76	4.71
28477	18Dec2017	4.79	5	4.85	4.87	4.96325	4.94	4.9	4.96	5.02	4.88	4.96	4.95	4.65	4.84	5	4.77	4.74	4.71
28478	19Dec2017	4.79	5	4.87	4.87	4.96245	4.94	4.9	4.97	7.89	4.88	4.96	4.95	4.65	4.85	5	4.77	4.74	4.72
28479	20Dec2017	4.79	5	4.89	4.86	4.96164	4.94	4.89	4.97	8	4.88	4.96	4.95	4.65	4.85	5	4.78	4.74	4.72
28480	21Dec2017	4.79	5	4.82	4.86	4.96084	4.94	4.89	4.96	5	4.87	4.96	4.96	4.65	4.85	5	4.76	4.72	4.72
28481	22Dec2017	4.78	5	4.84	4.86	4.96004	4.94	4.89	4.96	5	4.87	4.95	4.96	4.65	4.85	5	4.76	4.72	4.75
28482	23Dec2017	4.78	5	4.86	4.86	4.95927	4.93	4.89	4.96	8	4.87	4.95	4.96	4.65	4.84	5	4.77	4.72	4.78
28483	24Dec2017	4.78	5	4.87	4.86	4.95849	4.93	4.89	4.95	8	4.86	4.95	4.96	4.65	4.84	5	4.77	4.72	4.81
28484	25Dec2017	4.78	5	4.79	4.85	4.95769	4.92	4.88	4.95	5.03	4.86	4.95	4.96	4.65	4.84	5	4.75	4.72	4.83
28485	26Dec2017	4.78	5	4.8	4.85	4.95689	4.92	4.88	4.95	5.04	4.86	4.95	4.96	4.65	4.84	5	4.74	4.7	4.84
28486	27Dec2017	4.78	5	4.81	4.85	4.95608	4.91	4.88	4.95	5.03	4.85	4.95	4.96	4.65	4.84	5	4.74	4.7	4.85
28487	28Dec2017	4.78	5	4.74	4.85	4.95529	4.91	4.88	4.94	5.03	4.85	4.95	4.95	4.65	4.84	5	4.72	4.68	4.85
28488	29Dec2017	4.78	5	4.75	4.85	4.9545	4.91	4.88	4.94	5	4.85	4.95	4.95	4.65	4.84	5	4.7	4.68	4.86
28489	30Dec2017	4.78	5	4.76	4.85	4.95371	4.9	4.87	4.94	5.04	4.84	4.95	4.95	4.64	4.84	5	4.71	4.68	4.86
28490	31Dec2017	4.78	5	4.78	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	5	4.71	4.68	4.86
28491	01Jan2018	4.78	7	4.8	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8	4.71	4.68	4.87
28492	02Jan2018	4.78	7.01	4.83	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8	4.71	4.68	4.87
28493	03Jan2018	4.78	7.01	4.84	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28494	04Jan2018	4.78	7.01	4.85	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28495	05Jan2018	4.78	7.01	4.85	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28496	06Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28497	07Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28498	08Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28499	09Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87

Pensacola

Elevation ft PD	Area acre	Storage acre-ft
612	0	0
613	1	0.3
614	6	3.5
615	30	15
616	36	48
617	42	86
618	51	132
619	66	190
620	128	269
621	144	406
622	158	556
623	174	722
624	196	906
625	269	1126
626	298	1411
627	329	1724
628	365	2070
629	402	2453
630	471	2879
631	502	3366
632	529	3882
633	556	4425
634	587	4996
635	653	5601
636	687	6270
637	728	6977
638	781	7731
639	837	8539
640	924	9408
641	967	10354
642	1007	11341
643	1054	12371
644	1105	13450
645	1231	14594
646	1328	15876
647	1420	17250
648	1531	18723
649	1658	20317
650	1863	22045
651	1995	23978
652	2118	26035
653	2226	28209
654	2335	30489
655	2500	32884
656	2608	35441
657	2721	38105
658	2834	40883
659	2956	43776
660	3137	46798
661	3277	50008
662	3407	53350
663	3544	56826
664	3699	60446
665	3954	64239
666	4160	68300
667	4350	72556
668	4537	77000
669	4741	81636
670	5029	86486
671	5249	91629
672	5459	96984
673	5674	102550
674	5896	108336
675	6189	114350
676	6454	120680
677	6678	127249
678	6904	134040
679	7136	141059
680	7442	148319
681	7687	155888
682	7934	163699
683	8201	171765
684	8484	180108
685	8854	188752
686	9195	197780
687	9535	207146
688	9860	216848
689	10160	226859
690	10533	237178
691	10828	247869
692	11112	258838
693	11420	270099
694	11747	281679
695	12154	293602

Elevation ft PD	OPLEVEL 1 - 16.1
612	1
705.5	2
705.5001	3
727.8	4
742	5
742.0001	6
742.0002	7
742.0003	8
743.49	9
746.52	10
749.21	11
751.66	12
753.92	13
755	14
755.6	15
757	16
758	16.1

Elevation ft PD	Max Regulated Spill cfs	Induced Surcharge cfs
612	0	0
633	0	0
730	1	0
735	47200	0
740	84500	0
742	117000	0
745.01	190000	0
745.5	204000	0
745.95	217000	0
748	278000	0
752.4	422000	0
754	484000	0
754.8	515000	13500
754.85	518000	50000
754.9	520800	100000
754.95	523700	200000
754.98	525400	300000
754.99	526000	500000
755	527000	525000
756	557000	550000
756.7	567200	567200
757	614900	614900
758	700000	700000

Hudson

Elevation ft M.S.L.	Area acre	Storage acre-ft
558	0	0
559	1	1
560	1.5	2
561	2	3
562	9	8
563	22	23
564	59	57
565	74	127
566	80	204
567	93	290
568	119	395
569	184	535
570	221	745
571	240	975
572	262	1226
573	289	1501
574	337	1807
575	367	2164
576	391	2543
577	421	2948
578	459	3388
579	563	3876
580	641	4492
581	686	5156
582	733	5865
583	788	6624
584	916	7450
585	1040	8446
586	1137	9530
587	1251	10721
588	1429	12066
589	1807	13601
590	2143	15618
591	2399	17892
592	2615	20396
593	2860	23141
594	3210	26121
595	3515	29513
596	3751	33157
597	3987	37015
598	4269	41153
599	4693	45579
600	5019	50470
601	5238	55603
602	5464	60952
603	5690	66529
604	6160	72390
605	6525	78771
606	6782	85426
607	7033	92334
608	7300	99500
609	7717	106953
610	8101	114904
611	8366	123135
612	8633	131636
613	8905	140403
614	9309	149470
615	9687	159000
616	9976	168833
617	10277	178951
618	10608	189382
618.5	10819	194784
619	11029	200185
620	11210	211304
621	11570	222694
622	11930	234443
623	12300	246558
624	12670	259042
625	13065	271909
626	13460	285171
627	13880	298841
628	14300	312930
629	14800	327480
630	15300	342529
631	15855	358106
632	16410	374237
633	16975	390929
634	17540	408186
635	18145	426027
636	18750	444474
637	19440	463568
638	20130	483352
639	20880	503856
640	21630	525110

Elevation ft M.S.L.	OPLEVEL 1 - 16.1
558	1
618.5	2
618.5	3
618.5	4
619	5
619.001	6
619.002	7
619.003	8
621.16	9
625.12	10
628.65	11
631.81	12
634.66	13
636	14
636.001	15
645	16
648	16.1

Elevation ft M.S.L.	Max Regulated Spill cfs	Induced Surcharge cfs
558	0	0
599	29000	0
610	82800	0
619	220000	0
624	315000	0
630	449000	0
633	527500	0
635	583100	70000
635.43	594000	85000
635.77	606000	100000
635.94	611000	360000
635.99	612000	500000
636	613000	613000
645	884000	884000
648	974333	974333

Pensacola

Elevation ft PD	Area acre	Storage acre-ft	Elevation ft PD	OPLEVEL 1 - 16.1	Elevation ft PD	Max Regulated Spill cfs	Induced Surcharge cfs
696	12490	305932					
697	12813	318584					
698	13142	331561					
699	13487	344873					
700	13934	358558					
701	14259	372661					
702	14550	387069					
703	14846	401769					
704	15157	416769					
705	15584	432106					
706	15921	447863					
707	16263	463955					
708	16629	480402					
709	17016	497224					
710	17556	514468					
711	18036	532267					
712	18520	550554					
713	18986	569302					
714	19509	588551					
715	20190	608359					
716	20726	628825					
717	21262	649820					
718	21830	671364					
719	22478	693521					
720	23244	716333					
721	23859	739896					
722	24443	764054					
723	25007	788782					
724	25592	814081					
725	26354	840006					
726	26991	866684					
727	27655	894007					
728	28359	922021					
729	29035	950728					
730	29745	980096					
731	30386	1010168					
732	31052	1040888					
733	31788	1072304					
734	32607	1104503					
735	33530	1137530					
736	34275	1171445					
737	34989	1206086					
738	35760	1241453					
739	36638	1277662					
740	37788	1314761					
741	38918	1353101					
742	40021	1392678					
743	40636	1433025					
744	41221	1473920					
745	41779	1515412					
746	43551	1558073					
747	45323	1602507					
748	47095	1648714					
749	48867	1696692					
750	50639	1746443					
751	52411	1797965					
752	54184	1851261					
753	55956	1906328					
754	57728	1963167					
755	59300	2021679					
756	61100	2081877					
757	62950	2143900					
758	64800	2207773					

Hudson

Elevation ft M.S.L.	Area acre	Storage acre-ft	Elevation ft M.S.L.	OPLEVEL 1 - 16.1	Elevation ft M.S.L.	Max Regulated Spill cfs	Induced Surcharge cfs
641	22375	547111					
642	23120	569858					
643	23870	593352					
644	24620	617596					
645	25400	642605					
648	27910	722482					

Parsons-Commerce

Routing Coefficients	
Lag	Coeff
1	0.353
2	0.4568
3	0.1344
4	0.0395
5	0.0116
6	0.0034
7	0.001
8	0.0003

Commerce-Pensacola

Routing Coefficients	
Lag	Coeff
1	0.6
2	0.4

Pensacola-Hudson

Routing Coefficients	
Lag	Coeff
1	1

Hudson-Ft Gibson

Routing Coefficients	
Lag	Coeff
1	1

Appendix B. Operations Model Input Data

HEAD LOSS CALCULATIONS - 1 OF 6

Component	Pipe Size (ft)	Description	Reference for Headloss Estimation	Minor Losses Kv	A (ft^2)	L (ft)	Total Headloss Kq	Q (cfs)	hL (ft)
Trashrack	---	Trashrack losses neglected: very large area, low velocity	---	---	---	---	---	---	---
Inlet	15x15	Standard sharp-edged inlet loss	---	0.50	225.00	---	1.54E-07	2505	0.96
Contraction: 15' sq. to 15' diam.	15	Area 1 = 225.0 ft^2; Area 2 = 176.7 ft^2; A2/A1 = 0.78	[USACE HDC 228 - 4]	0.07	176.71	---	3.49E-08	2505	0.22
42° bend	15	r = 75'; Assume r/D=5	[USACE HDC 228-1]	0.075	176.71	---	3.74E-08	2505	0.23
Butterfly Valve	15	15' Diameter Butterfly Valve	[USACE HDC 331-1]	0.34	176.71	---	1.68E-07	2505	1.06
Penstock Friction	15	194' +/- Total Length	Darcy-Weisbach	---	---	194	5.58E-08	2505	0.35
						Totals:	4.50E-07	2505	2.82

Governing Equations:

$H = Q^2/(C^2 * A^2 * 2g)$

$Q = C * A * (2gH)^{1/2}$

$A = B * Go$

$H = Kv * V^2/(2g)$

$Q = A * (2gH/Kv)^{1/2}$

$Kv = 1/C^2$

$H = Q^2 * Kq$

$Q = (H/Kq)^{1/2}$

$Kq = 1/(C^2 * A^2 * 2g)$

where:

H = energy head immediately upstream of gate, measured to centerlin

Q = gate discharge (cfs)

A = open area of gate (ft^2)

B = gate width (feet)

Go = gate vertical opening (feet)

V = velocity through open area of gate (ft/s)

C = discharge coefficient

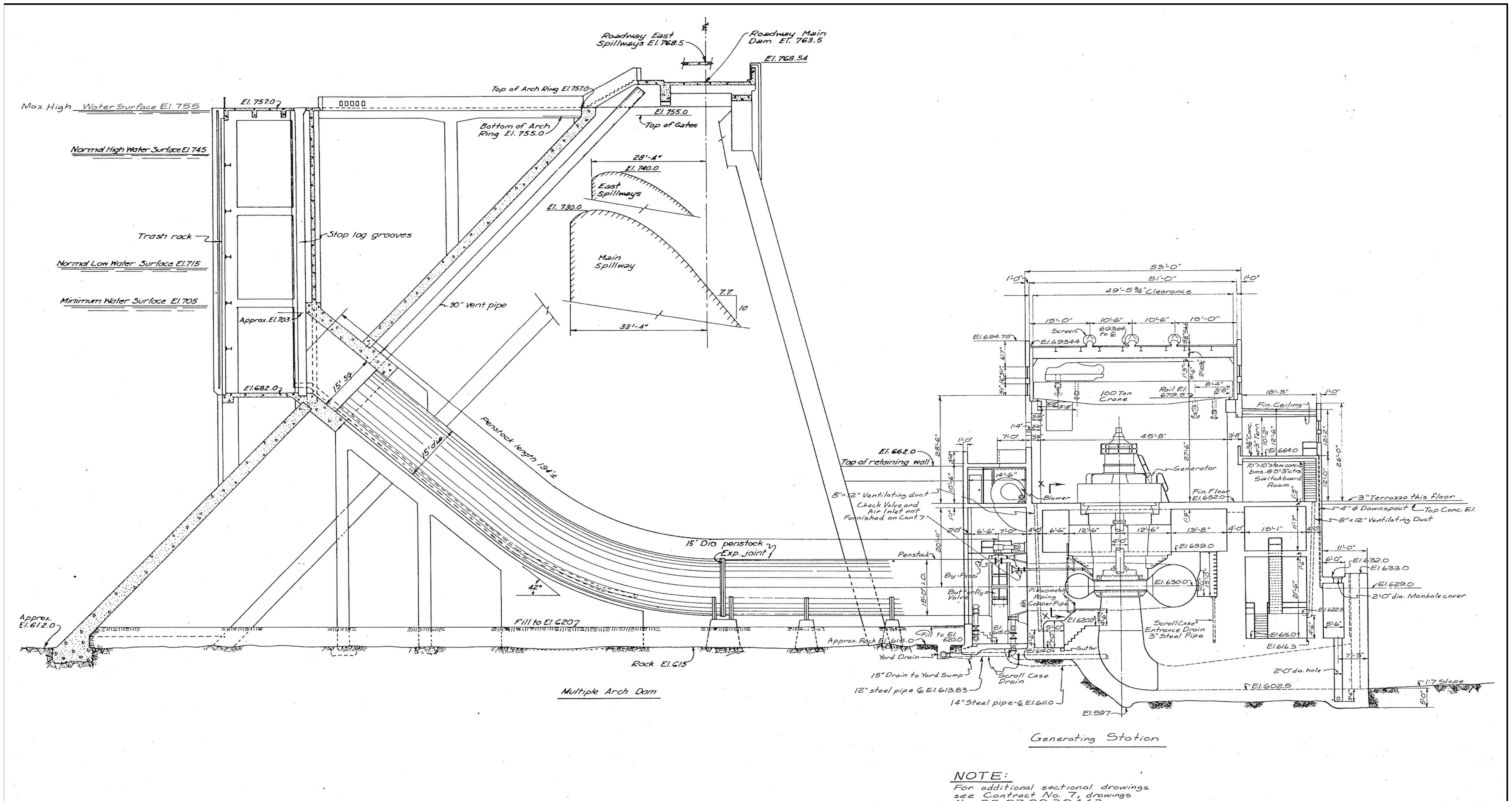
Kv = gate valve loss coefficient (velocity-based)

Kq = gate valve loss coefficient (discharge-based)

g (gravity constant) = 32.146 ft/s^2 [HDC 000-1]

Site Latitude = 36.5 deg

Site Elevation = 750 feet



Darcy-Weisbach Resistance Coefficients for Various Pipe Sizes and Discharges

Discharge (cfs)	Conduit Diameter (feet)	Gravity Constant (ft/s^2)	Wetted Area (ft^2)	Wetted Perimeter (feet)	Hydraulic Diameter (feet)	Velocity (ft/sec)	Fluid Type 3	Kinematic Viscosity ft^2/s	Density slugs/ft^3	Specific Weight lbf/ft^3	Reynolds Number (Re)	Conduit Material 2	Roughness (feet)	Relative Roughness	Laminar Zone (*f*)	Critical Zone (*f*)
1	**15**	32.14577	176.71	47.12	15	0.0	Water, 50° F	1.41E-05	1.94	62.36	6.03E+03	Steel or wrought Iron	0.00015	1.00E-05	0.010609	indeterminate
2	15	32.14577	176.71	47.12	15	0.0		1.41E-05	1.94	62.36	1.21E+04		0.00015	1.00E-05	0.005304	indeterminate
3	15	32.14577	176.71	47.12	15	0.0		1.41E-05	1.94	62.36	1.81E+04		0.00015	1.00E-05	0.003536	indeterminate
10	15	32.14577	176.71	47.12	15	0.1		1.41E-05	1.94	62.36	6.03E+04		0.00015	1.00E-05	0.001061	indeterminate
20	15	32.14577	176.71	47.12	15	0.1		1.41E-05	1.94	62.36	1.21E+05		0.00015	1.00E-05	0.000530	indeterminate
30	15	32.14577	176.71	47.12	15	0.2		1.41E-05	1.94	62.36	1.81E+05		0.00015	1.00E-05	0.000354	indeterminate
40	15	32.14577	176.71	47.12	15	0.2		1.41E-05	1.94	62.36	2.41E+05		0.00015	1.00E-05	0.000265	indeterminate
50	15	32.14577	176.71	47.12	15	0.3		1.41E-05	1.94	62.36	3.02E+05		0.00015	1.00E-05	0.000212	indeterminate
75	15	32.14577	176.71	47.12	15	0.4		1.41E-05	1.94	62.36	4.52E+05		0.00015	1.00E-05	0.000141	indeterminate
100	15	32.14577	176.71	47.12	15	0.6		1.41E-05	1.94	62.36	6.03E+05		0.00015	1.00E-05	0.000106	indeterminate
150	15	32.14577	176.71	47.12	15	0.8		1.41E-05	1.94	62.36	9.05E+05		0.00015	1.00E-05	0.000071	indeterminate
200	15	32.14577	176.71	47.12	15	1.1		1.41E-05	1.94	62.36	1.21E+06		0.00015	1.00E-05	0.000053	indeterminate
400	15	32.14577	176.71	47.12	15	2.3		1.41E-05	1.94	62.36	2.41E+06		0.00015	1.00E-05	0.000027	indeterminate
600	15	32.14577	176.71	47.12	15	3.4		1.41E-05	1.94	62.36	3.62E+06		0.00015	1.00E-05	0.000018	indeterminate
800	15	32.14577	176.71	47.12	15	4.5		1.41E-05	1.94	62.36	4.83E+06		0.00015	1.00E-05	0.000013	indeterminate
1000	15	32.14577	176.71	47.12	15	5.7		1.41E-05	1.94	62.36	6.03E+06		0.00015	1.00E-05	0.000011	indeterminate
1200	15	32.14577	176.71	47.12	15	6.8		1.41E-05	1.94	62.36	7.24E+06		0.00015	1.00E-05	0.000009	indeterminate
1400	15	32.14577	176.71	47.12	15	7.9		1.41E-05	1.94	62.36	8.45E+06		0.00015	1.00E-05	0.000008	indeterminate
1600	15	32.14577	176.71	47.12	15	9.1		1.41E-05	1.94	62.36	9.65E+06		0.00015	1.00E-05	0.000007	indeterminate
1800	15	32.14577	176.71	47.12	15	10.2		1.41E-05	1.94	62.36	1.09E+07		0.00015	1.00E-05	0.000006	indeterminate
2000	15	32.14577	176.71	47.12	15	11.3		1.41E-05	1.94	62.36	1.21E+07		0.00015	1.00E-05	0.000005	indeterminate
2200	15	32.14577	176.71	47.12	15	12.4		1.41E-05	1.94	62.36	1.33E+07		0.00015	1.00E-05	0.000005	indeterminate
2400	15	32.14577	176.71	47.12	15	13.6		1.41E-05	1.94	62.36	1.45E+07		0.00015	1.00E-05	0.000004	indeterminate
2600	15	32.14577	176.71	47.12	15	14.7		1.41E-05	1.94	62.36	1.57E+07		0.00015	1.00E-05	0.000004	indeterminate
2800	15	32.14577	176.71	47.12	15	15.8		1.41E-05	1.94	62.36	1.69E+07		0.00015	1.00E-05	0.000004	indeterminate
3000	15	32.14577	176.71	47.12	15	17.0		1.41E-05	1.94	62.36	1.81E+07		0.00015	1.00E-05	0.000004	indeterminate

Smooth Pipes				Transition Zone							
Guess Value (*f*)	Left Half Equation	Right Half Equation	Difference (<0.001)	Guess Value (*f*)	Left Half Equation	Right Half Equation	Difference (<0.001)	Rough Pipes (*f*)	Rough Pipe Limit (Re)	Flow Regime	Selected Coeff. (*f*)
0.035456	5.31074	5.31074	0.0000	0.035461	5.31039	5.31039	0.0000	0.008061	2.23E+08	Transition	0.035461
0.029406	5.83154	5.83154	0.0000	0.029417	5.83044	5.83044	0.0000	0.008061	2.23E+08	Transition	0.029417
0.026533	6.13908	6.13908	0.0000	0.026549	6.13726	6.13726	0.0000	0.008061	2.23E+08	Transition	0.026549
0.020045	7.06306	7.06306	0.0000	0.020082	7.05659	7.05659	0.0000	0.008061	2.23E+08	Transition	0.020082
0.017307	7.60133	7.60133	0.0000	0.017364	7.58876	7.58875	0.0000	0.008061	2.23E+08	Transition	0.017364
0.015950	7.91805	7.91806	0.0000	0.016024	7.89967	7.89967	0.0000	0.008061	2.23E+08	Transition	0.016024
0.015079	8.14354	8.14354	0.0000	0.015168	8.11954	8.11954	0.0000	0.008061	2.23E+08	Transition	0.015168
0.014450	8.31886	8.31886	0.0000	0.014553	8.28939	8.28939	0.0000	0.008061	2.23E+08	Transition	0.014553
0.013401	8.63831	8.63831	0.0000	0.013535	8.59563	8.59563	0.0000	0.008061	2.23E+08	Transition	0.013535
0.012723	8.86563	8.86563	0.0000	0.012883	8.81025	8.81025	0.0000	0.008061	2.23E+08	Transition	0.012883
0.011848	9.18689	9.18689	0.0000	0.012057	9.10727	9.10727	0.0000	0.008061	2.23E+08	Transition	0.012057
0.011280	9.41543	9.41543	0.0000	0.011530	9.31274	9.31274	0.0000	0.008061	2.23E+08	Transition	0.011530
0.010064	9.96796	9.96796	0.0000	0.010452	9.78138	9.78138	0.0000	0.008061	2.23E+08	Transition	0.010452
0.009440	10.29232	10.29233	0.0000	0.009937	10.03147	10.03147	0.0000	0.008061	2.23E+08	Transition	0.009937
0.009031	10.52295	10.52295	0.0000	0.009621	10.19489	10.19489	0.0000	0.008061	2.23E+08	Transition	0.009621
0.008731	10.70211	10.70211	0.0000	0.009403	10.31245	10.31245	0.0000	0.008061	2.23E+08	Transition	0.009403
0.008497	10.84866	10.84866	0.0000	0.009242	10.40205	10.40205	0.0000	0.008061	2.23E+08	Transition	0.009242
0.008306	10.97268	10.97268	0.0000	0.009117	10.47306	10.47306	0.0000	0.008061	2.23E+08	Transition	0.009117
0.008145	11.08020	11.08019	0.0000	0.009017	10.53095	10.53095	0.0000	0.008061	2.23E+08	Transition	0.009017
0.008008	11.17509	11.17509	0.0000	0.008935	10.57918	10.57918	0.0000	0.008061	2.23E+08	Transition	0.008935
0.007887	11.26003	11.26003	0.0000	0.008866	10.62006	10.62006	0.0000	0.008061	2.23E+08	Transition	0.008866
0.007781	11.33691	11.33691	0.0000	0.008808	10.65521	10.65521	0.0000	0.008061	2.23E+08	Transition	0.008808
0.007685	11.40712	11.40712	0.0000	0.008758	10.68577	10.68577	0.0000	0.008061	2.23E+08	Transition	0.008758
0.007599	11.47174	11.47174	0.0000	0.008714	10.71262	10.71262	0.0000	0.008061	2.23E+08	Transition	0.008714
0.007520	11.53159	11.53159	0.0000	0.008675	10.73640	10.73640	0.0000	0.008061	2.23E+08	Transition	0.008675
0.007448	11.58733	11.58733	0.0000	0.008641	10.75763	10.75763	0.0000	0.008061	2.23E+08	Transition	0.008641

-Weisbach Resistanc	
Discharge (cfs)	15' Dia. Steel
0	*0.03546*
1	0.03546
2	0.02942
3	0.02655
10	0.02008
20	0.01736
30	0.01602
40	0.01517
50	0.01455
75	0.01353
100	0.01288
150	0.01206
200	0.01153
400	0.01045
600	0.00994
800	0.00962
1000	0.00940
1200	0.00924
1400	0.00912
1600	0.00902
1800	0.00894
2000	0.00887
2200	0.00881
2400	0.00876
2600	0.00871
2800	0.00868
3000	0.00864
99999	*0.00864*
D_h =	15

d Friction Slope Factors	
Discharge (cfs)	15' Dia. Steel
0	0.00E+00
1	1.17E-09
2	3.87E-09
3	7.87E-09
10	6.61E-08
20	2.29E-07
30	4.75E-07
40	7.99E-07
50	1.20E-06
75	2.51E-06
100	4.24E-06
150	8.93E-06
200	1.52E-05
400	5.51E-05
600	1.18E-04
800	2.03E-04
1000	3.10E-04
1200	4.38E-04
1400	5.88E-04
1600	7.60E-04
1800	9.53E-04
2000	1.17E-03
2200	1.40E-03
2400	1.66E-03
2600	1.94E-03
2800	2.24E-03
3000	2.56E-03
99999	*2.56E-03*
D_h =	15

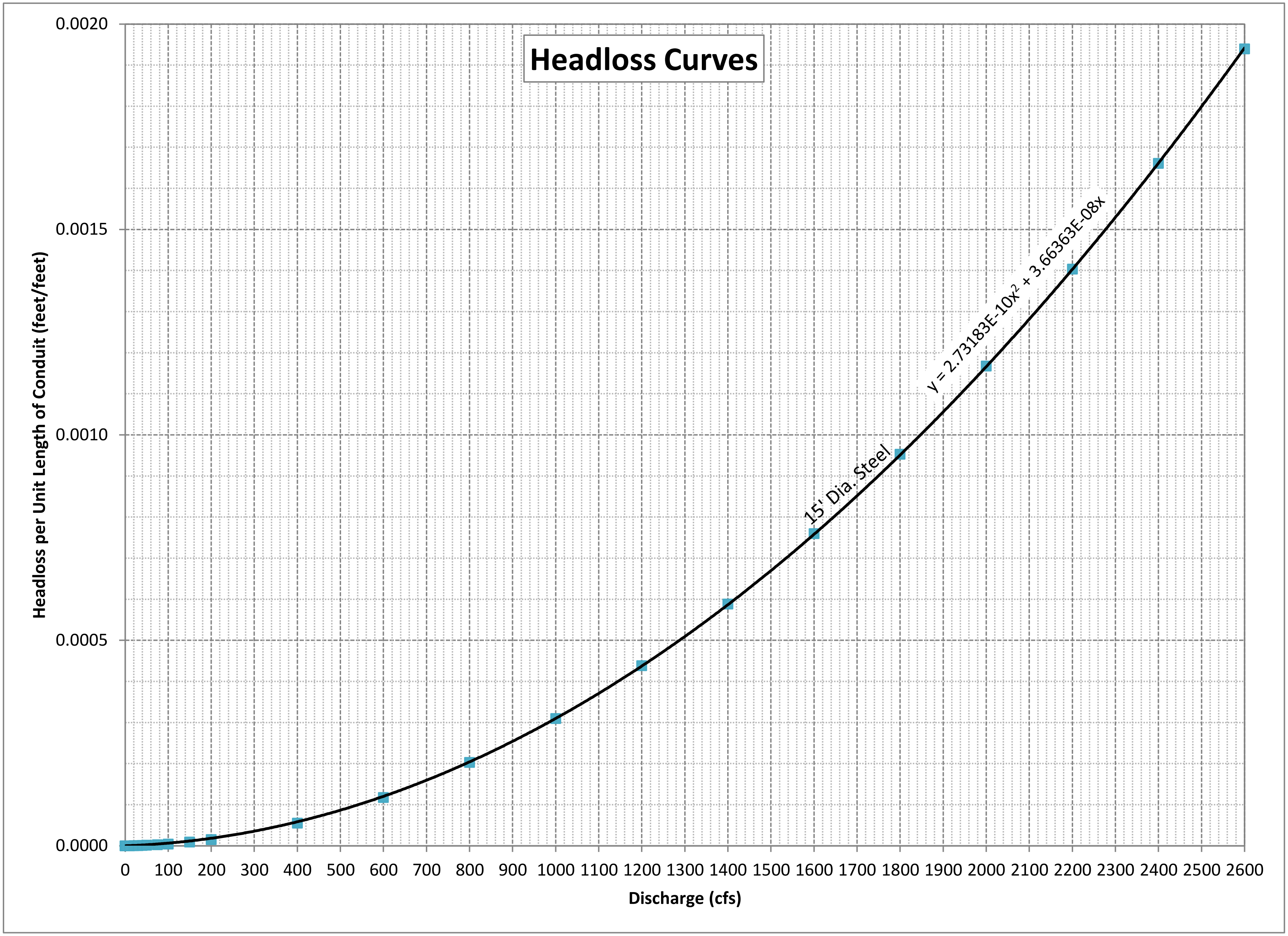
eadloss Coefficients (K	
Discharge (cfs)	15' Dia. Steel
0	1.17E-09
1	1.17E-09
2	9.68E-10
3	8.74E-10
10	6.61E-10
20	5.72E-10
30	5.28E-10
40	4.99E-10
50	4.79E-10
75	4.46E-10
100	4.24E-10
150	3.97E-10
200	3.80E-10
400	3.44E-10
600	3.27E-10
800	3.17E-10
1000	3.10E-10
1200	3.04E-10
1400	3.00E-10
1600	2.97E-10
1800	2.94E-10
2000	2.92E-10
2200	2.90E-10
2400	2.88E-10
2600	2.87E-10
2800	2.86E-10
3000	2.84E-10
99999	*2.84E-10*
D_h =	15

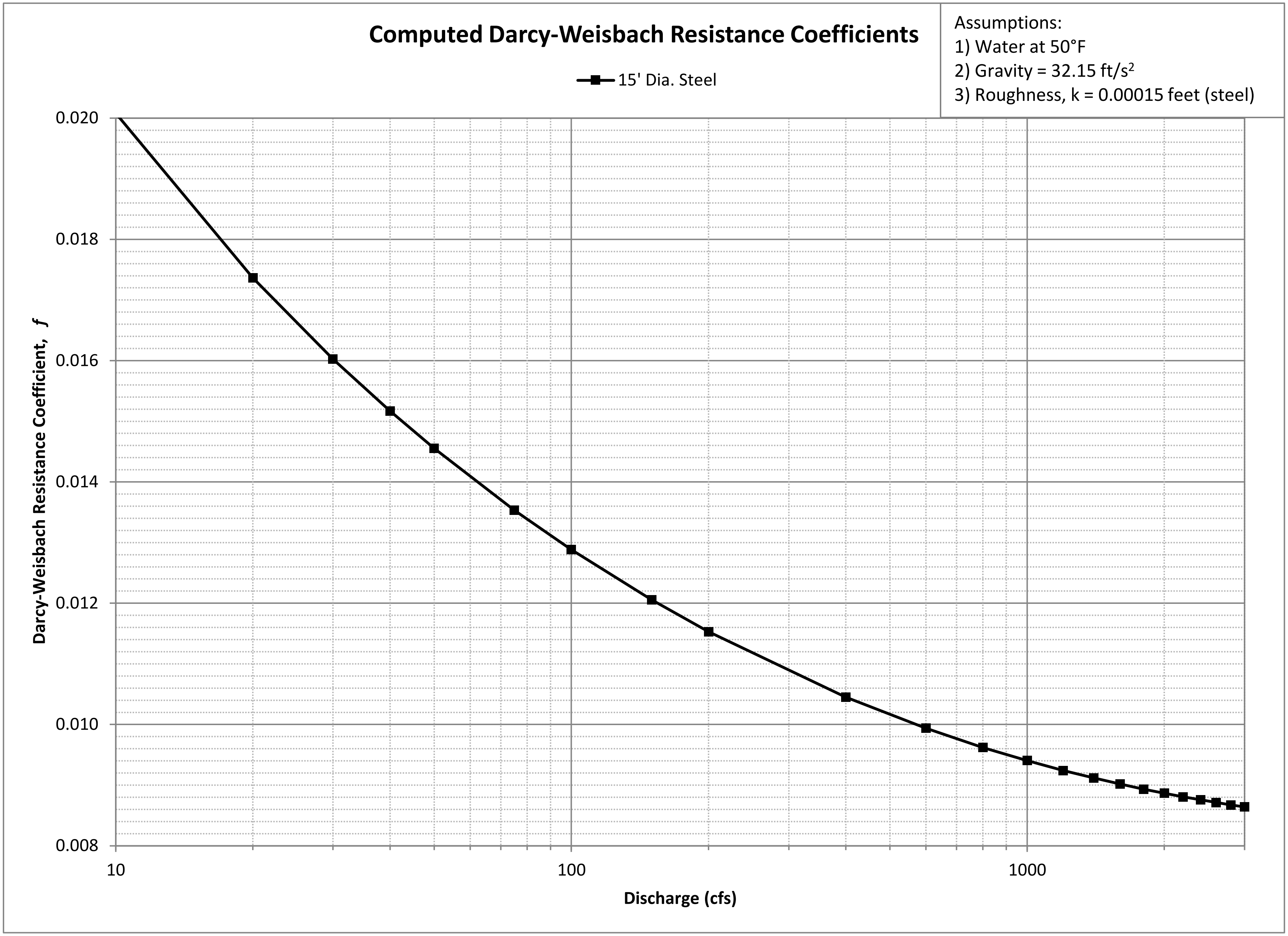
loss per Unit Length of Co	
Discharge (cfs)	15' Dia. Steel
0	0.00E+00
1	1.17E-09
2	3.87E-09
3	7.87E-09
10	6.61E-08
20	2.29E-07
30	4.75E-07
40	7.99E-07
50	1.20E-06
75	2.51E-06
100	4.24E-06
150	8.93E-06
200	1.52E-05
400	5.51E-05
600	1.18E-04
800	2.03E-04
1000	3.10E-04
1200	4.38E-04
1400	5.88E-04
1600	7.60E-04
1800	9.53E-04
2000	1.17E-03
2200	1.40E-03
2400	1.66E-03
2600	1.94E-03
2800	2.24E-03
3000	2.56E-03
99999	2.84E+00
D_h =	15

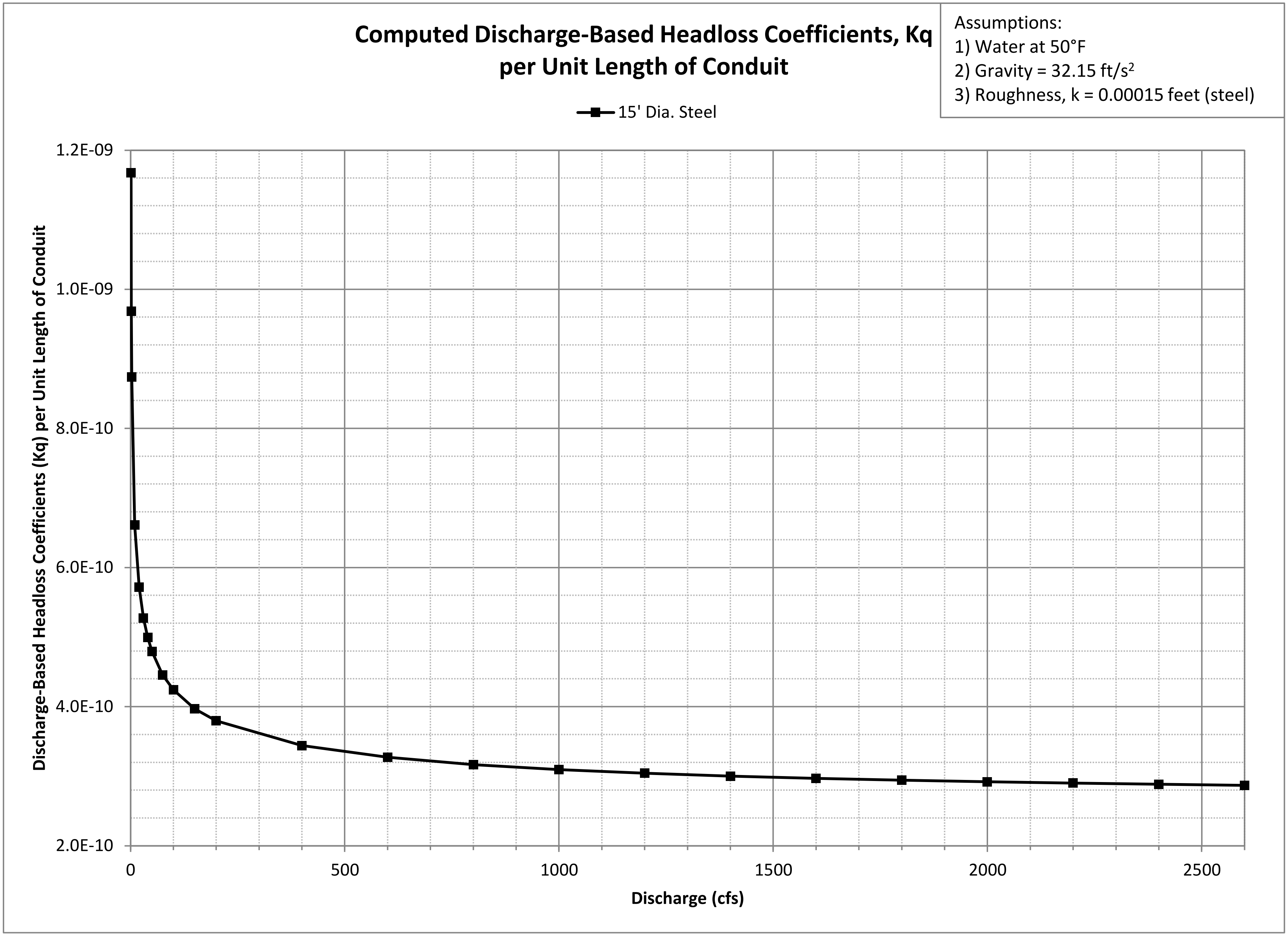
$y=ax^2+bx$; where y=headloss per foot, x=discharge, and a/b are constants determined from trendline equation

a = 2.73183E-10

b = 3.66363E-08


Headloss Curves
Headloss per Unit Length of Conduit (feet/feet)
0.0020
0.0015
0.0010
0.0005
0.0000
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Discharge (cfs)
15' Dia. Steel
y = 2.73183E-10x2 + 3.66363E-08x


Computed Darcy-Weisbach Resistance Coefficients
15' Dia. Steel
Assumptions:
1) Water at 50°F
2) Gravity = 32.15 ft/s²
3) Roughness, k = 0.00015 feet (steel)
Darcy-Weisbach Resistance Coefficient, f
0.020
0.018
0.016
0.014
0.012
0.010
0.008
10
100
1000
Discharge (cfs)


Computed Discharge-Based Headloss Coefficients, Kq
per Unit Length of Conduit
Assumptions:
1) Water at 50°F
2) Gravity = 32.15 ft/s²
3) Roughness, k = 0.00015 feet (steel)
15' Dia. Steel
1.2E-09
1.0E-09
8.0E-10
6.0E-10
4.0E-10
2.0E-10
0
500
1000
1500
2000
2500
Discharge (cfs)
Discharge-Based Headloss Coefficients (Kq) per Unit Length of Conduit

Pensacola Turbine-Generator Efficiency Hill Curve with Air Valves Closed

Discharge (cfs)	Total Turbine-Generator Efficiency (%) vs. Net Head (ft)												
	0	95	100	105	110	115	117.5	120	125	130	135	140	999
0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
700	0.0%	60.6%	54.1%	47.3%	40.4%	32.9%	28.3%	23.9%	16.2%	12.9%	12.2%	11.6%	0.0%
750	0.0%	68.2%	63.5%	56.2%	50.6%	45.1%	42.4%	39.7%	34.6%	31.9%	31.3%	30.6%	0.0%
800	0.0%	72.6%	72.0%	66.4%	60.9%	55.4%	52.7%	50.2%	47.2%	46.0%	45.6%	45.2%	0.0%
850	0.0%	74.8%	75.1%	74.5%	71.8%	65.9%	63.2%	61.5%	58.5%	57.7%	57.4%	57.0%	0.0%
900	0.0%	76.5%	77.0%	77.0%	75.7%	73.9%	73.4%	72.5%	69.9%	69.6%	69.2%	68.9%	0.0%
950	0.0%	77.7%	78.4%	78.6%	77.9%	76.4%	76.0%	75.5%	74.8%	74.4%	74.3%	74.3%	0.0%
1000	0.0%	78.7%	79.6%	79.9%	79.4%	78.3%	77.8%	77.5%	76.6%	76.0%	75.7%	75.5%	0.0%
1050	0.0%	79.3%	80.4%	81.0%	80.6%	79.7%	79.4%	79.0%	78.1%	77.4%	77.0%	76.7%	0.0%
1100	0.0%	79.7%	80.8%	81.6%	81.5%	80.9%	80.6%	80.2%	79.5%	78.7%	78.3%	77.9%	0.0%
1150	0.0%	80.0%	81.2%	81.9%	82.2%	81.8%	81.6%	81.3%	80.6%	80.0%	79.5%	79.1%	0.0%
1200	0.0%	80.4%	81.4%	82.2%	82.9%	82.6%	82.3%	82.1%	81.7%	81.1%	80.6%	80.2%	0.0%
1250	0.0%	80.8%	81.6%	82.5%	83.3%	83.3%	83.1%	82.9%	82.5%	82.1%	81.7%	81.2%	0.0%
1300	0.0%	81.2%	81.9%	82.8%	83.6%	84.0%	83.8%	83.7%	83.4%	83.0%	82.6%	82.2%	0.0%
1350	0.0%	81.7%	82.4%	83.2%	83.9%	84.5%	84.4%	84.3%	84.1%	83.8%	83.5%	83.1%	0.0%
1400	0.0%	82.2%	82.9%	83.6%	84.2%	84.8%	85.0%	84.9%	84.8%	84.5%	84.3%	84.0%	0.0%
1450	0.0%	82.7%	83.5%	84.1%	84.6%	85.1%	85.3%	85.5%	85.5%	85.3%	85.0%	84.7%	0.0%
1500	0.0%	83.2%	84.0%	84.7%	85.2%	85.7%	85.9%	86.1%	86.2%	86.0%	85.7%	85.4%	0.0%
1550	0.0%	83.8%	84.6%	85.3%	85.8%	86.2%	86.5%	86.6%	86.8%	86.7%	86.4%	86.1%	0.0%
1600	0.0%	84.7%	85.4%	86.0%	86.5%	86.9%	87.0%	87.2%	87.4%	87.4%	87.1%	86.8%	0.0%
1650	0.0%	85.6%	86.2%	86.8%	87.2%	87.5%	87.6%	87.7%	88.0%	88.1%	87.8%	87.5%	0.0%
1700	0.0%	86.5%	87.0%	87.6%	88.0%	88.2%	88.3%	88.4%	88.7%	88.8%	88.6%	88.2%	0.0%
1750	0.0%	87.4%	88.0%	88.5%	88.9%	88.9%	89.0%	89.1%	89.4%	89.6%	89.4%	89.0%	0.0%
1800	0.0%	88.5%	88.9%	89.3%	89.6%	89.9%	89.9%	90.0%	90.1%	90.2%	90.2%	89.7%	0.0%
1850	0.0%	89.5%	89.7%	90.1%	90.4%	90.6%	90.7%	90.8%	90.8%	90.8%	90.8%	90.5%	0.0%
1900	0.0%	90.0%	90.5%	90.8%	91.1%	91.2%	91.3%	91.4%	91.4%	91.4%	91.3%	91.0%	0.0%
1950	0.0%	89.9%	90.7%	91.3%	91.5%	91.6%	91.7%	91.8%	91.9%	91.8%	91.8%	91.5%	0.0%
2000	0.0%	89.5%	90.0%	91.0%	91.3%	91.5%	91.6%	91.7%	91.9%	92.0%	91.8%	91.4%	0.0%
2050	0.0%	89.1%	89.5%	90.3%	90.9%	91.2%	91.3%	91.4%	91.5%	91.6%	91.7%	91.3%	0.0%
2100	0.0%	88.5%	89.1%	89.6%	90.4%	90.6%	90.8%	91.0%	91.1%	91.2%	91.3%	91.1%	0.0%
2150	0.0%	87.7%	88.7%	89.2%	89.8%	90.2%	90.3%	90.4%	90.7%	90.8%	90.8%	90.7%	0.0%
2200	0.0%	87.0%	88.0%	88.7%	89.3%	89.8%	89.9%	90.0%	90.1%	90.3%	90.4%	90.5%	0.0%
2250	0.0%	86.2%	87.2%	88.1%	88.8%	89.4%	89.6%	89.7%	89.8%	89.9%	90.0%	90.2%	0.0%
2300	0.0%	85.5%	86.5%	87.4%	88.2%	88.9%	89.1%	89.3%	89.4%	89.5%	89.7%	89.8%	0.0%
2350	0.0%	84.6%	85.7%	86.6%	87.5%	88.2%	88.5%	88.7%	89.0%	89.2%	89.2%	89.3%	0.0%
2400	0.0%	83.6%	84.8%	85.8%	86.7%	87.5%	87.8%	88.0%	88.4%	88.7%	88.8%	88.7%	0.0%
2450	0.0%	82.3%	83.7%	84.9%	85.9%	86.7%	87.0%	87.3%	87.7%	88.1%	88.3%	88.1%	0.0%
2500	0.0%	80.7%	82.5%	83.9%	84.9%	85.7%	86.0%	86.4%	86.9%	87.4%	87.6%	87.5%	0.0%
2550	0.0%	78.0%	80.9%	82.5%	83.7%	84.6%	85.0%	85.4%	86.0%	86.6%	86.8%	86.9%	0.0%
2600	0.0%	74.7%	78.1%	80.7%	82.3%	83.4%	83.9%	84.3%	85.0%	85.6%	85.9%	86.0%	0.0%

Pensacola Turbine-Generator Efficiency Hill Curve with Air Valves Fully Open (90 degrees open)

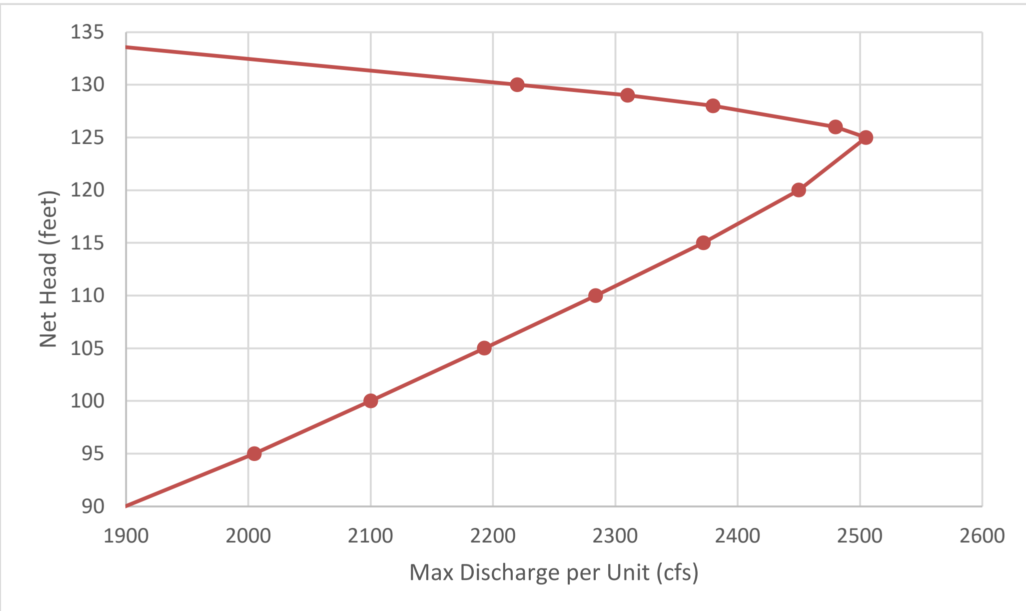
Discharge (cfs)	Total Turbine-Generator Efficiency (%) vs. Net Head (ft)												
	0	95	100	105	110	115	117.5	120	125	130	135	140	999
0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
700	0.0%	40.3%	36.0%	31.5%	26.9%	21.9%	18.9%	15.9%	10.8%	8.6%	8.1%	7.7%	0.0%
750	0.0%	38.0%	35.4%	31.3%	28.2%	25.1%	23.7%	22.2%	19.3%	17.8%	17.5%	17.1%	0.0%
800	0.0%	39.1%	38.8%	35.8%	32.8%	29.9%	28.4%	27.1%	25.5%	24.8%	24.6%	24.4%	0.0%
850	0.0%	39.4%	39.6%	39.2%	37.8%	34.7%	33.3%	32.4%	30.8%	30.4%	30.2%	30.0%	0.0%
900	0.0%	39.7%	40.0%	40.0%	39.3%	38.3%	38.1%	37.6%	36.3%	36.1%	35.9%	35.7%	0.0%
950	0.0%	44.0%	44.4%	44.4%	44.0%	43.2%	43.0%	42.7%	42.3%	42.1%	42.0%	42.0%	0.0%
1000	0.0%	48.4%	48.9%	49.1%	48.8%	48.1%	47.9%	47.6%	47.1%	46.7%	46.6%	46.4%	0.0%
1050	0.0%	50.7%	51.4%	51.8%	51.6%	51.0%	50.8%	50.6%	50.0%	49.6%	49.3%	49.1%	0.0%
1100	0.0%	53.1%	53.9%	54.4%	54.4%	54.0%	53.8%	53.5%	53.0%	52.6%	52.3%	52.0%	0.0%
1150	0.0%	55.6%	56.4%	56.9%	57.1%	56.9%	56.7%	56.6%	56.1%	55.6%	55.3%	55.0%	0.0%
1200	0.0%	58.2%	58.9%	59.5%	60.1%	59.9%	59.7%	59.5%	59.2%	58.8%	58.4%	58.1%	0.0%
1250	0.0%	60.9%	61.5%	62.2%	62.8%	62.8%	62.6%	62.5%	62.1%	61.8%	61.5%	61.2%	0.0%
1300	0.0%	63.5%	64.1%	64.8%	65.4%	65.7%	65.6%	65.5%	65.2%	64.9%	64.6%	64.3%	0.0%
1350	0.0%	66.4%	66.9%	67.5%	68.1%	68.6%	68.5%	68.4%	68.2%	68.0%	67.7%	67.4%	0.0%
1400	0.0%	69.2%	69.8%	70.3%	70.8%	71.3%	71.5%	71.4%	71.2%	71.1%	70.9%	70.6%	0.0%
1450	0.0%	72.2%	72.9%	73.4%	73.9%	74.3%	74.5%	74.6%	74.6%	74.4%	74.2%	74.0%	0.0%
1500	0.0%	75.1%	75.8%	76.4%	76.8%	77.3%	77.5%	77.7%	77.7%	77.6%	77.5%	77.2%	0.0%
1550	0.0%	77.7%	78.4%	79.1%	79.5%	79.9%	80.1%	80.3%	80.5%	80.4%	80.2%	79.9%	0.0%
1600	0.0%	79.7%	80.3%	80.9%	81.4%	81.7%	81.9%	82.1%	82.3%	82.2%	82.0%	81.8%	0.0%
1650	0.0%	81.3%	81.9%	82.4%	82.8%	83.1%	83.2%	83.3%	83.6%	83.7%	83.4%	83.2%	0.0%
1700	0.0%	82.2%	82.7%	83.3%	83.7%	83.8%	83.9%	84.1%	84.4%	84.5%	84.3%	83.9%	0.0%
1750	0.0%	82.7%	83.3%	83.8%	84.3%	84.3%	84.3%	84.5%	84.8%	84.9%	84.7%	84.4%	0.0%
1800	0.0%	83.3%	83.8%	84.2%	84.5%	84.7%	84.8%	84.9%	85.0%	85.1%	85.1%	84.7%	0.0%
1850	0.0%	84.0%	84.3%	84.7%	85.0%	85.1%	85.3%	85.4%	85.3%	85.4%	85.4%	85.0%	0.0%
1900	0.0%	84.3%	84.8%	85.1%	85.4%	85.5%	85.6%	85.7%	85.7%	85.7%	85.6%	85.3%	0.0%
1950	0.0%	83.9%	84.6%	85.2%	85.3%	85.5%	85.6%	85.7%	85.7%	85.7%	85.7%	85.5%	0.0%
2000	0.0%	83.2%	83.7%	84.6%	85.0%	85.1%	85.2%	85.3%	85.5%	85.6%	85.5%	85.2%	0.0%
2050	0.0%	82.3%	82.7%	83.4%	84.0%	84.3%	84.4%	84.5%	84.6%	84.8%	84.9%	84.6%	0.0%
2100	0.0%	81.3%	81.9%	82.4%	83.1%	83.4%	83.5%	83.6%	83.8%	83.9%	84.1%	83.9%	0.0%
2150	0.0%	80.1%	81.0%	81.5%	82.1%	82.4%	82.5%	82.6%	82.9%	83.1%	83.2%	83.1%	0.0%
2200	0.0%	78.6%	79.5%	80.2%	80.8%	81.2%	81.3%	81.4%	81.6%	81.8%	82.0%	82.1%	0.0%
2250	0.0%	77.1%	78.0%	78.8%	79.5%	80.0%	80.1%	80.3%	80.5%	80.7%	80.9%	81.0%	0.0%
2300	0.0%	75.7%	76.6%	77.4%	78.1%	78.8%	79.0%	79.2%	79.4%	79.6%	79.8%	79.9%	0.0%
2350	0.0%	74.5%	75.5%	76.3%	77.1%	77.7%	78.0%	78.3%	78.6%	78.8%	78.9%	79.1%	0.0%
2400	0.0%	73.3%	74.3%	75.2%	76.0%	76.8%	77.1%	77.3%	77.8%	78.1%	78.2%	78.3%	0.0%
2450	0.0%	72.0%	73.2%	74.2%	75.1%	75.8%	76.2%	76.5%	77.0%	77.3%	77.6%	77.6%	0.0%
2500	0.0%	70.7%	72.3%	73.5%	74.4%	75.1%	75.5%	75.8%	76.5%	76.9%	77.2%	77.3%	0.0%
2550	0.0%	68.5%	71.1%	72.5%	73.6%	74.4%	74.8%	75.2%	75.9%	76.4%	76.8%	77.0%	0.0%
2600	0.0%	66.0%	69.0%	71.2%	72.6%	73.7%	74.2%	74.6%	75.3%	75.9%	76.3%	76.7%	0.0%

Kerr Turbine Efficiency Hill Curve (Refurbished Units 2010)

Discharge (cfs)	Total Turbine-Generator Efficiency (%) vs. Head (ft)								
	0	35	51	54	56	58	61	80	999
0	0%	61.2%	76.5%	76.5%	76.7%	76.9%	76.9%	61.5%	0%
2000	0%	65.6%	83.8%	84.1%	84.4%	84.7%	84.7%	67.9%	0%
2500	0%	66.8%	85.3%	85.5%	85.8%	86.1%	86.2%	69.0%	0%
3000	0%	68.0%	86.7%	86.9%	87.2%	87.6%	87.7%	70.3%	0%
3500	0%	69.2%	88.1%	88.3%	88.7%	89.1%	89.1%	71.3%	0%
4000	0%	70.2%	89.4%	89.6%	89.9%	90.2%	90.1%	72.2%	0%
4500	0%	70.7%	90.0%	90.1%	90.4%	90.7%	90.7%	72.6%	0%
4750	0%	71.2%	90.5%	90.6%	90.9%	91.2%	91.2%	73.0%	0%
5000	0%	71.6%	90.9%	91.1%	91.3%	91.6%	91.6%	73.3%	0%
5250	0%	71.9%	91.3%	91.4%	91.7%	92.0%	91.9%	73.5%	0%
5500	0%	72.1%	91.4%	91.6%	91.9%	92.1%	92.0%	73.6%	0%
6000	0%	72.2%	91.4%	91.5%	91.7%	92.0%	91.9%	73.5%	0%
6500	0%	72.1%	91.0%	91.1%	91.3%	91.6%	91.5%	73.2%	0%
7000	0%	71.6%	90.2%	90.3%	90.6%	90.8%	90.7%	72.6%	0%
7500	0%	71.5%	89.8%	89.9%	90.2%	90.4%	90.3%	72.2%	0%
8500	0%	70.1%	87.9%	88.0%	88.2%	88.4%	88.2%	70.5%	0%
9000	0%	69.3%	87.0%	87.0%	87.2%	87.3%	87.2%	69.6%	0%

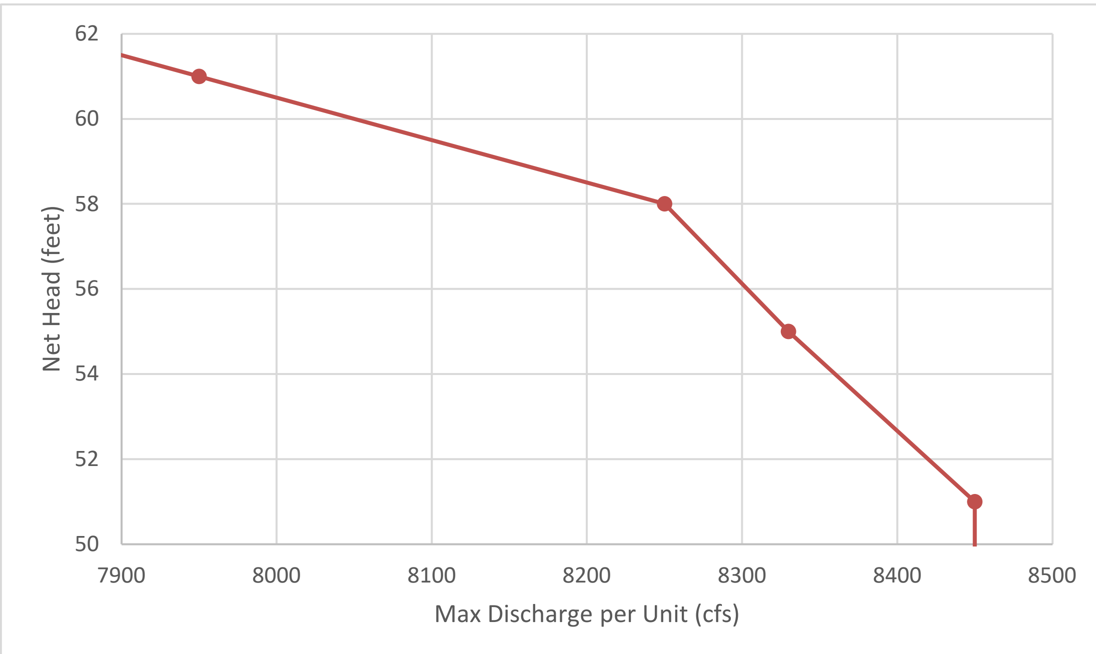
Pensacola Dam Maximum Discharge (cfs) per Unit vs. Net HeadDischarge Limited by Cavitation - 6 Units Total

Net Head (ft)	Max Discharge per Unit (cfs)	Max Discharge Total (cfs)
0	0	0
95	2005	12030
100	2100	12600
105	2193	13158
110	2284	13704
115	2372	14232
120	2450	14700
125	2505	15030
126	2480	14880
128	2380	14280
129	2310	13860
130	2220	13320
154.67	0	0
999.00	0	0



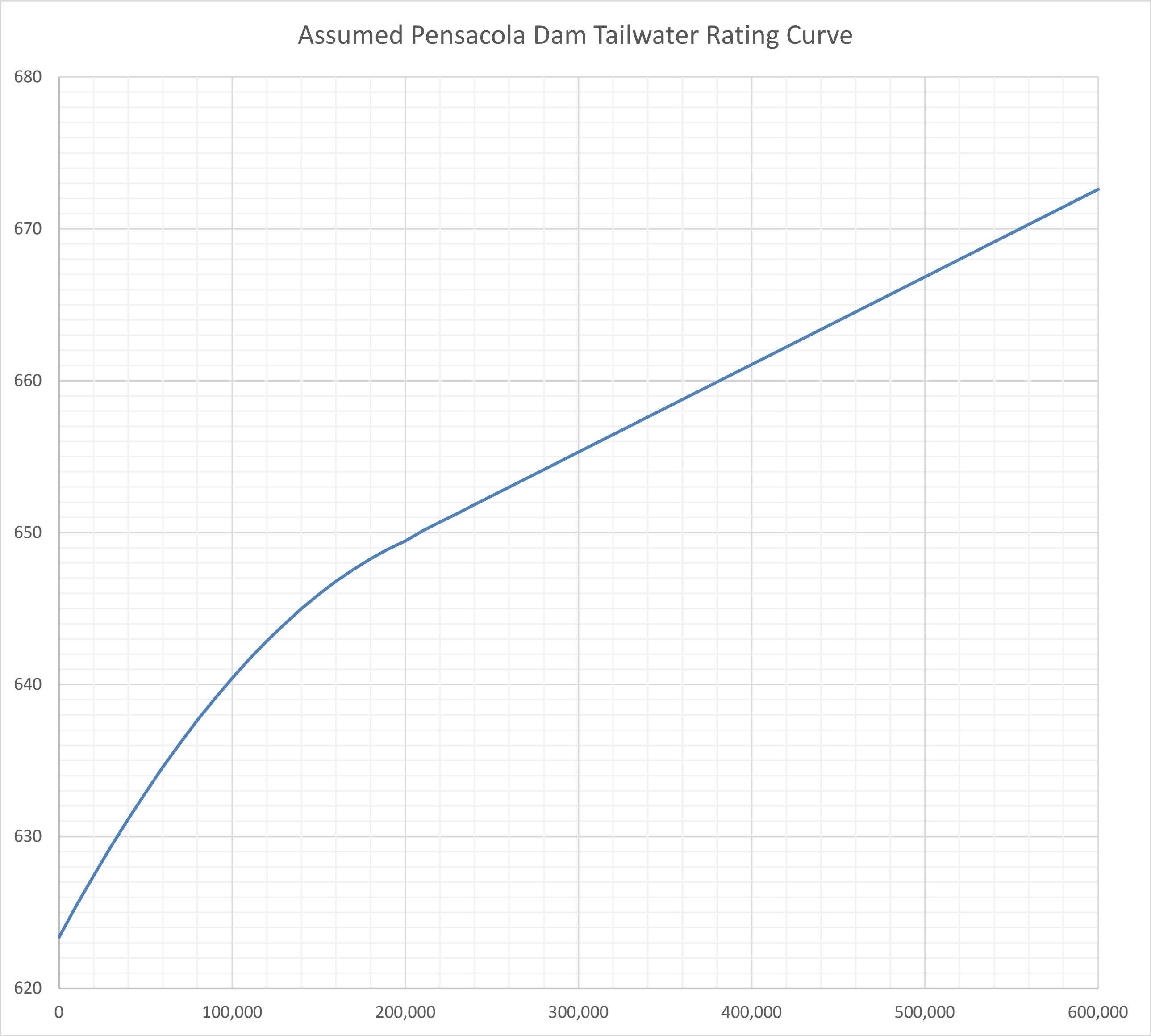
Kerr Dam Maximum Discharge (cfs) per Unit vs. Net HeadDischarge Limited by Cavitation - 4 Units Total

Net Head (ft)	Max Discharge per Unit (cfs)	Max Discharge Total (cfs)
0	8450	33800
51	8450	33800
55	8330	33320
58	8250	33000
61	7950	31800
140.50	0	0
999	0	0



Pensacola Dam Tailwater Rating Curve

Discharge (cfs)	TW Elev (ft PD)
0	623.37
10000	625.43
20000	627.42
30000	629.32
40000	631.15
50000	632.89
60000	634.56
70000	636.14
80000	637.65
90000	639.07
100000	640.41
110000	641.68
120000	642.86
130000	643.97
140000	644.99
150000	645.93
160000	646.80
170000	647.58
180000	648.28
190000	648.90
200000	649.45
210000	650.11
220000	650.69
230000	651.27
240000	651.84
250000	652.42
275000	653.86
300000	655.30
600000	672.61

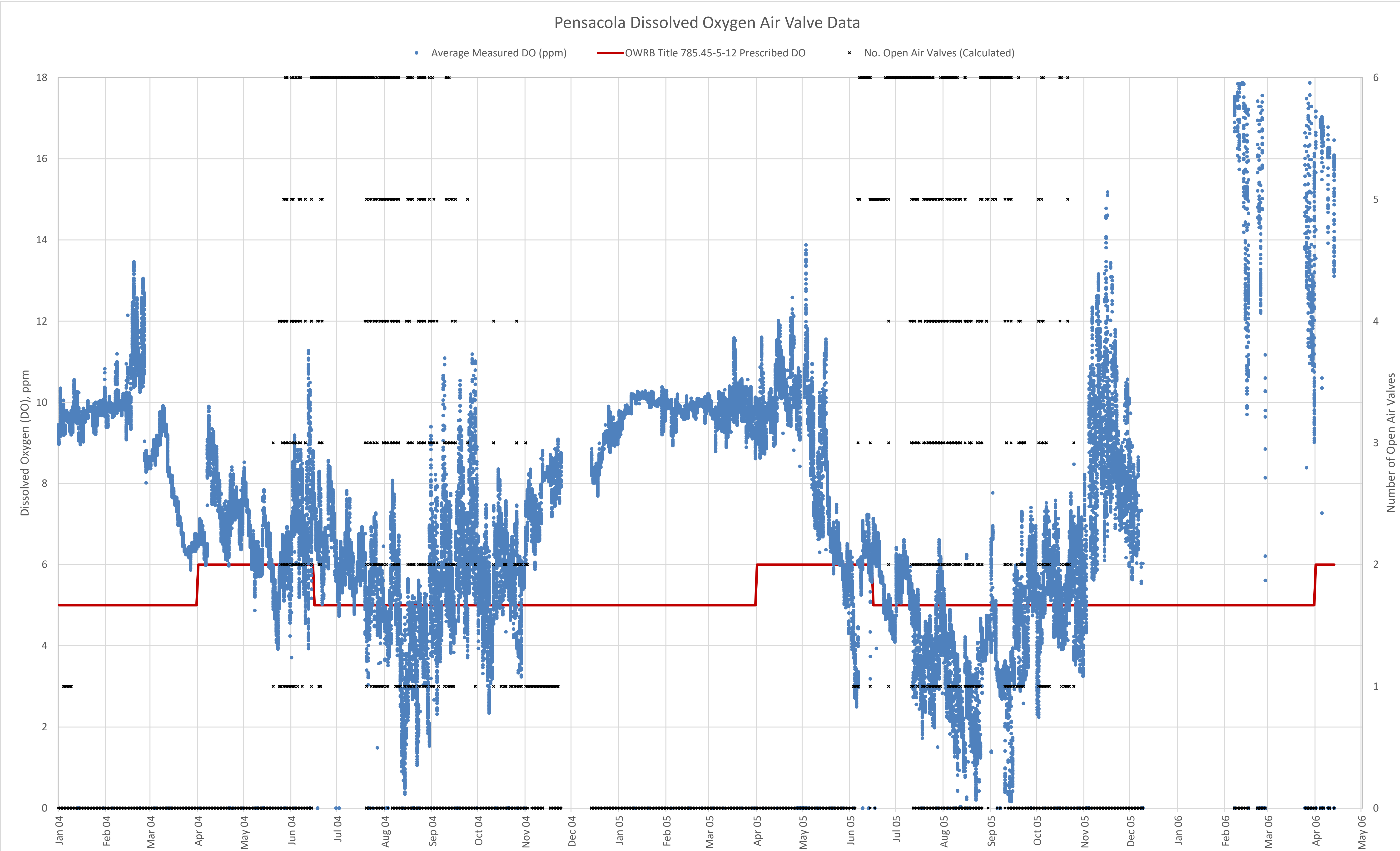


SAMPLE TURBINE-GENERATOR OUTAGE DATA

Plant	Unit No.	Outage Begin	Outage End
Pensacola	1	5/15/2003 13:00	5/15/2003 16:00
Pensacola	1	9/19/2004 5:00	10/3/2004 5:00
Pensacola	1	9/29/2004 7:00	10/3/2004 5:00
Pensacola	1	10/3/2004 5:00	10/6/2004 5:00
Pensacola	1	10/6/2004 5:00	10/15/2004 5:00
Pensacola	1	10/15/2004 5:00	2/1/2005 6:00
Pensacola	1	1/18/2005 6:00	2/15/2005 6:00
Pensacola	1	10/24/2005 5:00	10/25/2005 5:00
Pensacola	1	12/13/2005 23:00	12/16/2005 23:00
Pensacola	1	12/19/2005 6:00	12/20/2005 6:00
Pensacola	1	8/10/2006 5:00	8/15/2006 5:00
Pensacola	1	9/19/2006 12:00	9/22/2006 20:00
Pensacola	1	9/25/2006 20:00	9/27/2006 5:00
Pensacola	1	9/27/2006 12:00	10/2/2006 5:00
Pensacola	1	9/27/2006 14:00	10/2/2006 5:00
Pensacola	1	10/3/2006 13:00	10/5/2006 5:00
Pensacola	1	10/5/2006 5:00	10/6/2006 5:00
Pensacola	1	10/6/2006 5:00	10/8/2006 5:00
Pensacola	1	11/28/2006 18:00	12/31/2006 6:00
Pensacola	1	3/14/2007 13:00	3/15/2007 4:00
Pensacola	1	3/14/2007 19:00	3/15/2007 4:00
Pensacola	1	3/15/2007 14:00	3/17/2007 19:00
Pensacola	1	8/23/2007 5:00	8/25/2007 5:00
Pensacola	1	9/26/2007 13:00	9/29/2007 5:00
Pensacola	1	11/13/2007 18:00	11/15/2007 6:00
Pensacola	1	3/26/2008 20:08	3/29/2008 4:00
Pensacola	1	3/27/2008 12:00	3/29/2008 4:00
Pensacola	1	10/27/2009 13:00	1/30/2010 6:00
Pensacola	1	4/20/2010 5:00	4/30/2010 5:00
Pensacola	1	6/25/2010 11:00	6/25/2010 12:00
Pensacola	1	6/28/2010 11:00	6/28/2010 12:00
Pensacola	1	9/9/2010 20:25	9/10/2010 17:00
Pensacola	1	7/26/2011 17:05	7/31/2011 5:00
Pensacola	1	10/25/2011 15:02	12/31/2012 23:59
Pensacola	1	10/25/2011 15:02	12/31/2013 22:02
Pensacola	1	11/22/2011 8:10	11/23/2011 0:00
Pensacola	1	12/13/2011 8:00	12/13/2011 11:00
Pensacola	1	12/19/2011 8:00	12/19/2011 10:00
Pensacola	1	12/20/2011 9:31	12/21/2011 16:00
Pensacola	1	12/23/2011 9:19	12/23/2011 16:00
Pensacola	1	2/28/2012 8:11	3/6/2012 8:00
Pensacola	1	3/21/2012 13:05	3/22/2012 16:00
Pensacola	1	4/5/2012 9:05	4/5/2012 10:00
Pensacola	1	4/20/2012 13:30	4/20/2012 16:00
Pensacola	1	4/27/2012 9:41	4/27/2012 12:00
Pensacola	1	7/13/2012 9:39	8/1/2012 17:39
Pensacola	1	7/26/2012 8:03	7/26/2012 16:00
Pensacola	1	8/1/2012 9:36	8/2/2012 16:00
Pensacola	1	8/8/2012 14:59	8/8/2012 16:00
Pensacola	1	8/21/2012 12:40	8/21/2012 16:01
Pensacola	1	9/14/2012 9:35	9/14/2012 16:00
Pensacola	1	9/17/2012 8:03	9/17/2012 10:00
Pensacola	1	9/28/2012 12:31	9/29/2012 16:00
Pensacola	1	9/28/2012 12:53	9/29/2012 16:00
Pensacola	1	9/28/2012 13:00	9/29/2012 16:00
Pensacola	1	4/8/2013 7:33	4/8/2013 12:41
Pensacola	1	7/24/2013 18:32	7/24/2013 18:56
Pensacola	1	8/13/2013 15:10	8/13/2013 16:33
Pensacola	1	9/19/2013 6:05	9/19/2013 10:59
Pensacola	1	3/19/2014 0:54	3/19/2014 3:32
Pensacola	1	3/26/2014 12:57	3/26/2014 13:18
Pensacola	1	9/2/2014 14:16	9/2/2014 14:49
Pensacola	1	11/18/2014 6:41	11/18/2014 10:20
Pensacola	1	6/20/2015 18:40	6/20/2015 19:14
Pensacola	1	9/21/2015 10:54	9/21/2015 12:30
Pensacola	1	9/24/2015 15:35	9/24/2015 16:27
Pensacola	1	9/28/2015 9:15	12/9/2015 15:50
Pensacola	2	5/15/2003 13:00	5/15/2003 16:00
Pensacola	2	8/14/2003 5:00	8/15/2003 5:00
Pensacola	2	9/5/2004 5:00	9/19/2004 5:00
Pensacola	2	9/25/2004 11:00	10/2/2004 5:00
Pensacola	2	4/4/2005 14:00	4/4/2005 20:00
Pensacola	2	10/31/2005 19:00	12/31/2005 6:00
Pensacola	2	1/1/2006 18:00	2/28/2006 6:00
Pensacola	2	3/1/2006 6:00	3/31/2006 6:00
Pensacola	2	8/10/2006 5:00	8/15/2006 5:00
Pensacola	2	9/19/2006 12:00	9/22/2006 20:00
Pensacola	2	9/25/2006 20:00	9/27/2006 5:00
Pensacola	2	9/27/2006 12:00	10/2/2006 5:00
Pensacola	2	9/27/2006 14:00	10/2/2006 5:00
Pensacola	2	10/3/2006 13:00	10/5/2006 5:00
Pensacola	2	10/5/2006 5:00	10/6/2006 5:00
Pensacola	2	10/6/2006 5:00	10/8/2006 5:00
Pensacola	2	11/28/2006 18:00	12/31/2006 6:00
Pensacola	2	3/14/2007 13:00	3/15/2007 4:00
Pensacola	2	3/14/2007 19:00	3/15/2007 4:00
Pensacola	2	3/15/2007 14:00	3/17/2007 19:00
Pensacola	2	10/3/2007 17:00	10/4/2007 21:00
Pensacola	2	11/14/2007 3:50	11/15/2007 6:00
Pensacola	2	11/15/2007 6:00	11/22/2007 6:00
Pensacola	2	11/24/2007 6:00	11/30/2007 6:00
Pensacola	2	11/30/2007 6:00	12/31/2007 6:00
Pensacola	2	3/25/2008 12:00	3/27/2008 4:00
Pensacola	2	1/30/2009 22:04	2/3/2009 6:00
Pensacola	2	2/3/2009 6:00	2/7/2009 6:00
Pensacola	2	5/10/2010 20:14	5/20/2010 5:00
Pensacola	2	6/25/2010 11:00	6/25/2010 12:00
Pensacola	2	10/4/2010 5:00	1/21/2011 22:00
Pensacola	2	8/20/2011 18:30	8/23/2011 5:00
Pensacola	2	8/25/2011 0:00	8/26/2011 5:00
Pensacola	2	8/31/2011 20:02	9/1/2011 20:30
Pensacola	2	10/3/2011 5:00	12/31/2011 6:00
Pensacola	2	10/25/2011 15:02	12/31/2012 23:59
Pensacola	2	10/25/2011 15:02	12/31/2013 22:02
Pensacola	2	12/13/2011 8:00	12/13/2011 11:00
Pensacola	2	12/20/2011 10:22	12/21/2011 16:00
Pensacola	2	4/27/2012 9:41	4/27/2012 12:00
Pensacola	2	5/7/2012 21:31	5/7/2012 23:00
Pensacola	2	7/17/2012 10:42	7/18/2012 16:00
Pensacola	2	8/8/2012 14:26	8/8/2012 16:00
Pensacola	2	8/21/2012 12:40	8/21/2012 16:03
Pensacola	2	8/27/2012 10:23	8/27/2012 16:00
Pensacola	2	9/12/2012 8:13	9/12/2012 16:12
Pensacola	2	9/17/2012 8:03	9/17/2012 10:00
Pensacola	2	8/13/2013 15:10	8/13/2013 15:42
Pensacola	2	9/19/2013 6:05	9/19/2013 10:59
Pensacola	2	12/22/2013 19:52	12/22/2013 20:13
Pensacola	2	7/6/2014 20:15	7/6/2014 21:30

Plant	Unit No.	Outage Begin	Outage End
Pensacola	2	10/29/2014 16:05	10/29/2014 16:06
Pensacola	2	1/6/2015 7:40	1/6/2015 9:44
Pensacola	2	1/12/2015 9:43	1/26/2015 14:47
Pensacola	2	3/8/2015 7:23	3/8/2015 9:38
Pensacola	2	3/21/2015 14:03	3/21/2015 16:10
Pensacola	2	6/20/2015 18:40	6/20/2015 19:14
Pensacola	2	9/24/2015 15:35	9/24/2015 16:28
Pensacola	2	10/2/2015 17:11	10/2/2015 20:55
Pensacola	2	10/29/2015 9:08	10/30/2015 10:36
Pensacola	3	2/10/2003 6:00	3/1/2003 6:00
Pensacola	3	5/15/2003 13:00	5/17/2003 5:00
Pensacola	3	8/14/2003 5:00	8/15/2003 5:00
Pensacola	3	8/23/2003 5:00	8/28/2003 5:00
Pensacola	3	12/1/2003 6:00	3/1/2004 6:00
Pensacola	3	6/10/2004 5:00	6/14/2004 5:00
Pensacola	3	9/2/2004 5:00	9/5/2004 5:00
Pensacola	3	9/9/2004 13:00	9/10/2004 21:00
Pensacola	3	5/31/2005 17:00	6/1/2005 21:00
Pensacola	3	6/1/2005 21:00	6/2/2005 17:00
Pensacola	3	12/13/2005 23:00	12/16/2005 23:00
Pensacola	3	12/17/2005 6:00	12/20/2005 6:00
Pensacola	3	2/27/2006 6:00	3/4/2006 6:00
Pensacola	3	8/10/2006 5:00	8/15/2006 5:00
Pensacola	3	9/19/2006 12:00	9/22/2006 20:00
Pensacola	3	9/25/2006 20:00	9/27/2006 5:00
Pensacola	3	9/27/2006 12:00	10/2/2006 5:00
Pensacola	3	9/27/2006 14:00	10/2/2006 5:00
Pensacola	3	10/3/2006 13:00	10/5/2006 5:00
Pensacola	3	10/3/2006 13:02	10/5/2006 5:00
Pensacola	3	10/5/2006 5:00	10/6/2006 5:00
Pensacola	3	10/6/2006 5:00	10/8/2006 5:00
Pensacola	3	11/28/2006 18:00	12/31/2006 6:00
Pensacola	3	3/8/2007 5:00	3/8/2007 18:00
Pensacola	3	3/14/2007 13:00	3/15/2007 4:00
Pensacola	3	3/14/2007 19:00	3/15/2007 4:00
Pensacola	3	3/15/2007 14:00	3/17/2007 19:00
Pensacola	3	3/12/2008 15:00	3/14/2008 14:00
Pensacola	3	1/7/2009 13:32	3/1/2009 20:00
Pensacola	3	1/7/2009 14:00	3/1/2009 20:00
Pensacola	3	6/25/2010 11:00	6/25/2010 12:00
Pensacola	3	8/10/2010 12:00	8/17/2010 21:00
Pensacola	3	8/1/2011 12:38	8/5/2011 21:00
Pensacola	3	8/1/2011 13:00	8/5/2011 21:00
Pensacola	3	10/25/2011 15:02	12/31/2012 23:59
Pensacola	3	10/25/2011 15:02	12/31/2013 22:02
Pensacola	3	12/13/2011 8:00	12/13/2011 11:00
Pensacola	3	12/20/2011 12:23	12/20/2011 20:00
Pensacola	3	12/20/2011 19:05	12/21/2011 16:00
Pensacola	3	1/12/2012 8:32	1/12/2012 10:00
Pensacola	3	2/18/2012 20:20	2/19/2012 0:01
Pensacola	3	2/26/2012 5:30	2/27/2012 10:00
Pensacola	3	4/27/2012 9:41	4/27/2012 12:00
Pensacola	3	7/16/2012 12:04	7/16/2012 16:00
Pensacola	3	7/17/2012 8:19	7/18/2012 16:00
Pensacola	3	8/8/2012 13:45	8/8/2012 16:03
Pensacola	3	8/28/2012 12:20	8/28/2012 16:00
Pensacola	3	8/30/2012 8:36	8/30/2012 16:00
Pensacola	3	9/10/2012 7:57	9/10/2012 13:59
Pensacola	3	9/17/2012 8:03	9/17/2012 10:00
Pensacola	3	7/8/2013 12:48	7/8/2013 14:51
Pensacola	3	8/13/2013 15:10	8/13/2013 15:42
Pensacola	3	9/19/2013 6:05	9/19/2013 10:59
Pensacola	3	12/22/2013 20:22	12/22/2013 20:34
Pensacola	3	10/1/2014 0:01	12/22/2014 7:25
Pensacola	3	6/20/2015 18:40	6/20/2015 19:14
Pensacola	3	7/24/2015 20:37	7/25/2015 9:45
Pensacola	3	8/11/2015 21:39	8/12/2015 2:16
Pensacola	3	8/12/2015 9:29	8/12/2015 11:19
Pensacola	3	9/24/2015 15:35	9/24/2015 16:27
Pensacola	3	10/2/2015 15:30	10/2/2015 20:55
Pensacola	3	11/13/2015 19:42	11/14/2015 10:13
Pensacola	3	12/16/2015 8:01	12/16/2015 8:54
Pensacola	4	1/29/2003 14:30	1/29/2003 17:00
Pensacola	4	2/7/2003 6:00	2/8/2003 6:00
Pensacola	4	2/10/2003 6:00	2/11/2003 6:00
Pensacola	4	2/11/2003 6:00	2/13/2003 6:00
Pensacola	4	9/8/2003 14:00	10/9/2003 5:00
Pensacola	4	10/31/2003 6:00	11/4/2003 6:00
Pensacola	4	4/5/2005 14:00	4/5/2005 20:00
Pensacola	4	12/13/2005 23:00	12/16/2005 23:00
Pensacola	4	12/17/2005 6:00	12/20/2005 6:00
Pensacola	4	8/10/2006 5:00	8/15/2006 5:00
Pensacola	4	9/19/2006 12:00	9/22/2006 20:00
Pensacola	4	9/25/2006 20:00	9/27/2006 5:00
Pensacola	4	9/27/2006 14:00	10/2/2006 5:00
Pensacola	4	10/3/2006 13:00	10/5/2006 5:00
Pensacola	4	10/5/2006 5:00	10/6/2006 5:00
Pensacola	4	10/6/2006 5:00	10/8/2006 5:00
Pensacola	4	11/28/2006 18:00	12/31/2006 6:00
Pensacola	4	3/14/2007 19:00	3/15/2007 4:00
Pensacola	4	3/29/2008 12:00	3/31/2008 4:00
Pensacola	4	12/19/2008 6:00	12/29/2009 14:33
Pensacola	4	5/13/2010 12:30	5/15/2010 17:00
Pensacola	4	6/25/2010 11:00	6/25/2010 18:00
Pensacola	4	12/13/2010 12:00	3/11/2011 22:00
Pensacola	4	10/3/2011 6:00	12/31/2011 6:00
Pensacola	4	10/3/2011 8:13	12/31/2011 0:00
Pensacola	4	10/3/2011 13:13	12/31/2011 6:00
Pensacola	4	10/25/2011 15:02	12/31/2012 23:59
Pensacola	4	10/25/2011 15:02	12/31/2013 22:02
Pensacola	4	12/20/2011 12:52	12/20/2011 14:00
Pensacola	4	3/13/2012 7:13	3/13/2012 12:00
Pensacola	4	3/14/2012 8:29	3/14/2012 16:00
Pensacola	4	3/14/2012 13:42	3/14/2012 16:00
Pensacola	4	7/19/2012 12:20	7/20/2012 16:00
Pensacola	4	7/23/2012 8:10	7/23/2012 16:00
Pensacola	4	8/9/2012 13:04	8/9/2012 16:00
Pensacola	4	8/21/2012 13:16	8/21/2012 16:00
Pensacola	4	8/27/2012 12:52	8/28/2012 16:00
Pensacola	4	9/7/2012 8:06	9/8/2012 16:06
Pensacola	4	9/15/2012 0:05	9/15/2012 3:00
Pensacola	4	9/17/2012 8:03	9/17/2012 10:00
Pensacola	4	9/20/2012 5:19	9/20/2012 9:58
Pensacola	4	9/21/2012 7:00	9/21/2012 18:00
Pensacola	4	10/3/2012 9:17	10/3/2012 15:58
Pensacola	4	12/10/2012 8:33	12/10/2012 16:00
Pensacola	4	12/11/2012 8:00	12/11/2012 16:00
Pensacola	4	12/27/2012 8:00	12/27/2012 12:00

Plant	Unit No.	Outage Begin	Outage End
Pensacola	4	1/30/2013 13:22	1/30/2013 14:19
Pensacola	4	2/7/2013 9:43	2/7/2013 12:50
Pensacola	4	8/13/2013 15:10	8/13/2013 16:29
Pensacola	4	9/19/2013 6:05	9/19/2013 10:59
Pensacola	4	12/6/2013 18:00	12/7/2013 9:35
Pensacola	4	12/7/2013 9:35	12/7/2013 10:37
Pensacola	4	12/24/2013 9:46	12/24/2013 13:43
Pensacola	4	1/5/2015 5:30	1/5/2015 7:45
Pensacola	4	4/18/2015 15:21	4/18/2015 20:26
Pensacola	4	6/20/2015 18:40	6/20/2015 19:14
Pensacola	4	6/24/2015 10:44	6/24/2015 11:03
Pensacola	4	9/24/2015 15:35	9/24/2015 16:27
Pensacola	4	10/2/2015 15:30	10/2/2015 20:55
Pensacola	5	1/24/2003 15:00	2/3/2003 22:00
Pensacola	5	11/6/2004 13:24	11/8/2004 22:00
Pensacola	5	12/13/2005 23:00	12/16/2005 23:00
Pensacola	5	12/17/2005 6:00	12/20/2005 6:00
Pensacola	5	8/10/2006 5:00	8/15/2006 5:00
Pensacola	5	9/19/2006 12:00	9/22/2006 20:00
Pensacola	5	9/25/2006 20:00	9/27/2006 5:00
Pensacola	5	9/27/2006 12:00	10/2/2006 5:00
Pensacola	5	9/27/2006 14:00	10/2/2006 5:00
Pensacola	5	10/3/2006 13:00	10/5/2006 5:00
Pensacola	5	10/5/2006 5:00	10/6/2006 5:00
Pensacola	5	10/6/2006 5:00	10/8/2006 5:00
Pensacola	5	11/28/2006 18:00	12/31/2006 6:00
Pensacola	5	1/4/2007 16:00	3/4/2007 6:00
Pensacola	5	3/14/2007 19:00	3/15/2007 4:00
Pensacola	5	4/12/2007 13:11	4/17/2007 5:00
Pensacola	5	2/4/2008 15:10	2/5/2008 20:30
Pensacola	5	3/29/2008 18:15	4/2/2008 4:00
Pensacola	5	3/31/2008 12:00	4/2/2008 4:00
Pensacola	5	12/19/2008 6:00	1/31/2009 6:00
Pensacola	5	6/25/2010 11:00	6/25/2010 18:00
Pensacola	5	12/13/2010 12:00	3/11/2011 22:00
Pensacola	5	9/12/2011 18:25	10/1/2011 5:00
Pensacola	5	10/25/2011 15:02	12/31/2012 23:59
Pensacola	5	10/25/2011 15:02	12/31/2013 22:02
Pensacola	5	12/8/2011 14:00	12/8/2011 17:00
Pensacola	5	1/17/2012 10:30	1/18/2012 16:00
Pensacola	5	1/20/2012 11:39	1/20/2012 16:00
Pensacola	5	1/23/2012 14:47	1/24/2012 12:00
Pensacola	5	7/24/2012 12:28	7/25/2012 16:00
Pensacola	5	8/21/2012 13:16	8/21/2012 16:00
Pensacola	5	8/21/2012 13:26	8/21/2012 16:00
Pensacola	5	8/28/2012 8:20	8/28/2012 16:00
Pensacola	5	9/2/2012 20:56	9/3/2012 16:00
Pensacola	5	9/6/2012 8:00	9/6/2012 14:00
Pensacola	5	9/17/2012 8:03	9/17/2012 10:00
Pensacola	5	9/21/2012 7:00	9/21/2012 18:00
Pensacola	5	10/1/2012 0:00	12/31/2012 0:00
Pensacola	5	10/1/2012 8:00	3/11/2013 16:00
Pensacola	5	12/10/2012 8:33	12/10/2012 16:00
Pensacola	5	12/11/2012 8:00	12/11/2012 16:00
Pensacola	5	12/27/2012 8:00	12/27/2012 12:00
Pensacola	5	3/4/2013 9:42	3/4/2013 9:43
Pensacola	5	8/8/2013 2:23	8/8/2013 3:15
Pensacola	5	8/8/2013 14:38	8/8/2013 15:33
Pensacola	5	8/13/2013 15:10	8/13/2013 15:59
Pensacola	5	9/19/2013 6:05	9/19/2013 10:59
Pensacola	5	4/14/2014 18:45	4/14/2014 19:24
Pensacola	5	2/6/2015 13:17	2/6/2015 14:42
Pensacola	5	3/20/2015 9:37	3/20/2015 10:06
Pensacola	5	6/20/2015 18:40	6/20/2015 19:14
Pensacola	5	8/31/2015 14:31	8/31/2015 14:57
Pensacola	5	9/24/2015 15:35	9/24/2015 16:30
Pensacola	5	9/28/2015 9:03	9/28/2015 14:01
Pensacola	5	10/2/2015 15:30	10/2/2015 20:55
Pensacola	5	11/5/2015 8:53	11/6/2015 13:25
Pensacola	6	5/31/2003 5:00	6/15/2003 5:00
Pensacola	6	10/26/2005 5:00	10/27/2005 5:00
Pensacola	6	12/13/2005 23:00	12/16/2005 23:00
Pensacola	6	12/17/2005 6:00	12/20/2005 6:00
Pensacola	6	8/10/2006 5:00	8/15/2006 5:00
Pensacola	6	9/19/2006 12:00	9/22/2006 20:00
Pensacola	6	9/25/2006 20:00	9/27/2006 5:00
Pensacola	6	9/27/2006 12:00	10/2/2006 5:00
Pensacola	6	9/27/2006 14:00	10/5/2006 5:00
Pensacola	6	10/5/2006 5:00	10/6/2006 5:00
Pensacola	6	10/6/2006 5:00	10/8/2006 5:00
Pensacola	6	11/28/2006 18:00	12/31/2006 6:00
Pensacola	6	3/14/2007 19:00	3/15/2007 4:00
Pensacola	6	11/5/2007 14:28	12/5/2007 6:00
Pensacola	6	1/7/2008 6:00	2/7/2008 4:00
Pensacola	6	3/31/2008 18:08	4/4/2008 4:00
Pensacola	6	4/2/2008 12:00	4/4/2008 4:00
Pensacola	6	12/19/2008 6:00	1/31/2009 6:00
Pensacola	6	1/22/2009 16:59	1/24/2009 6:00
Pensacola	6	6/25/2010 11:00	6/25/2010 18:00
Pensacola	6	12/13/2010 12:00	3/11/2011 22:00
Pensacola	6	5/16/2011 19:37	5/18/2011 5:00
Pensacola	6	10/25/2011 15:02	12/31/2012 23:59
Pensacola	6	10/25/2011 15:02	12/31/2013 22:02
Pensacola	6	1/19/2012 9:42	1/20/2012 16:00
Pensacola	6	3/16/2012 5:45	3/16/2012 16:03
Pensacola	6	7/25/2012 7:34	7/25/2012 15:58
Pensacola	6	8/21/2012 13:34	8/21/2012 16:00
Pensacola	6	8/28/2012 9:59	8/28/2012 16:00
Pensacola	6	9/5/2012 7:55	9/6/2012 16:00
Pensacola	6	9/5/2012 23:08	9/6/2012 16:00
Pensacola	6	9/17/2012 8:03	9/17/2012 10:00
Pensacola	6	9/21/2012 7:00	9/21/2012 18:00
Pensacola	6	12/10/2012 8:33	12/10/2012 16:00
Pensacola	6	12/11/2012 8:00	12/11/2012 16:00
Pensacola	6	12/27/2012 8:00	12/27/2012 12:00
Pensacola	6	5/8/2013 16:21	5/8/2013 17:34
Pensacola	6	8/13/2013 15:10	8/13/2013 15:59
Pensacola	6	9/19/2013 6:05	9/19/2013 10:59
Pensacola	6	10/1/2013 8:00	12/10/2013 12:57
Pensacola	6	3/27/2014 14:10	3/27/2014 14:15
Pensacola	6	6/20/2015 18:40	6/20/2015 19:14
Pensacola	6	10/2/2015 15:30	10/2/2015 20:55
Pensacola	6	11/9/2015 18:31	11/10/2015 9:50
Pensacola	6	11/12/2015 8:33	11/12/2015 14:00



Pensacola Dissolved Oxygen Air Valve Data
Average Measured DO (ppm)
OWRB Title 785.45-5-12 Prescribed DO
No. Open Air Valves (Calculated)
Dissolved Oxygen (DO), ppm
Number of Open Air Valves
0
2
4
6
8
10
12
14
16
18
0
1
2
3
4
5
6
Jan 04
Feb 04
Mar 04
Apr 04
May 04
Jun 04
Jul 04
Aug 04
Sep 04
Oct 04
Nov 04
Dec 04
Jan 05
Feb 05
Mar 05
Apr 05
May 05
Jun 05
Jul 05
Aug 05
Sep 05
Oct 05
Nov 05
Dec 05
Jan 06
Feb 06
Mar 06
Apr 06
May 06